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LOW CARBON DEVELOPMENT IN CHINA AND INDIA

Issues and Strategies

低碳发展

LOW CARBON DEVELOPMENT IN CHINA AND INDIA

Issues and Strategies

About the cover

The cover of the book depicts the national flowers of China and India which are Peony and Lotus, respectively. These flowers symbolize 'prosperity' in the two countries.

LOW CARBON DEVELOPMENT IN CHINA AND INDIA

Issues and Strategies

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The Energy and Resources Institute

National Centre for Climate Change Strategy and International Cooperation

Central University of Finance and Economics

Zhejiang University

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FOREWORD BY XIE ZHENHUA

Climate change, at present, is one of the most serious challenges being faced by the world. It is not only an environment issue but also a development issue, concerning future development space of every country. Thus, cooperation among the international society is needed to jointly address climate change.

The current concentration of atmospheric carbon dioxide has passed 400 ppm, whereas it was only 279 ppm in the 1750s. The average global surface temperature has risen by 0.85 degrees Celsius during 1880 to 2012. In recent years, global climate change has caused frequent occurrences of various extreme climatic events, incurring huge losses in economy, people's lives, and properties in every country, especially in developing countries, including China and India. Both as large developing countries as well as emitters, China and India are now in the development stage of rapid industrialization and urbanization, and during the process are faced by multiple challenges that include effective poverty eradication, control of greenhouse gas emissions, protection of the environment and biodiversity, as well as moving towards a future of low carbon sustainable development. Meanwhile, achievements made by the two countries in addressing climate change will significantly influence global efforts in realizing the goal of limiting the average global surface temperature increase of 2 degrees Celsius over the pre-industrial average. Thus, the two countries have to achieve innovations in development pathways and low carbon transition.

Initiated by the United Nations Development Programme (UNDP), *Low Carbon Development in China and India – Issues and Strategies* is a very helpful effort by Chinese and Indian think tanks to collaborate in exploring new national development pathways as well as promoting international cooperation in climate change. In this project, Chinese and Indian experts have reviewed low carbon development strategies and policies, as well as future emission trends in the two countries; summarized current technology innovation and diffusion policies, and provided recommendations on how to promote strategies, policies, and international cooperation in low carbon technology development between the two countries in the future based on case studies; and conducted in-depth research in supportive financing tools for urban low carbon development, and analysed the viability of various financing tools in the application of developing low carbon economy in urban areas. Moreover, the study has revisited low carbon development practices taken by the two countries and offered related policy recommendations. The outcome of this joint study has a positive impact on implementing the UNFCCC by two large developing countries, encouraging the international society to reach an agreement in Paris, France in 2015, and innovating the development pathways of both countries.

In this regard, I want to thank the UNDP for this visionary initiative as well as the Chinese and Indian experts for their diligent work. Although the report only discusses several aspects of research in climate change and low carbon sustainable development strategies and policies in China and India, it has already moved beyond academia and reflected different thoughts and perceptions, as well as collisions and blending of ideas, on the challenges posed by climate change from various disciplines and experts in China and India. I sincerely hope this joint study will open up the door for further enhanced cooperation between thinks tanks from the two countries in the future, and establish a role model as well as open an academic platform for future cooperation between thinks tanks from all developing countries, contributing to global efforts in the exploration of addressing climate change and low carbon sustainable development.

解振华

Xie Zhenhua
China's Special Representative for Climate Change
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FOREWORD BY PRAKASH JAVADEKAR

The challenge of climate change has been referred to as the defining global issue of our time and it is not an issue that can be solved by individual academic or scientific disciplines working in isolation. Being a global public good, deeper effort at collective action is required to ensure climate resilient development, especially in emerging and developing countries where there are greater needs for adaptations, because of their higher vulnerability to the adverse impacts of climate change. This is obviously relevant for China and India. China and India will need to play a catalytic role to limit the extent of climate change and global warming to the levels which the Intergovernmental Panel on Climate Change (IPCC) has been working on. India and China cannot by themselves solve the problem of global warming. A truly global effort is needed and the industrialized countries in particular have to make a major transition. Hopefully, the ongoing discussions in the United Nations Framework Convention on Climate Change (UNFCCC) will produce an agreed formula for equitable sharing of the burden across countries.

While there are differences between the two countries in terms of socio-economic attributes, natural resource endowments, and political systems, both China and India face similar challenges and opportunities when it comes to addressing local and global environmental and sustainability issues. India required continued rapid economic growth which in turn requires an expansion in energy use. Current levels of energy efficiency and the current mix of energy supply sources in India will be unsustainable and continuation of present levels of dependence on fossil fuels also has implications for energy security.

India has taken several initiatives to explore the scope for low carbon development. In 2008, India adopted the National Action Plan on Climate Change which outlines policies directed at mitigation and adaptation to climate change. India’s Twelfth Five-Year Plan, covering the period 2011–12 to 2016–17 calls for faster, more inclusive, and sustainable growth. At the China–India Strategic Economic Dialogues, the two countries have emphasized to work towards sustainable development, energy, and climate change cooperation. South-South cooperation between China and India on existing and upcoming issues will greatly enhance mutual trust and expand common interests.

Low carbon development strategies, while considering climate change mitigation, also have to be understood in the context of sustainable development to include aspects of energy security, livelihood security, and equity.

I am very happy that The Energy and Resources Institute (TERI) along with the National Centre for Climate Change Strategy and International Cooperation, the Central University of Finance and Economics, and Zhejiang University have worked together in examining issues around low carbon strategies.

The collaborative study on low carbon development for China and India is directed towards developing specific strategies for low carbon development in crosscutting areas, such as financing, technology and innovation policy, and sub-national initiatives. The project focuses on understanding peer-country experiences, promoting knowledge exchange and dissemination to shape domestic policies and implementation. By engaging with policymakers, the project will seek to support policy incubation and development at both the national and sub-national level.

The areas of financing, science technology, and innovation policy, and sub-national actions, deserve to be examined in the context of low carbon development. Promoting an active mindset geared towards low carbon development initiatives would be instrumental. I am confident that this initiative will set directions for low carbon development by examining key issues and highlighting peer practices that could be considered for India and China.

Prakash Javadekar
Hon'ble Minister of State (IC)
Environment, Forest and Climate Change
Ministry of Environment, Forest and Climate Change
Government of India

FOREWORD BY HELEN CLARK

China and India have followed similar trajectories of rising energy consumption and greenhouse gas emissions. Both have been going through economic transformations as their economies have shifted to stronger reliance on the manufacturing and service sectors. In terms of energy consumption, both countries rely heavily on carbon-based fuel sources—largely as a result of their natural endowment.

Moving to a low-emission, climate-resilient, development pathway can have enormous societal and development benefits in both countries, while also making a major contribution to global efforts to reduce greenhouse gas emissions and lessen the impacts of climate change.

Both governments are now guided by forward-looking, national development plans which encompass low-emissions economic growth. The lessons learned from these experiences will be informative for many other developing countries embarking on similar pathways. It is this desire to engage in South-South knowledge sharing on low carbon development that has prompted both governments, with the support of United Nations Development Programme (UNDP), to work jointly on this *China-India Low Carbon Study*.

The study examines two key factors in low carbon development—*financing* and *low carbon technologies*—as well as opportunities for future collaboration. The study also provides concrete examples of low carbon development efforts at the provincial level in China and the state level in India.

Existing financial mechanisms in both countries which are relevant to low carbon development were studied, and recommendations have been provided on how to refine fiscal instruments to promote low carbon development and incentivize green investment behaviours. For instance, the study proposes a stimulus package in India which is targeted to developing its low carbon industries to strengthen economic development. Greenhouse gas emissions reduction would be a co-benefit.

For China, it is recommended that revenue-sharing arrangements between Central and local governments are revised, so that local governments could have more disposable revenue to invest in their local green, low carbon economy.

On the technology front, the report analyses the current status of low carbon technology development in the two countries, as well as related policies and strategies. The study argues that transition to a low carbon pathway could be accelerated by incentives, such as national directives to promote research and development on low carbon technologies; establishment of low carbon technology 'incubation centres' with strong links between the government, academia, and industries; facilitation of technology transfer through existing and new Technology Transfer Offices; and a focus on low carbon innovations in the informal sector, among others.

Finally, the study identifies several opportunities for cooperation between China and India, including around energy-saving technologies in the industrial, building, and transportation sectors; wind and solar power utilization; cleaner vehicles; and smart grid measures.

This study is of particular significance since it is one of the first collaborative efforts between the two key research institutes of both countries which are working on climate change-related issues: the National Development and Reform Commission (NDRC) of China and The Energy and Resources Institute (TERI) of India. This is a very encouraging development.

This research was compiled by a distinguished team of Indian and Chinese experts from TERI, the Chinese National Centre for Climate Change Strategy and International Cooperation, and the Central University of Finance and Economics and Zhejiang University. As an organization strongly committed to South-South cooperation, UNDP is proud to have partnered with these institutions on this important topic.

I would like to extend my congratulations to all the authors for their outstanding work. I also express my appreciation and gratitude to the Government of Norway and its Embassy in Beijing and to the Shakti Sustainable Energy Foundation for their generous financial support.

Helen Clark
Administrator
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ABOUT THE PROJECT

The collaborative study on low carbon development for China and India is directed towards developing specific strategies for low carbon development in crosscutting areas, such as financing, technology and innovation policy, and sub-national initiatives. The project focuses on understanding peer-country experiences, promoting knowledge exchange, and dissemination to shape domestic policies and implementation. By engaging with policymakers, the project seeks to support policy incubation and development at both the national and sub-national levels. Targeted policymaker engagement and advocacy supports design and adoption of new policies and programmes, based on findings from the study. The intended outcome of the collaborative project on low carbon development for China and India is supporting policy development by facilitating South-South cooperation, creating relevant knowledge, and building capacities through exchange of experiences and ideas.

The project is collaborative in nature. The Indian research institute is The Energy and Resources Institute, New Delhi. From China, the National Centre for Climate Change Strategy and International Cooperation is the lead research institute with Central University of Finance and Economics, and Zhejiang University as partner institutes. The National Development and Reform Commission steered the activities of the China component of the project. On the India component, activities of the project were guided by a steering committee.

This publication examines three areas important for operationalizing low carbon development; these include technology and innovation policy, financing, and informing sub-national actions.

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ABBREVIATIONS AND ACRONYMS

ABRC	Advanced Biomass Research Centre
ACX	Australian Climate Exchange
ACX-Change	Singapore Asia Carbon Exchange
AER	Alternative Energy Replacement
AF	Adaptation Fund
AFD	French Development Agency
APGENCO	Andhra Pradesh Power Generation Corporation Limited
APP	Average Power Purchase Agreement
APPCDC	Asia–Pacific Partnership on Clean Development and Climate
ASEM	Asia–Europe Meeting
ASX	Australian Securities Exchange
AUWSP	Accelerated Urban Water Supply Programme
BAIF	Bharathiya Agro Industries Foundation
BAT	Best Available Techniques
BAU	Business As Usual
BEE	Bureau of Energy Efficiency
BFIs	Bilateral Financial Institutions
BMPTC	Building Materials and Technology Promotion Council
BOVs	Battery Operated Vehicles
BSE	Bombay Stock Exchange
CBM	Coal-bed Methane
CCEA	Cabinet Committee of Economic Affairs
CCERs	Chinese Certified Emissions Reductions
CCFE	Chicago Climate Futures Exchange
CCPP	Combined Cycle Power Plant
CCS	Carbon Capture and Storage
CCSA	China Communications Standards Association
CCUS	Carbon Capture, Utilization and Storage
CCX	Chicago Climate Exchange
CDM	Clean Development Mechanism
CEA	Central Electricity Authority
CEM	Clean Energy Ministerial
CEPT	Centre for Environmental Planning and Technology
CER	Cleaning Energy Replacement

CERC	Central Electricity Regulatory Commission
CERs	Certified Emission Reductions
CERT	Center for Environmental Research & Technology
CESI	China Electronic Standardization Institute
CH_4	Methane
CHUEE	China Utility-Based Energy Efficiency Finance Program
CIF	Climate Investment Fund
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COP	Conference of the Parties
CPIS	Coconut Palm Insurance Scheme
CPSUs	Central Public Sector Undertakings
CPWD	Central Public Works Department
CSIR	Council for Scientific and Industrial Research
CSLF	Carbon Sequestration Leadership Forum
CSR	Corporate Social Responsibility
CUFE	Central University of Finance and Economics
DAC	Department of Agriculture and Cooperation
DAE	Department of Atomic Energy
DARE	Department of Agricultural Research and Education
DBT	Department of Biotechnology
DCAAI	Development Council for Automobile and Allied Industrie
DEFRA	Department of Environment, Food and Rural Affairs
DENA	Designated Energy Auditors
DHI	Department of Heavy Industry
DIPP	Department of Industrial Policy and Promotion
DOD	Department of Ocean Development
DoS	Department of Space
DOSTI	Development Organization of Standards for Telecommunications in India
DSIR	Department of Scientific and Industrial Research
DSM	Demand Side Management
EC	Energy Conservation Act
ECBC	Energy Conservation Building Codes
ECX	European Climate Exchange
EEA	European Environmental Agency
EEFP	Energy Efficiency Financing Platform
EEX	European Energy Exchange
EIA	Environmental Impact Assessment
EIB	European Investment Bank
ESCerts	Energy Saving Certificate

ESCOs	Energy Service Companies
ETF	Exchange-traded Funds
ETIS	Energy Technology Innovation System
ETP	Energy Technology Perspectives
EU	European Union
FEEED	Framework for Energy-Efficient Economic Development
FEX	Australian Financial and Energy Exchange
FITs	Feed-in-tariffs
FSI	Forest Survey of India
FTE	Full Time Equivalent
FTFT	Farmers' Technology Transfer Fund
FTP	Federal Test Procedure
FYP	Five-Year Plan
GBS	Government Budgetary Support
GCI	Glazing Council of India
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIM	Green India Mission
GIS	Geographical Information System
GRIHA	Green Rating for Integrated Habitat Assessment
GS	Gas Scope
GSSR	Global Sustainable Systems Research
HC	Hydro Carbon
HCPTCs	High-capacity Power Transmission Corridors
HEVs	Hybrid Electric Vehicles
HVAC	Heating, Ventilation and Air Conditioning
IBRD	International Bank Reconstruction and Development
ICAR	Indian Council of Agricultural Research
ICE	Internal Combustion Engine
ICFRE	Indian Council of Forestry Research and Education
ICGF	Infrastructure Credit Guarantee Fund
ICI	International Climate Initiative
ICLEI	International Council for Local Environmental Initiatives
IDA	International Development Association
IDFC	Infrastructure Development Finance Company
IDSMT	Integrated Development of Small and Medium Towns
IEA	International Energy Agency
IFC	International Finance Corporation
IGBC	Indian Green Building Council
IGCC	Integrated Gasification Combined Cycle

IIFCL	India Infrastructure Finance Corporation Limited
IIFM	Indian Institute of Forest Management
IISc	Indian Institute of Science
ILC	Improving Load Capacity
IPIRTI	Indian Plywood Industries Research and Training Institute
IPO	Initial Public Offering
IPPs	Independent Power Producers
IR/UV	Infrared and Ultraviolet Beams
IREDA	Indian Renewable Energy Development Agency
ISSRC	International Sustainable Systems Research Center
IVE	International Vehicle Emission
JFSF	Japan Fast-start Fund
JICA	Japan International Cooperation Agency
JNNSM	Jawaharlal Nehru National Solar Mission
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
KfW	Kreditanstalt für Wiederaufbau
KP	Kyoto Protocol
KVKs	Krishi Vigyan Kendras
KYC	Know Your Customer
LaBL	Lighting a Billion Lives
LCD	Low Carbon Development
LCDSs	Low Carbon Development Strategies
LCTs	Low Carbon Technologies
LEAP	Long-range Energy Alternatives Planning System
LED	Light-Emitting Diode
LEED	Leadership in Energy and Environmental Design
LTL	Less Than Truckload
M&V	Monitoring and Verification
MBT	Mechanical Biological Treatment
MCX	Multi Commodity Exchange of India
MFIs	Multilateral Financial Institutions
MIGA	Multinational Investment Guarantee Agency
MIGI	Multilateral Investment Guarantee Institution
MIIT	Ministry of Industry and Information Technology
MNRE	Ministry of New and Renewable Energy
MoEF	Ministry of Environment and Forests
MoEFCC	Ministry of Environment, Forest and Climate Change
MoM	Ministry of Mines
MoP	Ministry of Power
MoST	Ministry of Science and Technology
MRCP	Mercury Cell Process
MTEE	Market Transformation for Energy Efficiency

N_2O	Nitrous Oxide
NABARD	National Bank for Agriculture and Rural Development
NAIP	National Agriculture Innovation Project
NAIS	National Agricultural Insurance Scheme
NAMAs	Nationally Appropriate Mitigation Actions
NAPCC	National Action Plan on Climate Change
NATP	National Agriculture Technology Project
NBC	Net Bank Credit
NBFIS	National Basic Forestry Inventory System
NCEF	National Clean Energy Fund
NDRC	National Development and Reform Commission
NEF	National Energy Fund
NEMMP	National Electric Mobility Mission Plan
NFAP	National Forest Action Programme
NFRP	National Forestry Research Plan
NGOs	Non-governmental Organizations
NIPFP	National Institute of Public Finance and Policy
NLDC	National Load Despatch Centre
NMBA	National Mission on Bamboo Applications
NMEEE	National Mission for Enhanced Energy Efficiency
NMSA	National Mission for Sustainable Agriculture
NMSKCC	National Mission on Strategic Knowledge for Climate Change
NO	Nitric oxide
NO_X	Oxides of Nitrogen
NPOF	Network Project on Organic Farming
NPP	National Perspective Plan
NSC	National Steering Committee
NSFC	Natural Science Foundation of China
O&M	Operations and Maintenance
O_3	Ozone
OAS	Organic Agriculture Systems
ODA	Official Development Assistance
OECD	Organization for Economic Co-operation and Development
PAT	Performance, Achieve, and Trade
PDFSR	Project Directorate for Farming Systems Research
PEC	Primary Energy Consumption
PECE	Programme of Energy and Climate Economics
PFC	Power Finance Corporation
PGCIL	Power Grid Corporation of India Ltd
PHEV	Plug-in Hybrid Electric Vehicles

PPAs	Power Purchase Agreements
PPP	Public–Private Partnership
PRGF	Partial Risk Guarantee Fund
PXIL	Power Exchange of India Limited
RBI	Reserve Bank of India
RD&D	Research, Development, and Demonstration
RDD&D	Research, Design, Development, and Demonstration
RDF	Refuse Derived Fuel
REC	Renewable Energy Certificates
REDD	Reducing Emissions from Deforestation and Forest Degradation
REE	Rare Earth Elements
RGGI	Regional Greenhouse Gas Initiative
RPOs	Renewable Purchase Obligations
RR	Retro Reflector
RSoP	Research Scheme on Power
SAC	Standardization Administration of China
SAPCC	State Action Plan on Climate Change
SASTIND	State Administration for Science, Technology, and Industry for National Defence
SAUs	State Agricultural Universities
SBI	State Bank of India
SCCF	Special Climate Change Fund
SCRD	Standing Committee on Research and Development
SDC	Swiss Development Corporation
SDF	Steel Development Fund
SEC	Specific Energy Consumption
SECF	State Energy Conservation Fund
SEEP	Super Energy-Efficient Programme
SERC	State Electricity Regulatory Commission
SERI	Solar Energy Research Initiative
SFDCC	Strategic Framework for Development and Climate Change
SIDBI	Small Industries Development Bank of India
SMX	Singapore Mercantile Exchange
SNC	Second National Communication
SPVs	Special Purpose Vehicles
SSL	Solid State Lighting
STI	Science, Technology and Innovation
SUAEE	Shanghai United Assets and Equity Exchange
SWM	Solid Waste Management
TDL	Tunable Laser Diode
TEQUP	Technology and Quality Upgradation

TERI	The Energy and Resources Institute
TFYP	Twelfth Five-Year Plan
TIF	Tax Incremental Financing
TIFAC	Technology Information, Forecasting and Assessment Council
TMTT	Technology Mission on Technical Textiles
TRIPS	Trade Related Aspects of Intellectual Properties
TTOs	Technology Transfer Offices
UCG	Underground Coal Gasification
ULBs	Urban Local Bodies
UMPPs	Ultra Mega Power Projects
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNOSSC	United Nations Office for South–South Cooperation
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
UV-DOAS	Ultraviolet Differential Optical Absorption Spectroscopy
VC/PE	Venture Capital and Private Equity
VCFEE	Venture Capital Fund for Energy Efficiency
VGF	Viability Gap Funding
WB	World Bank
WBCIS	Weather Based Crop Insurance Scheme
WCI	Western Climate Initiative
WEF	World Economic Forum
WII	Wildlife Institute of India
WTO	World Trade Organization
WWF	World Wildlife Fund

PART I

DIMENSIONS OF LOW CARBON DEVELOPMENT IN CHINA AND INDIA

CHAPTER 1

DIMENSIONS OF LOW CARBON DEVELOPMENT IN CHINA AND INDIA

1.1 Emerging Concepts in Global Sustainability

Concepts such as 'green growth', 'green economy', and 'low carbon development strategies' have gained global policy prominence and are increasingly being discussed among major stakeholder groups, including national governments, business and industry, civil society, and research and academia. From a development policy perspective, it becomes important to understand low carbon development in relation to the three pillars of sustainable development, namely, society, economy, and the environment. In the multilateral fora, 'low carbon' development found mention in the Bali Roadmap and the subsequent United Nations Framework Convention on Climate Change Conference of the Parties (UNFCCC COP) documents. Table 1.1 depicts the contextualization of low carbon development in UNFCCC documents.

It may be said that the concept of 'low carbon' has become more mainstreamed in climate policy since the Bali Roadmap in 2007. It is also interesting to note the different contexts in which low carbon development has been deliberated in the international climate discourse. At Bali, the focus was low carbon technology transfer to developing countries; at Copenhagen, the context was financial assistance to developing countries for adaptation and development needs; and at Cancun, 'low carbon development' strategy was discussed as being indispensable for sustainable development. While COP16 recognized that developing countries will take a longer time to be able to take on mitigation targets, it called for scientific identification of a time-frame for global peaking of greenhouse gas emissions, based on the best available scientific knowledge and to consider the same at subsequent climate policy discourses.

Thus, it may be said that the concept of low carbon development in developing countries has recognized climate change mitigation as an important aspect but is being (and still has to be) understood in the context of development and the complexity of issues that arise when examining low carbon in development policy.

Table 1.1 Low carbon contextualization in global policy discussion

Low-carbon in UNFCCC documents	Context	UNFCCC document
…decides that the following…are important for funding through existing vehicles and new initiatives…Licenses to support the access to and transfer of low-carbon technologies and know-how;	Technology transfer	COP 13, Decision: 4
…agrees that Parties should cooperate in achieving the peaking of global and national greenhouse gas emissions as soon as possible, recognizing that the time frame for peaking will be longer in developing countries, and bearing in mind that social and economic development and poverty eradication are the first and overriding priorities of developing countries and that a low-carbon development strategy is indispensable to sustainable development; in this context, further agrees to work towards identifying a time frame for global peaking of greenhouse gas emissions …	Deliberations for commitments for global and national GHG, based on peaking periods	COP 16, Decisions: 1
….identifying currently available climate-friendly technologies for mitigation and adaptation that meet their key low-carbon and climate-resilient development needs…	Climate friendly technology	COP 18, Decision: 2
…to facilitate the transition to low-carbon societies; to facilitate access to climate change financing for clean technologies; to support both public and private financing mechanisms; to support national processes for implementing sustainable forest management plans; to improve the understanding of climate change science and its use in sound policymaking; and to improve the general understanding of climate change…	Role of the UN system for facilitate access to financing, clean technologies; and support national policy processes	COP 18, Decision: 1, 14, 21
… long-term green and low-carbon development strategy, plan or programme, as appropriate…	National policies on low carbon	COP 18, Decision: 1

Source: Compiled from UNFCCC COP statements.

The European Union (EU) was an early advocate of 'low carbon economy'. A 2003 white paper titled, 'UK energy white paper: Our energy future—creating a low carbon economy' by the Department of Environment, Food and Rural Affairs (DEFRA), was presented to the Parliament by the Secretary of State for Trade and Industry by Command of Her Majesty. The paper describes 'low carbon economy' as being characterized by higher resource productivity—producing more with fewer natural resources and less pollution—and contributing to higher living standards and a better quality of life (DEFRA 2003).

In climate change negotiations, the EU advocated the concept of 'low carbon pathways' to growth with an implied peaking point for carbon emissions. In 2007, EU, in climate change negotiations, set a target that the 2020 emission levels should be 20 per cent lower than that of 1990; it has stated its intention of aiming for a 30 per cent reduction if other countries, with high emissions, also commit to comparable emission cuts and has also said that it would like to contain global warming below an average temperature increase of 2 degrees Celsius as a global ambition.[1] According to a 2010 report by the European Environmental Agency (EEA), in 2009, the EU-27 emissions level stood approximately 17.3 per cent below the 1990 level, and therefore very close to the 20 per cent emission reduction target (European Environmental Agency 2012). Other analyses (Cranston and Hammond 2011) find that for developing countries, even by the most optimistic scenario—IPCC (IPCC 2000) B2—global carbon footprints could fall only around 2035. All these analyses suggest that given the level of development, challenges regarding low carbon development measures by developing countries are enormous.

Many developing countries have redefined the low carbon approach with the view of emphasizing harmony with the over-riding priority of poverty eradication and sustainable development. In the developing country context, concepts around low carbon development have clearly recognized mitigation as one of the outcomes but also recognize the need to achieve sustainable development goals. The Office of the President of Guyana describes 'low carbon development' as investing in infrastructure of low carbon economy, increasing input of the capital and human resources to low carbon economy sectors, realizing sustainable development of forestry-based economic sectors, and improving human capital.

The Energy and Resources Institute (TERI) conducted a poll to capture global perceptions around low carbon/green growth. It was conducted during the Delhi Sustainable Development Summit (DSDS) (31 January–2 February 2013) through an online survey. The poll captured opinions of experts on the subject of inclusive green growth for sustainable development and a total of 130 respondents were approached, in person, during various events of the Summit and other events at TERI. The respondents made a fair representation from government, multilateral organizations, civil society, media, business and industry, and research and academia. Out of the 124 respondents, 40 per cent were from Organization of Economic Cooperation and

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1 Available at <http://ec.europa.eu/clima/policies/brief/eu/index_en.htm>; last accessed May 15, 2013.

Development (OECD) countries and 60 per cent were from non-OECD countries. The respondents also represented a good geographical scope with representations from countries of South Asia; East Asia and Pacific; Europe and Central Asia; America and Caribbean; Sub-Saharan Africa; and Middle East and North Africa. Figure 1.1 captures the perceptions around the emerging global policy concepts.

Majority of the respondents (86 per cent) felt that low carbon development has the potential to promote inclusiveness. This is an issue that has been much deliberated in international dialogues.

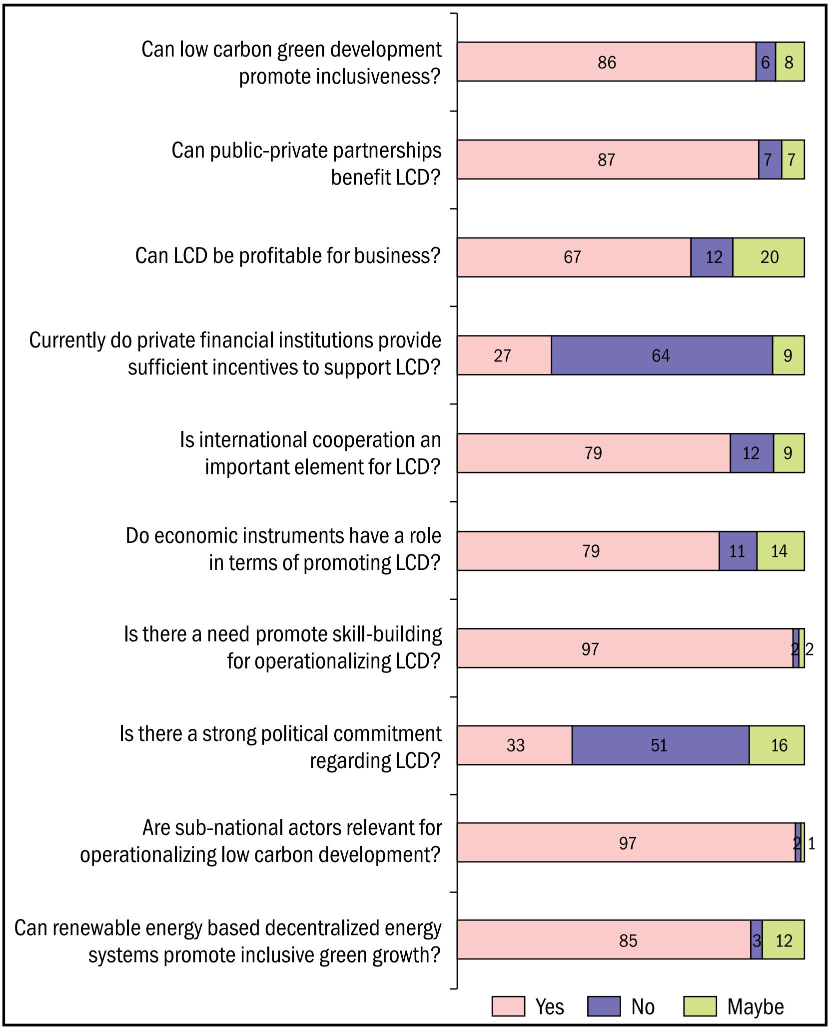


Figure 1.1 Perceptions on Low Carbon Development and Green Growth
Source: TERI Poll

Generally, it was felt that there is a need for greater political will and also incentives to spur private investments for LCDSs. It was also felt that the role of a skilled workforce was important for LCDSs apart from a stronger role of sub-national governments. Regional partnerships and international cooperation have always been recognized as an instrument to promote sustainable, economic, and social development. The poll embarked upon this aspect as well and it was found that 79 per cent of the respondents perceived international cooperation to be important for a country's low carbon development strategy.

1.2 Development in China and India

The sustainability of development patterns followed by India and China has significant socioeconomic and environmental implications for the two countries (CAEP-TERI 2011). Though China's per capita income levels, energy consumption, and progress on socioeconomic indicators are higher than India (Figure 1.2), the two countries show similarity in trends of rising energy consumption and greenhouse gas emissions coupled with a decline in energy intensity figures. Both these countries are also witnessing structural shifts in their economies with an increasing share of gross domestic product (GDP) coming from the services and manufacturing sectors. However, due to variations in resource availability and governance structures, there may be differences in the energy and environment-related policies and options in these two countries.

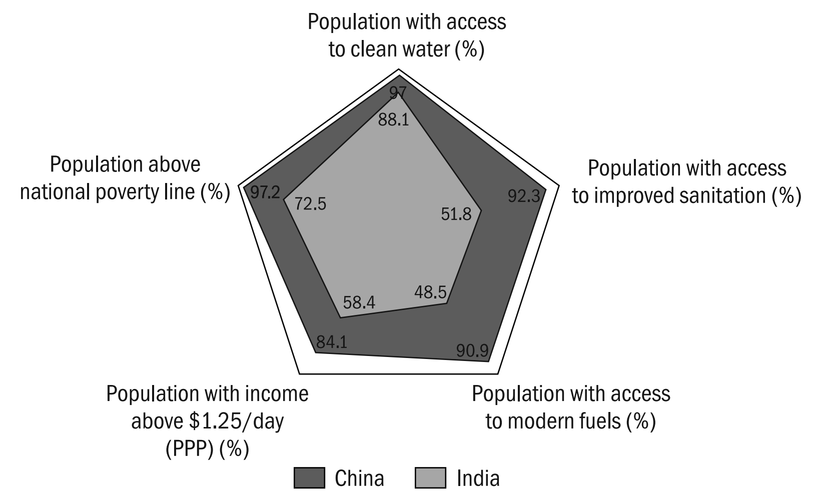


Figure 1.2 Key Socioeconomic Indicators: China and India
Source: Based on UNDP (2011)

China and India together constituted about 12 per cent of the global GDP in 2010 with China contributing to about 9.4 per cent and India contributing to about 2.7 per cent. During 1990–2010, both India and China experienced good economic growth, with their GDP growing at CAGR (compound annual growth rate calculated at current USD) of 8.5 per cent for India and at 15 per cent per annum for China. It is important to note that the CAGR for India rose to more than threefold (3.8 per cent to 13.5 per cent) between 1990–2000 and 2000–2010. In China, the CAGR has increased from 12.9 per cent during 1990–2000 to 17.3 per cent during 2000–2010.

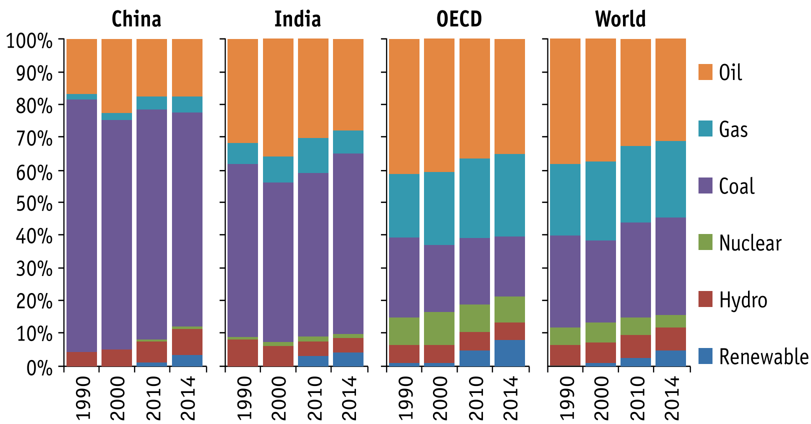
While, the industry and service sectors together account for over 80 per cent of GDP in India and China, the agriculture sector has witnessed a steep fall in its contribution towards GDP. The contribution of agriculture to GDP has declined from 29 per cent in 1990 to 17 per cent in 2010 in India whereas for China, it declined from 27 per cent in 1990 to 10 per cent in 2010.

Currently, at the aggregate level, India and China consume about 4.3 per cent and 20 per cent of the world's primary energy, respectively. India's primary energy consumption had risen at a CAGR of 5 per cent in the period 1990–2010 and stood at 520 MTOE in 2010. China's primary energy consumption had risen at a CAGR of 7 per cent in the period 1990–2010 and stood at 2402 MTOE, overtaking the United States (US) to emerge as the largest consumer of energy in the world in 2010. Figure 1.3 shows the percentage share of primary energy consumption for different sources including oil, natural gas, coal, nuclear energy, hydroelectricity, and renewables in the energy mix for China, India, OECD and the World respectively for the years of 1990, 2000, 2010 and 2014.

As can be seen from the following figures, both China and India have high dependency on coal, though the dependence rate in India is less than that in China. Both China and India have also seen a high rate in growth of renewables in the period of 1990-2014. It is also important to note that OECD has seen decline in coal and nuclear in the period 1990-2014.

1.3 The Basis for South–South Cooperation on Low Carbon Development between China and India

Globally, there is an increasing awareness of the need to move away from a carbon-intensive growth path. This, however, requires fundamental policy changes in key sectors of the economy including, but not restricted to, the energy sector. Beyond the energy sector,



CAGR according to fuel consumption (1990–2014)

	Renewable	Hydro	Nuclear	Coal	Gas	Oil
China	58.07	9.27	3.91	5.65	10.82	6.57
India	32.87	2.87	5.79	5.69	6.16	4.85
OECD	9.75	0.62	−0.86	−0.22	1.93	0.19
Total World	10.50	2.47	−0.13	2.33	2.32	1.20

Note: For nuclear, CAGR is considering the period 2000–2014

Figure 1.3: Primary energy consumption in China, India, OECD and World in key fuels
Source: Based on BP Stats (2015)

factors, such as overall level of development, governance structure, and vulnerability to climate change will also determine a country's targets and strategies. There is no single low carbon development blueprint that can be universally applicable.

The concept of low carbon development (LCD) has been articulated in the policy arenas in both China and India. Low carbon development in these sectors can result in co-benefits that include energy security, health benefits, and addressing local environmental pollution.

In China, the National Development and Reform Commission (NDRC) describes low carbon development as the development of the socioeconomic system that can realize low carbon emissions. India's National Action Plan on Climate Change highlights the co-benefit approach for low carbon activities that could in turn ensure energy security, reduced local pollution, and increased access to energy through distributed and decentralized forms of energy systems.

India's National Action Plan on Climate Change (NAPCC) was adopted in 2008. NAPCC outlines policies directed at climate change mitigation and adaptation. China's National Climate Change

Programme was approved in 2007 and includes measures to strengthen the energy legal system.

In it's Twelfth Five-Year Plan, China has, for the first time, set for itself, a carbon-intensity reduction target of 17 per cent by 2015. Similarly, the Government of India, in the Twelfth Five-Year Plan, has recognized low carbon development and inclusive growth. Table 1.2 lists the domestic policy objectives related to low carbon growth in China and India.

The visit of President of the People's Republic of China to India in September 2014 and the visit of the Indian Prime Minister to the People's Republic of China in May 2015 reinforced China-India bilateral cooperation with the signing of thirty six agreements between the two countries. To strengthen the bilateral ties between the two countries the Indian government has set the goal of "INCH (India-China) towards MILES (Millennium of Exceptional Synergy).

In May 2015, a "Joint Statement on Climate Change between India and China" was released that highlighted that "the two biggest developing countries, China and India are undertaking ambitious actions domestically on combating climate change through plans, policies and measures on mitigation and adaptation despite the enormous scale of their challenges in terms of social and economic development and poverty eradication". The Agreement underscored the bilateral partnership on climate change as being mutually beneficial and global relevant to address the challenge of climate change. The two countries look to enhance bilateral dialogue on domestic climate policies and multilateral negotiations. In addition to adaptation, the countries have emphasized on cooperation in several low carbon development areas such as clean energy technologies, energy conservation, energy efficiency, renewable energy, sustainable transportation, and low-carbon urbanization.

At the 15th session of the Conference of the Parties (COP15) to the United Nations Framework Convention on Climate Change, India and China, along with their BASIC partners (Brazil and South Africa) made a significant contribution in drafting the 'Copenhagen Accord'. Under this Accord, India and China have pledged to reduce the emissions intensity of their GDP by 20–25 per cent and 40–45 per cent, respectively, by 2020 in comparison to their respective 2005 levels. In its Twelfth Five-Year Plan, China has set prudent economic growth targets while emphasizing on social sectors and addressing key environment issues (including pollutants). For the first time in a Five Year Plan, apart from energy intensity targets, China has set for itself a

Table 1.2 Policy Objectives and Low Carbon Development in China and India

Themes	China	India
Copenhagen Accord target	40–45 per cent by 2020 in comparison to 2005 levels	20–25 per cent by 2020 in comparison to 2005 levels
INDC target (emission intensity)	60–65 per cent by 2030 in comparison to 2005 levels	33–35 per cent by 2030 in comparison to 2005 levels
INDC: Peaking	2030 or earlier	-
INDC: Non-fossil fuel	Non-fossil fuels in primary energy consumption to be around 20% by 2030	To achieve 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030
INDC: Forestry and land use	To increase the forest stock volume by around 4.5 billion cubic meters on the 2005 level by 2030	Create additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030
INDC: Financing needs	-	USD 2.5 trillion (at 2014-15 prices) will be required for meeting India's climate change actions between now and 2030.
National climate policy	China's Policies and Actions on Climate Change (2014) National Strategy for Climate Adaptation	National Action Plan on Climate Change (2008) National Adaptation Fund
Key national agency coordinating climate change	The National Development and Reform Commission	Ministry of Environment, Forest and Climate Change
Sub-national initiatives	Low-carbon Pilot Projects in Provinces and Cities	State Action Plan on Climate Change
Emissions/ energy trading	Carbon Emissions Trading Pilot Program	Energy Saving Certificate and Renewable Energy Certificates
Technology development	China's Science and Technology Actions on Climate Change	Climate Change Centers in states
South-South cooperation	Fund for South-South Cooperation on Climate Change	International Solar Alliance

Source: Author compilation

carbon-intensity reduction target of 17 per cent and intends to achieve it by 2015. Similarly, India's Twelfth Five Year Plan recognized that "India needs to adopt a low carbon strategy for inclusive growth in order to improve the sustainability of its growth process, while carbon mitigation will be an important co-benefit. Any such strategy must ensure that the focus is not just on low carbon development, but on increasing productivity that effectively lowers the use of fossil fuels."

1.4 Emissions Profile: Global, India, and China

According to the following well-known Kaya equation, reducing the energy consumption intensity (energy consumption per GDP) and the CO_2 emission intensity (CO_2 emission per energy consumption), given the precondition that population and GDP per capita keep growing in the future, are the basic approaches to control total emissions. To realize the former target, we need to improve energy efficiency, enhance value addition of industries, and upgrade the economic structure; and for the latter, we need to adjust energy structure and increase carbon sinks.

$$CO_2\,\text{emission} = \frac{CO_2\,\text{emission}}{\text{Energy consumption}} \times \frac{\text{Energy consumption}}{\text{GDP}} \times \frac{\text{GDP}}{\text{Population}} \times \text{Population}$$

(Kaya equation)

Figure 1.4 gives the energy intensity for the given economic structure for the regions including US, Japan, China, India, and the world during 1990–2010. A lower energy consumption intensity ratio or energy intensity ratio depicts a higher share of low-energy intensive economic activities. As can be seen in the figure, the energy intensity for China has been continuously on a decline over the last two decades. The energy intensity of the Indian economy has been historically low and it has also experienced a decline in the last two decades. For the year 2010, India's energy intensity was 0.31 kgoe per USD; for China, it was 0.41 kgoe per USD; and for the world, it was 0.19 kgoe per USD 1,000. This indicates that the share of energy intensive sectors like industries and manufacturing is high for China, as compared to India and other countries of the world.

In 2010, China's absolute value of CO_2 emission per GDP (2005 price) was still 4.6 times that of the US, 7.4 times that of the countries of the EU27, and 7.5 times that of Japan. Since 1970, China's carbon intensity has been gradually decreasing, dropping 70 per cent, from 6.31 kg of CO_2 per dollar (2005 price) in 1971 to 1.88 kg of CO_2 per dollar in 2010. This is one of the best achievements in reducing carbon

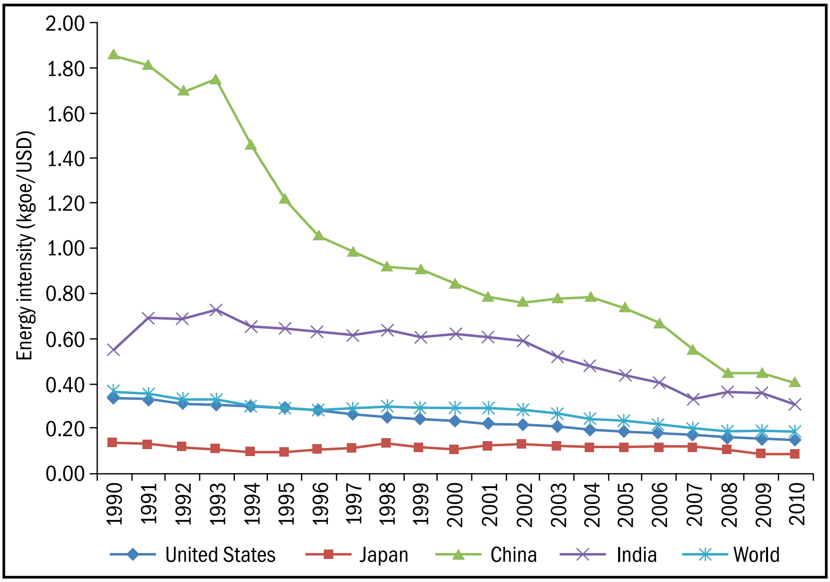


Figure 1.4: Energy Intensity Trend: US, Japan, China, India, and the World
Source: Based on BP Stats (2012) and The World Bank (2012)

intensity worldwide. India's absolute level of CO_2 emissions per GDP is relatively less than that of China, which is about 70 per cent that of China. Moreover, unlike China, its carbon intensity in 2011 was 1.3 kg of CO_2 per dollar (2005 price), which was almost the same as the level in 1971.

In future, the fall in the energy intensity in China and India could be driven by a number of factors, including structural shifts in economic activity towards services and efficiency improvements in energy-intensive sectors, such as industry and transportation. It is evident that with development, agriculture's share of economic activity has been substituted by growth in industry and services. The ways in which China and India develop themselves is of great importance not only to these two nations and their peoples, but also to the whole world. It is also possible for China and India to work together towards low carbon development as they have similar planning based approaches to economic development and the two countries are investing considerable time, effort, and resources in building more sustainable futures.

According to studies which have assessed a number of greenhouse gas abatement opportunities across major consumer sectors and across geographic regions, the following demand-side measures need to be prioritized: efficient lighting, efficient residential appliances and equipment, efficient residential and commercial buildings, and efficient vehicles. Attractive supply-side options include power plant upgrades, and transmission and distribution system efficiency improvements. There is a need to better understand barriers to low carbon development in China and India; some of these barriers could include limited access to technology, economic and financial constraints, weak legal and regulatory frameworks, irrational pricing and subsidy policies, information sharing bottlenecks, institutional limitations, and poor governance. The Energy Service Company (ESCO) industry which was established in India and China about two decades ago could play a greater role in realizing energy savings in both India and China, in a more conducive policy environment.

A majority—more than 66 per cent—of the world's greenhouse gas emissions originate in the energy sectors which include power generation, industry, transportation, buildings, and appliances. Figure 1.5 depicts key sectors and the type and volume of greenhouse gases that result from them at a global level in 2004.

China and India have common emission trends and characteristics. The two countries also face similar mitigation pressures and this suggests the possibility and priority of cooperation between China and India. Figure 1.6 shows the trends in the fossil fuel CO_2 emission trends for US, EU27 countries, China, and India.

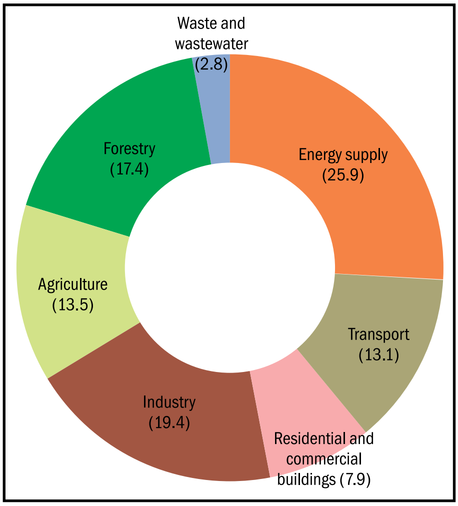


Figure 1.5: Global GHG Emissions by Sector in 2004 (%)
Source: Based on IPCC (2007), WG-III, pg 29

Figure 1.7 discusses the share of US, EU27 nations, China, and India in the world fossil fuel emissions. China and India are now the first and fourth largest fossil fuel CO_2 emitters, respectively, in the world. Their emissions account for about 24.6 per cent and 6.5 per cent of the world, total emission, respectively, in 2011. Since 2002, the annual economic growth in China accelerated from 4 per cent to 11 per cent, on average.

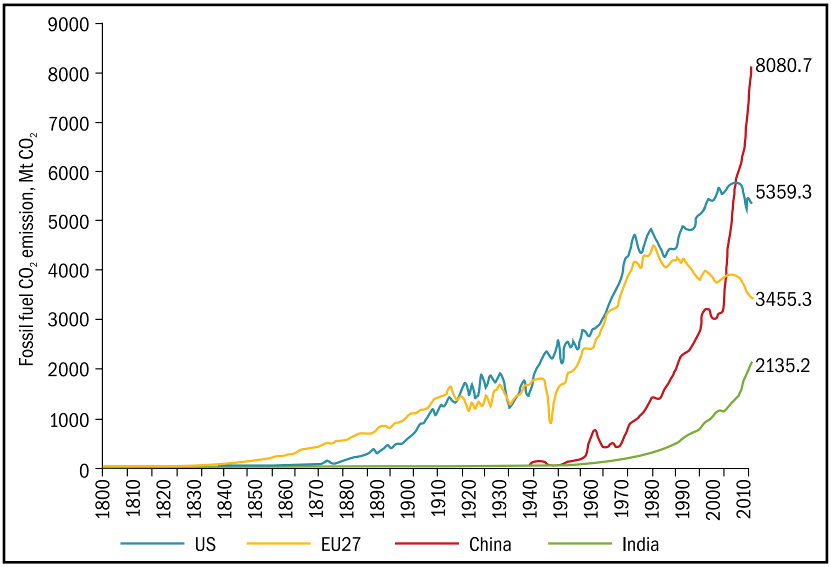


Figure 1.6: CO_2 Emission Trends from Fossil Fuel Use
Source: Carbon Dioxide Information Analysis Center (CDIAC), cdiac.ornl.gov

The CO_2 emissions have increased by 142.5 per cent in China and in India by 83 per cent. In 2011, China's fossil fuel CO_2 emissions jumped 9.4 per cent to 8.08 billion tonnes. This increase was consistent with the increase in thermal power generation of 14.7 per cent (mostly in coal-fired power stations), in steel production of 7.3 per cent (also a large coal user) and in cement production of 10.8 per cent as reported by the National Bureau of Statistics of China (NBS 2012). Meanwhile, India's CO_2 emissions continued to increase in 2011 by 7.4 per cent to 2.14 billion tonnes of CO_2.

Figure 1.8 discusses the CO_2 emissions per capita from fossil fuel use. As already discussed in Figure 1.3, China and India are two of the few countries in the world whose main energy source is coal; however, the dependence on coal in India is still less than China. Although the energy structure of China has begun to show a trend

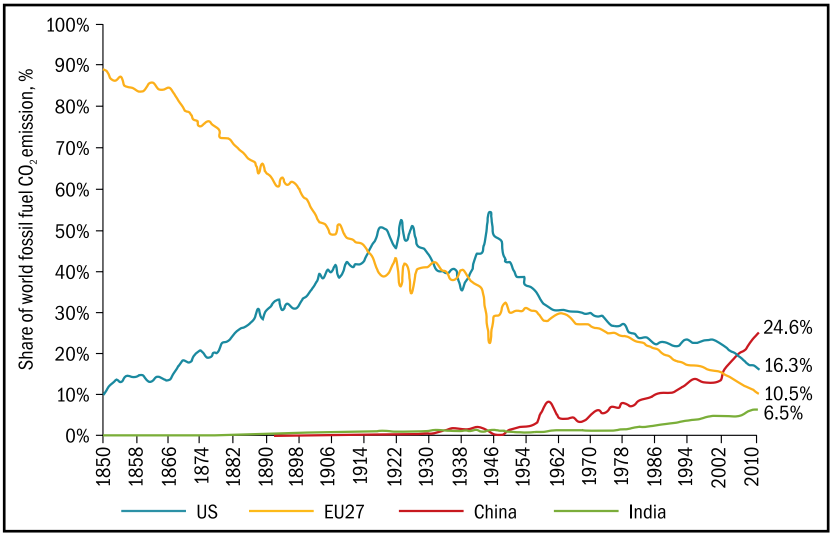


Figure 1.7: Share of Fossil Fuel based CO_2 Emissions
Source: Carbon Dioxide Information Analysis Center (CDIAC), cdiac.ornl.gov

of de-carbonization over the last three decades, coal still occupies a dominant position and a much larger share than in other countries.

Although emissions in China and other developing countries have increased very rapidly in recent years, in relative and in absolute figures, the picture is different for CO_2 emissions per capita. Since 1990, in China, CO_2 emission per capita has tripled, increasing from 2 to 6 tonnes, while it decreased in the EU27 from 8.7 to 6.8 tonnes per capita, and in the US from 19 to 17.2 tonnes per capita. China's CO_2 emission per capita has passed the world average in 2007 and will catch up with that of EU27 in the next 1–2 years. In comparison, in 2011, the US was still one of the largest emitters of CO_2, with 17.2 tonnes in per capita emissions, after a steep decline mainly caused by the recession in 2008–2009, high oil prices compared to low fuel taxes and an increased share of natural gas. In 2011, although per capita emissions in India have doubled since 1990, it is clear that with 1.7 tonnes, the country's per capita emission was still much lower than those in industrialized countries and the world average.

It is evident that China and India's endowment of energy resources will make it more difficult to control greenhouse gas emissions than will be the case in other high-emitting countries. Due to the different energy endowment, China's carbon intensity per energy supply is around 30 per cent higher than those of other developed countries.

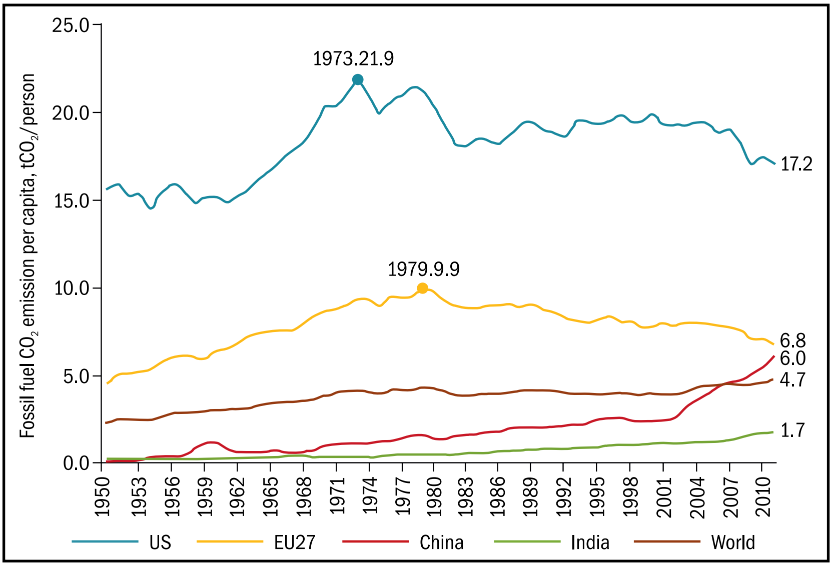


Figure 1.8: CO_2 Emissions per Capita from Fossil Fuel Use
Source: Carbon Dioxide Information Analysis Center (CDIAC), cdiac.ornl.gov

India's carbon intensity per energy supply is relatively low, similar to that of developed countries, which is mainly caused by its large share of traditional biomass. Moreover, one important challenge for India is that its carbon intensity per energy supply is increasing steadily since 1990. This will pose an additional future mitigation challenge for India. In this regard, Figure 1.9 discusses the CO_2 emissions from fossil fuel per total primary energy supply.

It is useful to understand the sectoral share of CO_2 emission in China and India; how these are different from that of developed countries. Based on the sectoral classification adopted by the International Energy Agency (IEA), the electricity and heating industries have the highest share of total CO_2 emissions at nearly half of the total, followed by the manufacturing and construction industries with a 32.3 per cent share and 24.7 per cent, respectively, in China and India. Transportation and residential sectors each have fairly low shares (Figure 1.10).

There is a clear relationship between emission trajectory (including the peak) and income level (development stage) with different corresponding income level for the peak. According to Figure 1.11, most developed countries get their peak of CO_2 emission per capita at a GDP per capita level of around US$ 25 thousand (2010 price). Japan and Australia have not reached a stable peaking although their level of

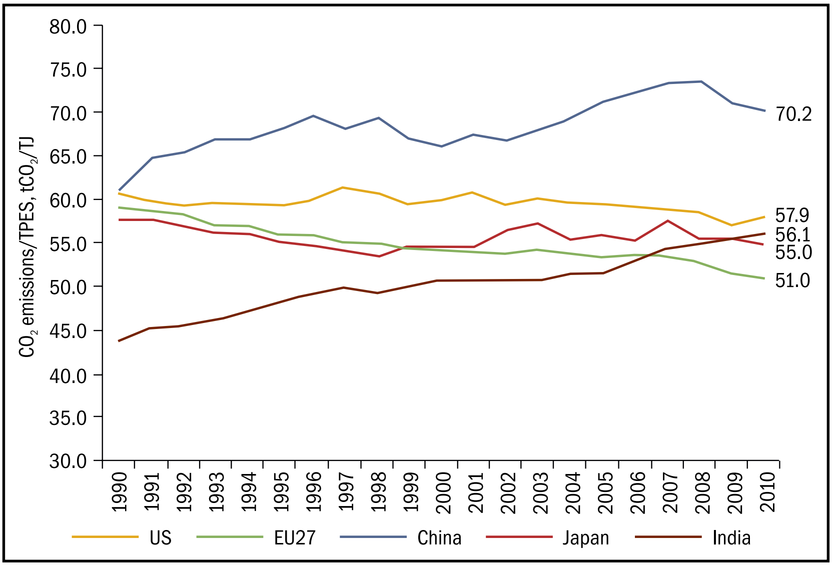


Figure 1.9: CO_2 Emissions from Fossil Fuel per Total Primary Energy Supply
Source: International Energy Agency, http://www.iea.org/statistics/

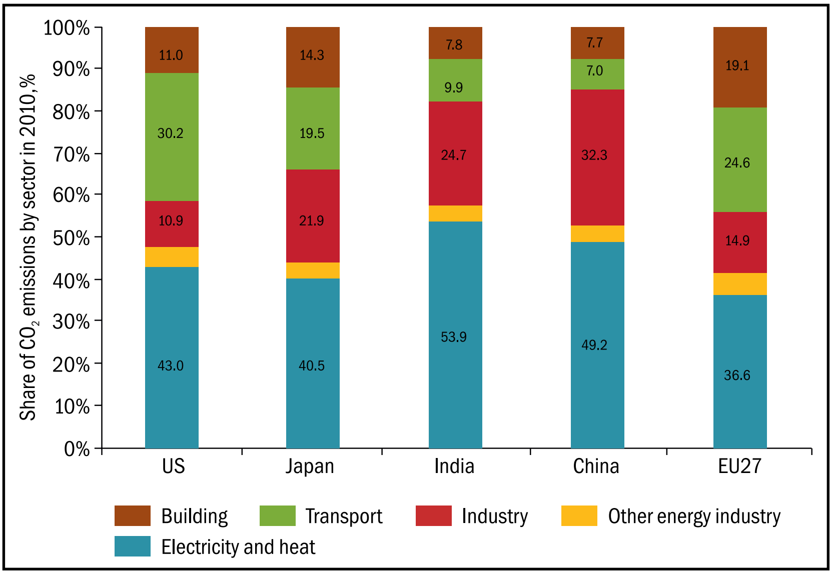


Figure 1.10: Share of CO_2 emissions from fossil fuels by sector in 2010
Source: International Energy Agency, http://www.iea.org/statistics/

GDP per capita already exceeds US$ 40 thousand (2010 price). China and India are still located on the left side of the Kuznets curve.

This kind of increasing emission trend will continue in the years to come, though the pace of growth may be reduced. According to IEA's estimation (Figure 1.12), China and India's total CO_2 emissions will still keep growing in the course of industrialization and urbanization over the next few decades, which will induce higher mitigation pressure for the two countries.

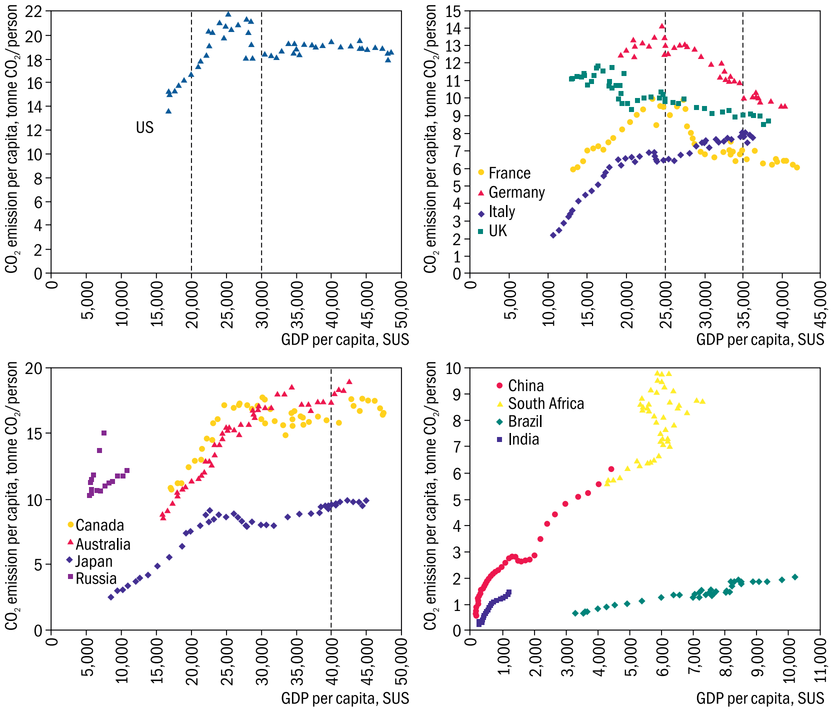


Figure 1.11: GDP per Capita and CO_2 Emission per Capita in Major Economies
Source: Carbon Dioxide Information Analysis Center (CDIAC), cdiac.ornl.gov; The World Bank, data.worldbank.org

1.5 The Way Forward

India and China, which together account for about 36 per cent of the world's population, are responsible for about 22 per cent of the world's demand for primary energy, and about 1/3rd of the world's CO_2 emission. With India and China staying on their impressive economic growth trajectories, respectively, seen in recent years, their energy demand and CO_2 emission will continue to grow, and the two

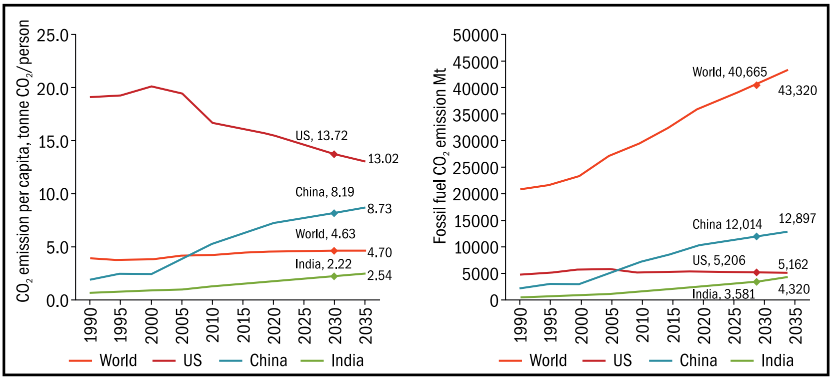


Figure 1.12: Future CO_2 Emission Trends from Fossil Fuel Use
Source: World Energy Outlook 2011, Current Policy Scenario

countries together will account for more than 50 per cent of the world's incremental energy demand and CO_2 emission over the next two decades. Hence, in order to stabilize greenhouse gas concentrations and achieve the 2 degree target globally, low carbon transitions in both countries are of significant importance to global efforts on tackling climate change and achieving sustainable development.

Both China and India are moving on the right track regarding low carbon development with strong political willingness, fairly well-designed domestic policies, and consistent international engagement. The key to China's and India's low carbon technology future is through innovation, development, and commercialization of new technologies and focusing on indigenous solutions. In addition, technology transfer from developed countries and joint R&D with developed countries can also help the two countries leapfrog to cleaner development patterns and become leaders in rapidly emerging economic sectors like renewable energy. However, both China and India need to overcome a series of social and economic barriers in order to achieve a low carbon future. For instance, meeting poverty reduction needs, expanding energy services, ensuring energy security, maintaining and increasing employment rate, reducing environmental pollution, protecting biodiversity, have to be kept in mind while moving down a low carbon development path.

Difficulties for both China and India, as emerging economies, in developing, deploying, and adopting low carbon technologies is mostly due to the additional cost associated with it and in some cases technical barriers to implementation. Besides, collaboration and open stakeholder involvement from various sectors including government, industry, academic, and civil society between the two countries is essential in framing and coordinating policies and measures between them, so that low carbon technology development policies can be implemented to promote sustainable development, spur innovative business, and meet the poverty reduction needs of the two largest developing countries in the world.

The present book compiles reports of parallel studies carried out in China and India deliberating around the issue of low carbon development in the two countries. Research papers from Chinese and Indian studies have been discussed as chapters in Parts II and III of the book, respectively.

PART II

LOW CARBON DEVELOPMENT IN CHINA

CHAPTER 1

LOW CARBON TECHNOLOGY AND INNOVATION POLICY

1.1 Introduction

Although China and India are late developers of climate-friendly technologies, they have made impressive progress in recent years. The energy use of the most energy-intensive industrial products decreased in 2010 over 2000. Table 1.1 shows that although China has made remarkable progress in energy efficiency of major energy-intensive industrial products since 2000, it still lags behind the international advanced level.

Table 1.1 International Comparison Using Energy Use Indicator in Energy-intensive Industries in 2010

Energy use indicator	China			Advanced International Level	2010 Gap	
	2000	2005	2010		Energy Use	%
Coal consumption of thermal generators (grams of coal equivalent/kWh)	363	343	312	290	22	7.1%
Comparable energy use of steel (large- and medium-sized enterprises) (kg coal equivalent/tonne)	784	732	675	610	65	9.6%
AC power consumption of aluminium electrolysis (kWh/tonne)	15,418	14,575	13,979	13,800	179	1.3%
Comprehensive energy use of copper metallurgy (kg coal equivalent/tonne)	1,277	780	500	360	140	28.0%
Comprehensive energy use of cement (kg coal equivalent/tonne)	183	178	143	118	25	17.5%
Comprehensive energy use of plate glass (kg coal equivalent/weigh box)	25	22.7	16.9	13	3.9	23.1%
Comprehensive energy use of crude processing (kg coal equivalent/tonne)	118	114	100	73	27	27.0%

Comprehensive energy use of ethylene (kg coal equivalent/tonne)	1125	1073	950	629	321	33.8%
Comprehensive energy use of synthetic ammonia (kg coal equivalent/tonne) (large-scale)	1699	1700	1587	990	597	37.6%
Comprehensive energy use of caustic soda (kg coal equivalent/tonne) (membrane method)	1439	1297	1006	910	96	9.5%
Comprehensive energy use of sodium carbonate (kg coal equivalent/tonne)	406	396	332	310	22	6.6%
Comprehensive energy use of calcium carbide (kg coal equivalent/tonne)	3475	3450	3340	3000	340	10.2%
Comprehensive energy use of paper and paper boards (kg coal equivalent/tonne)	1540	1380	1200	580	620	51.7%

Notes International advanced level is the average of the advanced countries in the world.
Source Wang Qingyi 2012; Energy Data 2013

As illustrated in Table 1.1, the coal consumption of thermal generators fell from 363 to 312 grams of standard coal; the comparable energy use per tonne of steel in key enterprises decreased from 784 to 675 grams of standard coal; and the overall energy use of copper metallurgy decreased by more than 50 per cent from 1,277 kg to 500 kg of coal equivalent per tonne. The energy use of China's aluminium electrolysis sector has reached an advanced world level.

Despite the achievements made in improving energy efficiency and introducing renewable energy, China's overall technological level is still well behind that of developed countries overall. Using international energy intensity comparisons, China ranks first in terms of energy intensity among the world's major countries (see Table 1.2). In 2005, China's energy intensity was seven times that of Japan. Even compared with India, China fell behind in terms of energy efficiency levels. China's industry energy intensity is also behind that of developed countries. Despite China (70 per cent reduction) and India (43 per cent reduction) having improved their energy intensity since 1990, their absolute values are still relatively higher than those of developed countries. Energy intensity improvement does not necessarily imply direct increases in energy efficiency; other factors can play a role, such as structural changes that base a higher share of the economy on less energy-intensive industry, and fluctuating materials prices.

Table 1.2 International Comparison of 2000 and 2005 Energy Intensity (TCE/Million USD)

Country/Group	2000	2005
China	743	790
USA	236	212
Japan	113	106
EU	204	197
India	664	579
OECD	208	195
Non-OECD	603	598
World	284	284

Note According to the 2000 value of USD
Source The Institute of Energy Economics, Japan, 2008

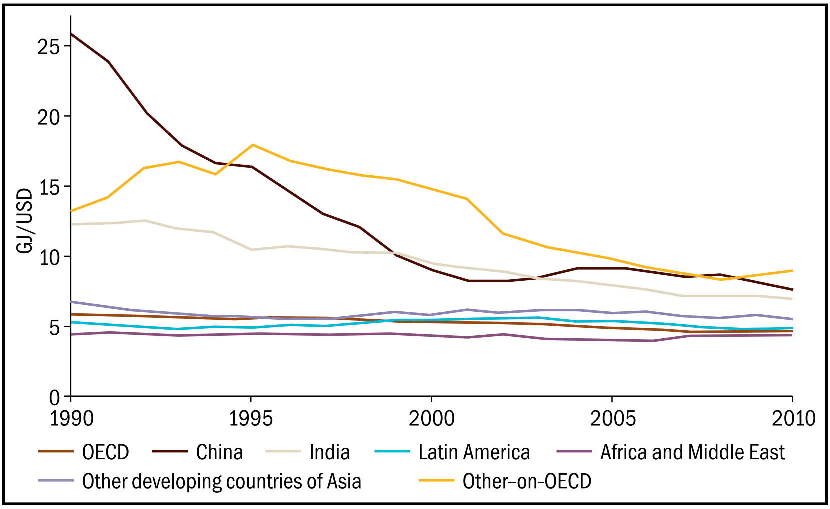


Figure 1.1 Aggregate Industry Energy Intensity (1990–2010)
Source: IEA, Energy Technology Perspective 2012

The gap between China's energy efficiency and the advanced international level, as shown in Table 1.1, is expressed in terms of not only energy intensity, but also the main energy-intensive products. The energy use of nearly all energy-intensive industrial products is above the advanced international level, although this gap has been narrowing.

The AC power consumption of aluminium electrolysis and the comparable energy use of steel (large- and medium-sized enterprises) are not far below the advanced international level, while the energy use of all other products is 10 per cent higher than the international level. Hence, a large potential exists to reduce energy use and CO_2 emissions from energy and industry sectors. Take iron and steel sector as an example. According to the IEA's analysis, the sector has technical potential to reduce energy use by 5.4 EJ—about 19 per cent of the sector's energy use in 2010—through application of best available techniques (BAT) (Figure 1.2). Around 67 per cent of the world's energy saving potential for iron and steel sector is in China and 9 per cent of this potential is in India. The development of a low carbon economy and technologies, while major challenges for China and India, are also opportunities to undertake major reforms that are good for the economy and human development. As the allowable space for carbon emissions shrinks, low carbon technologies will become the core of future international competitiveness. If China and India can make important breakthroughs in low carbon technologies, they will improve their technological competitiveness and create green job opportunities that will help ease their employment pressures domestically.

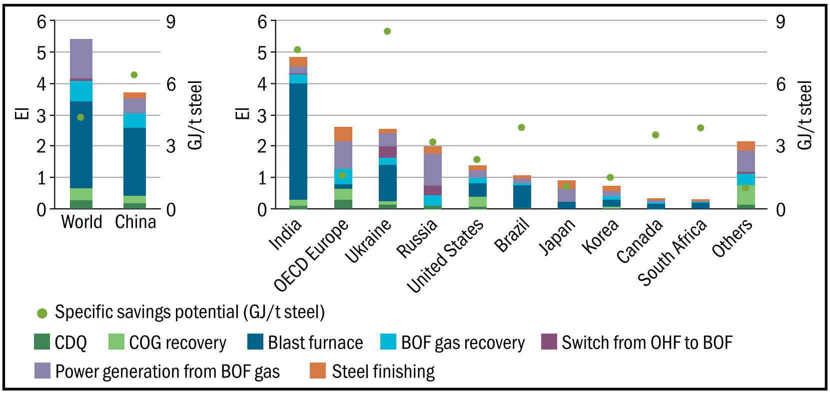


Figure 1.2 Energy Savings Potential for Iron and Steel, based on BAT
Source: IEA, Tracking Clean Energy Progress 2013

Although India's overall energy intensity is much better than China due to its different industry structure, for specific technologies, China is generally more advanced in many energy and manufacturing technologies, e.g., majority of the coal-fired power generation in India is sub-critical while a large number in China is super-critical and ultra-supercritical. As a result, the CO_2 emissions per kWh from electricity generation, using coal/peat in China, has reduced to 840 kg CO_2/kwh in 2010, while that in India is still more than 1100 kg CO_2/kwh.

China and India have achieved an impressive overall growth in the field of renewable energy in recent years, but they have not yet acquired the corresponding capability at the technological level. For example, although the installed capacity of China's wind-driven generators has doubled every year in the past few years and the domestic market share of China's wind turbine manufacturing enterprises is more than 50 per cent, most of the world's wind power related patents are owned by developed countries' companies (Table 1.3), and the applications for renewable energy-related patents have been applied for by foreign enterprise subsidiaries in China. China's top four applicants for wind power patents are all developed country enterprises (Table 1.4). Among the top ten, only four are Chinese applicants. Furthermore, although the total amount of patent applicants from China is increasing recently, the quality of patent applicants, e.g., share of invention patents, is still far behind. Thus, although much wind power equipment is produced by Chinese enterprises, the real owners of its technologies are companies of foreign countries (mainly developed countries).

The Programme of Energy and Climate Economics (PECE) of Renmin University of China conducted a research on energy industry, iron and steel industry, transportation industry, construction industry, and other important sectors of the national economy, identifying more than 20 important low carbon technologies which include ultra-supercritical power generation technology, renewable technology, and high-performance pure electric vehicle technology, and so on. Through a comparison of the status of development of these technologies at home and abroad (the details are presented in Table 1.5), it came to the conclusion that at present, China still lags far behind developed countries in core technologies.

In sum, China and India cannot narrow the gap between their countries and the developed world in the field of low carbon technologies overnight. Against the backdrop of increasingly pressing climate change, China and India should maintain their own independent development of high-efficiency energy use technologies and various clean energy technologies and also engage in technological cooperation and support with the international community.

Table 1.3 World's Top Ten Owners of Wind Power Related Patents

Company	Total patents	Country
GENERAL ELECTRIC CO	931	US
VESTAS WIND SYSTEMS AS	690	Denmark
SIEMENS AG	449	Germany
MITSUBISHI JUKOGYO KK	321	Japan
MITSUBISHI HEAVY IND CO LTD	293	Japan
WOBBEN A	175	Germany
REPOWER SYSTEMS AG	173	Germany
NORDEX ENERGY GMBH	142	Germany
GAMESA INNOVATION&TECHNOLOGY SL	137	Spain
LM GLASFIBER AS	102	Denmark

Source Derwent Innovations Index, accessed on March 14, 2013

Table 1.4 China's Top Ten Applicants for Wind Power Related Patents

Applicants	Total patents	Invention patents	Share of invention patents (%)	Country
GENERAL ELECTRIC CO	607	607	100	US
SIEMENS AG	269	257	95.5	Germany
VESTAS WIND SYSTEMS A	171	166	97.1	Denmark
MITSUBISHI HEAVY IND CO. LTD	154	154	100	Japan
GUODIAN UNITED POWER	154	75	48.7	China
SINOVEL	138	31	22.5	China
VESTAS WIND SYSTEMS S	103	97	94.2	Denmark
SANY	100	54	54	China
GAMESA INNOVATION & TECHNOLOGY SL	75	75	100	Spain
MINGYANG WIND POWER	73	40	54.8	China

Source Derwent Innovations Index, accessed on March 14, 2013

Table 1.5 Comparison of Key Technology Gap between China and Developed Countries

Sector	Technology	Development Status in China and Abroad
Energy (mainly power sector)	Ultra-supercritical power generation technology	The technology is developing rapidly in China, with an import substitution rate of more than 80%. Though there is still room for efficiency improvement. R&D on a new generation of high power ultra-supercritical units, with an efficiency rate of 55% is going on in the world, while key technologies in high-temperature materials, casting and forging are still restricted to developed countries.

IGCC power generation technology	The new generation of IGCC has a high efficiency rate (more than 50%), and low pollution emission rate, and incorporates a new type of cost-effective clean coal technology. Meanwhile, there has not been any project experience in China yet. China is lagging behind in integrated design control, large-scale coal gasification and gas turbine technologies. These technologies are of strategic importance to China and China must acquire them. However, taking into consideration the lessons learned from the failed import of gasifiers and gas turbines, and the fact that is no operation experience of high efficiency, large-scale IGCC power generation project abroad, it is important to do both joint-research and independent research in China, in order to avoid being an experimental laboratory to foreign enterprises.
Large-scale onshore and offshore wind power generation technology	So far, China has the production capacity of MW-level turbines and some components, but the key technologies of the control system, turbine and blade design still rely on foreign imports.
Highly efficient thin film solar cell	China is lacking in thin-film cell production technology, and has no experience in the commercialization of technology (flexible solar energy production process) and the whole set of production equipment and key equipment, such as vacuum pumps. Countries like Switzerland, the United Kingdom, Italy, and Germany have these key technologies.
Solar photovoltaic technology	The high cost of the solar cell is the major constraint in the development of solar photovoltaic power generation. More than 90% of the high-purity raw materials used in the solar cell are imported from other countries. These imported raw materials are expensive and countries who own the technologies blockade them, which have resulted in the high cost of the solar cell. Besides, China lacks key materials and manufacturing equipment, and needs to further improve the conversion efficiency.
Smart grid	At present, China does not have the key manufacturing technology for the production of inverters, not much large-scale on-grid power plant experience, nor does it have a commercial operation model. In the world, the United States, Germany, and Japan are the main possessors of these technologies.
Second-generation bio-energy technologies	The second generation plants which use cellulosic ethanol as liquid fuel should have wider application. There have been many years of R&D experiences abroad, and many enterprises are planning/constructing demonstration plants, although they are not widely commercialized. The cellulose enzyme technology is one of the most critical technologies.

	Energy storage technology	Wind and the sun are intermittent energy sources, and affect the stability of the power grid. Hence, the power grid has limited capacity for such kind of energy. Efficient storage technology needs to be developed. At present, this technology is in the hands of European countries and the United States. The technology is still in the R&D stage.
	Carbon capture and storage (CCS) technology	Taking into account China's coal-based resource endowment, CCS technology will be of great significance to mitigation. Currently, there has not been a commercial demonstration of CCS technology. The research is still in the preliminary stage, and a long way from large-scale commercial implementation. China needs to do joint R&D and keep track of the latest developments. In addition, China needs to study both pre-combustion carbon capture and post-combustion carbon capture technologies.
Steel	Coke dry quenching (CDQ)	By the end of May 2008, 57 units of CDQ devices have been put into operation in China, accounting for 13.5% of the total coke production capacity (360 million tonne). Most of the CDQ techniques in China were imported. Domestic metallurgical coke design institutes such as Capital Steel & Iron Design Institute and Anshan Coking & Refractory Engineering Institute have the capacity to design a CDQ process, and some are able to manufacture CDQ equipment, but they still lack the capacity to design and manufacture high-pressure CDQ technology, which is in the hands of Japanese companies.
	Residual heat and pressure recovery technologies	Including sintering waste heat recovery technology, converter gas recovery (LT), converter of low pressure steam for power generation, hydrogen production from coke oven gas technology, and so on. The residual heat and energy recovery in China's iron and steel sector is low (only 45.6%), while advanced international enterprises, such as Japan's Nippon Steel can have a recovery rate of more than 92%. Thus, there is great potential for China's iron and steel industry to improve its waste recovery rate.
	Coal moisture control (CMC)	CMC has great mitigation potential and have been developed extensively in Japan, which has widespread use of third-generation technology of CMC. In China, however, only second-generation of CMC is widely used.
	Combined cycle power plant (CCPP) technology with low calorific value gas in iron and steel plants	Low calorific value gas turbine and some core components need to be imported, because they only have 10–20 years of service life and cost high. There are joint-ventures, such as NAC and GE who make gas turbines and core components, but they can only make 50,000 kilowatts. Anything more than 150,000 kilowatts needs to be imported.

	Smelting reduction technologies	Smelting reduction technology is based on direct coal coke and iron ore powder technology. Since there is no coke, or sintering, or pelletizing plant involved, the technology simplifies the iron-making process. There are dozens of technologies, but only COREX and FINEX have been tested and implemented in industries. Baosteel has successfully introduced COREX technology, but no breakthrough has been achieved. Smelting reduction technology has very little value in reducing CO_2 emissions, but they are of significant importance to environment protection.
Cement	NSP technology	Although the proportion of NSP kiln is raised continuously, the proportions of old production processes such as shaft kiln are still high. There is still a wide gap between technologies used in China and the advanced technologies in the world, especially in some key areas, such as the automatic control device and the level of integrated operation.
	Eco-cement technology	The substitution rate of secondary fuel in the cement industry is more than 50% in the Netherlands, Germany and Switzerland. Although some academic institutions and some cement enterprises in Beijing, Shanghai, Guangzhou, and Sichuan have made numerous experiments and pilot productions, it has not been promoted nationally. Hence, the utilization rate of alternative fuels in the cement industry is close to zero.
Transport	The motorcycle engine technology, power train technology and lightweight vehicle technology to improve fuel economy	Traditional technologies in vehicle energy saving and fuel economy improving have high market proportions. There is a huge gap between these domestic technologies and advanced technologies in the world.
	Hybrid electric vehicle technology	In the world, the R&D of the hybrid electric vehicle started 30 years ago. Now the hybrid vehicle has been industrialized and commercialized. China's auto industry has begun to research, develop and manufacture hybrid vehicles, but the vehicle produced is lagging behind in recovery efficiency and matching technology of full hybrid vehicles.
	High performance pure electric vehicle technology	Developed countries have developed a series of pure electric cars, high speed pure electric vehicles, pure electric buses, and electric touring buses. China needs to improve the technology integration and wire transport technology in the pure electric vehicle area.

Building and residential	LED technology	The United States, Japan, Germany, and Taiwan are most advanced in LED technology. The majority of patented technologies are in the hands of a small number of large companies, and the core technology has been securely protected. China is currently doing packaging and heat sink, and has not acquired core technologies.
	New building envelope materials and parts	China has induced and learned a number of technologies in external wall and roof insulation. Major breakthrough has been made in the technology advancement in external windows and glass curtain walls but the level of technology diffusion is low; there is a huge gap in technology compared with foreign advanced companies in the outdoor sunshade field.
	Regional combined heat and power (BCHP) technologies	BCHP offers a solution to the energy supply of large public buildings. Compared with direct access to grid electricity, the technology can save primary energy by 20% ~ 30%. Major technical obstacles include: high power efficiency, low emission gas fired power plants, and high density, high conversion efficiency thermal driven air conditioning.
General technology	High power electronic devices, especially power semiconductor component technology	There is still a gap between the level of China's high power electronic products and foreign electronic products. Represented by Siemens and ABB, the European Union is in the leading position in high power electronic products and technologies. IGBT and IGCT devices have been the constraints of China's electric and electronics industry, especially the high power electronics industry.
	Permanent magnet DC brushless motor	Micro, small areas implication of this technology is relatively mature. Japan is in the leading position in this technology. Even with China's rare earth resources, technology providers from developed countries continue to lead in this field.

1.2 Strategies and Policies for Low Carbon Technology Development in China and India

1.2.1 Energy Technology Innovation System: Concept and Characteristics

Earlier, technology innovation processes were often referred to as 'linear' models. These models emphasized the role of basic, largely publicly funded science in a linear innovation process from basic research to applied development, demonstration, and concluding with the diffusion process (see the upper part of Figure 1.3). However, in reality, it is well understood that the innovation process is neither linear nor unidirectional (Mowery and Rosenberg 1979; Landau and Rosenberg 1986; Freeman and Hobday 1994). Rather, the stages of the innovation process are linked with feedbacks between each stage, giving rise to the term 'chain-linked' model (Kline and Rosenberg 1986). This is illustrated in the lower part of Figure 1.3.

Figure 1.3 represents the main modifications and additions to this 'chain-linked' model of the innovation process. In this improved model, there are multiple feedbacks among the different stages and their interaction, combining elements of 'supply push' (forces affecting the generation of new knowledge), and 'demand pull' (forces affecting the demand for innovations). Indeed, the stages often overlap with one another; the more interaction among the various stages, the more efficient the innovation process is, offering more possibilities for learning, and knowledge and technology spillovers.

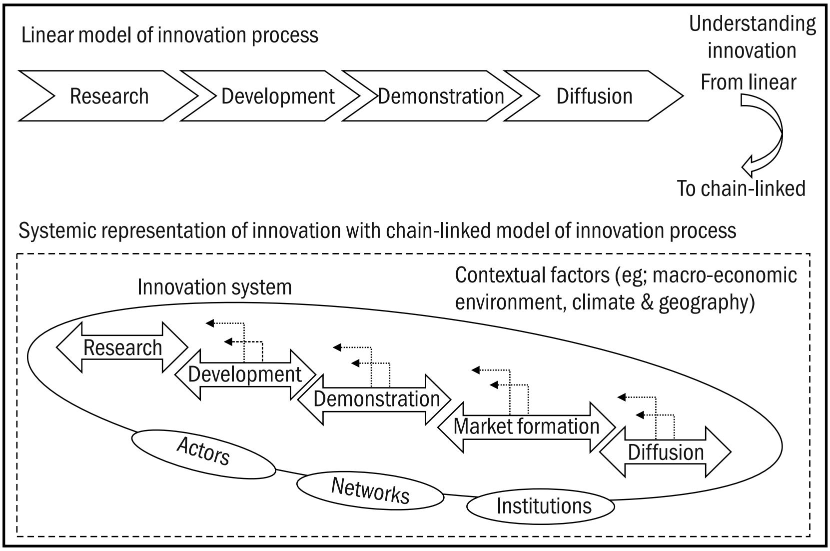


Figure 1.3 Systematic Representation of the Innovation Chain
Source: Adapted from IIASA (2012)

Box 1.1: Definition of the Stages of Energy Technology Innovation

The process of technological innovation is often described, for analytical and prescriptive purposes, as a linear process composed of several stages or steps that include research, development, demonstration, deployment and diffusion. Mapping innovation in the real world is clearly more complex, as the process of innovation is not a linear progression. Feedback occurs between the different stages of the process. For example, demonstration projects can result in significant changes to the product. Feedback from the market and from technology users during the commercialization and diffusion phases can lead to additional RD&D, driving continuous innovation.

Free-market competition at the later stages of the RD&D chain, when technologies are closer to commercialization, also plays an important role for continuous innovation.

Innovation is the implementation of a new or significantly improved product (good or service) or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations that reduces costs or improves performance.

Research and development (R&D) comprises creative work undertaken on a systematic basis to devise new products, processes and applications, and improve existing ones. The term covers basic research, applied research and experimental development (OECD 2002). Demonstration is a fundamental part of the development of new technologies and can be defined as a project involving an innovation operated at or near full scale in a realistic environment to aid policy or promote the use of innovation (OECD 2002), and to show the viability of its application to manufacturers and potential buyers.

The distinction between supply push and demand pull has traditionally been important, especially, as they imply different technology policy instruments—e.g., public R&D expenditures or incentives for private R&D as classic technology 'supply' instruments versus government purchase programmes, mandated quantitative portfolio standards, regulated feed-in-tariffs, or subsidies as classic technology 'demand' policy instruments. Transformative technological change generally requires the simultaneous leveraging of all innovation stages, processes, and feedbacks, and thus a combination of both supply- and demand-side technology policy instruments.

In an additional improvement over previous models, a market formation stage has been added in explicit recognition of the so-called 'valley of death' observed in this innovation process between technology demonstration and diffusion. Many technologies fail at this or a similar hurdle between development and demonstration if they are too expensive, otherwise uncompetitive, too difficult to scale up, or lack perceived market demand. Market formation activities support new technologies that can struggle to compete with incumbent technologies which enjoy economies of scale and the learning advantages resulting from their more mature technology life cycle.

The importance of the institutional context in which innovation occurs is also increasingly emphasized (Nelson 1993; Geels 2004). The chain-linked model points to the need for a more systemic approach to innovation, extending beyond the technology-focussed 'hardware' innovation process to also include analysis of actors, networks, and institutions.

Finally, the broader context of the innovation system matters. Technological, national or geographical factors affect the relative importance, roles and relationships between components of the innovation system or the specific incentive structures in place. The concept of a 'national systems of innovation' (Nelson 1993; Lundvall 2009) describes this specificity. As a result of this specificity, innovation systems for specific energy technologies vary substantively in their details—involving different sets of actors (e.g., incumbents or new entrants), interacting in different ways (e.g., research or market development), focussing on different problems (e.g., problem solving or learning by doing), and acting at different spatial scales (e.g., national or global) (Jacobsson and Lauber 2006; Hekkert *et al*. 2007).

Energy technology innovation system (ETIS) is the application of a systemic perspective on innovation to energy technologies. In terms of the innovation system, this means the synthesis and analysis of data in the various stages of the innovation process; on different inputs, outputs, and outcomes; on actors and institutions; and on the key innovation processes. In terms of the energy system, this means the synthesis and analysis of data on both the energy supply side and the energy demand side; on different energy technologies; and in both developed and developing countries. ETIS is thus an integrative approach that aims to comprehensively cover all the components of the energy technology innovation system, in terms of innovations, mechanisms of change and supporting policies, and energy technologies (supply and end use), as well as in terms of geographical and actor network coverage. The systemic perspective necessitates an integrative analysis: from large-scale supply side technologies to dispersed end use technologies within the energy system and from early stage R&D through market formation to diffusion activities.

1.2.2 Policy for the Innovation System

Policies for innovation can directly tackle the innovation process, support the innovation system, or unintentionally impact innovation while targeting an unrelated concern.

Direct policies for innovation vary according to their target and their timing during the innovation process. Policy is needed at each stage of this process (see the top of Figure 1.4 for examples). The role of the government is typically viewed as being most evident at the earliest stage of basic science and research. However, together with the private sector, governments are also engines of applied energy R&D. Governments must also play an important role in leveraging private sector investment at the early commercialization stages by supporting demonstration activities (to reduce risks) and market formation (to underwrite demand). Finally, through regulations and other policies, including tax and fiscal policies, governments also have a strong influence on the diffusion of energy technologies.

There is often an intermediate stage between demonstration and diffusion that can be considered a market formation or early deployment stage. Here too, the government can play a critical role as policies are often needed to create an initial market to ease the penetration of new energy technologies into the market place. First-of-a-kind technologies are often more expensive, and governments can create niche markets through procurement and other policies (e.g., feed-in-tariffs or technology portfolio standards) to create demand for advanced or cleaner energy technologies. With this support, entrepreneurs can experiment and test the market. Technological learning occurs through experience. Even after the niche market has been exploited, policy intervention may be needed to broaden and deepen the market through the elimination of market hurdles, provision of information, tax incentives, or low interest loans. At some point, a given technology becomes competitive in the market place, and the government can exit the market formation stage. For new, cleaner energy technology to be competitive in the broader market, government policies are also needed to correct for market externalities and define the rules of the game (e.g., through a carbon tax). Because there are so many market distortions, technologies cannot be assumed to freely compete in the global market place. The innovation process is situated within an overarching system comprising actors, institutions, and networks involved in developing and commercializing a technology.

Innovation policies must therefore also target the smooth functioning of the innovation system (see bottom of Figure 1.4). Although government policy affects all stages of innovation, rarely do we see evidence of comprehensive government strategies to optimize the efficiency of the ETIS. Instead, government policies persistently aim at isolated components of the system, such as support for R&D with regard to which policies are needed to maximize feedbacks in the system, or which market formation policies will be needed whether and when the technologies emerge in the demonstration phase.

Policies on issues, such as education, taxes and subsidies, and market regulation, can exert an important but indirect influence on innovation supply and demand. This reinforces the need for consistency, not just between direct innovation policies but also between the broader regulatory and institutional environments for innovation.

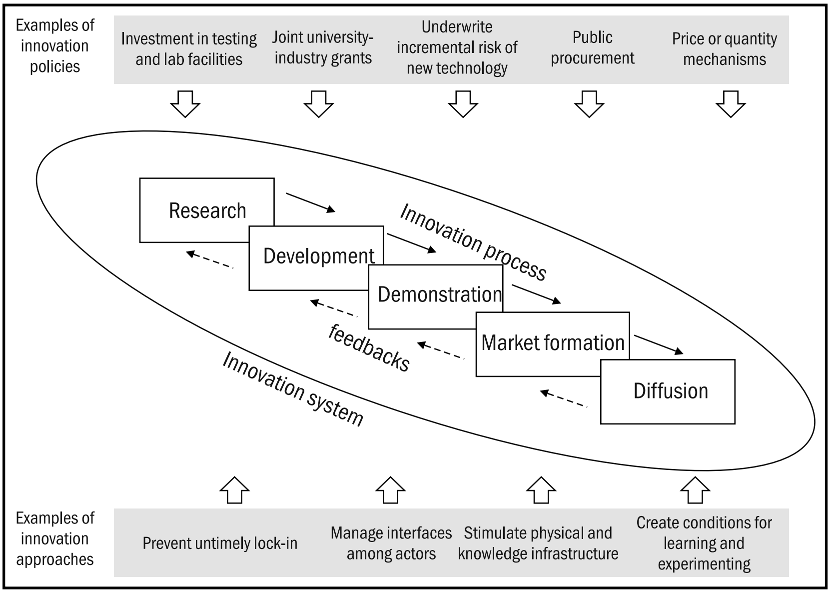


Figure 1.4 Overview of Policies for the Innovation System
Source: Adapted from IIASA (2012)

Policies supporting the supply of innovations or the development of technologies include investments in R&D, intellectual property protection, laboratory and testing infrastructure, training and skills development, university–industry collaborations, formal and informal mechanisms of knowledge exchange, and technology roadmaps to guide the direction of innovation, and financial incentives such as tax credits for private investments. Not all innovation, however, stems from formal research and development activities. Problem solving and incremental improvements in existing technologies are also of great importance and can be stimulated and supported by public sector policies that lead to the creation of outreach, extension, and technical support programmes. Policies supporting the demand for innovations as commercialized technologies include demonstration projects, public procurement, market niche creation (e.g., supply obligations), and the creation of appropriate market incentives. Market incentives may be created via changes in relative prices (e.g., environmental taxes or feed-in-tariffs), standards, and regulations. These supply push and demand pull policies are context-specific complements rather than substitutes. Innovation success stories are typically characterized by comprehensive and consistent policy support throughout the entire innovation process (see Figure 1.3). Particular innovation policies must account for specific local conditions or be otherwise tailored to the technological or market characteristics of an innovation.

1.2.3 Energy and Climate Technology Innovation System in China and India

Energy and Climate Technology Innovation System in China

As one of the countries in the world which have been long involved in climate change research, China strives to make scientific and technological advances and innovations in climate change, and actively promotes international scientific and technological cooperation. In 2006, the Government of China released the National Guidelines for Medium- and Long-term Plan for Scientific and Technological Development (2006–20) which identified energy and environment as the first priorities for scientific and technological development, and enlisted global environment change monitoring and response strategies as one of the priority research themes in the area of environment. In 2007, in association with the National Development and Reform Commission and 13 other ministries or commissions, the Ministry of Science and Technology (MoST) released China's Scientific and Technological Actions on Climate Change. In 2010, together with other relevant departments, MoST organized the preparation of the national scientific and technological development plan for addressing climate change for the Twelfth Five-Year Plan (FYP) period. It made an overall deployment for scientific and technological work in response to climate change in this FYP period. In recent years, China has continuously enhanced the macro-management and coordination for scientific research and technological development, and increased investments in R&D. In support of research on energy conservation, emission reduction and addressing climate change, China had invested over RMB 13 billion in total in key Science and Technology (S&T) research programmes, under which more than 150 research projects had been funded in the 11th FYP period. China has made significant progress in scientific research and technological development in response to climate change, with a fully improved S&T capacity for tackling climate change.

Current Status on Technological Research and Development

In the Eleventh FYP period, MOST had systematically forged ahead with technological R&D for climate change mitigation and adaptation under the National S&T Enabling Program and the National High-tech

R&D Program (863 Programs). It had systematically deployed a number of research projects for developing energy conservation technologies and new energies for climate change mitigation and adaptation. These projects have provided effective technological supports and reserves for addressing climate change.

Vigorously pursuing R&D in energy-conservation technologies: Under the 863 Program and S&T Enabling Program, MOST has launched a series of R&D projects, e.g., technologies for efficient use of clean energies; energy conservation technologies and equipment used in key industries; key energy-saving technologies and materials for buildings; technologies used for integrated resource exploration and development, ecological management and restoration; and key technologies and equipment for clean production in major industries.

Actively promoting R&D of new energies and other mitigation technologies: MOST has deployed a number of projects on development and utilization of renewable or new energies and key smart-grid technologies. Among them, the carbon capture, utilization and storage, CO_2 reduction and utilization for blast furnace iron-making, high concentration CO_2 capture and geological storage in coal-to-oil production, CO_2 capture from oxygen-enriched combustions, integrated gasification combined cycle (IGCC) with carbon capture, CO_2utilization and storage, CO_2 mineralization, biodiesel production from bio-fixation of CO_2, for example—by microalgae, have been deployed by MoST under its S&T Enabling Program.

Current Status on Technology Demonstration and Industrialization

The Government of China has launched a number of energy conservation and new energy technology demonstration projects, e.g., 'Ten Cities-Thousand New Energy Vehicles', 'Ten Cities-Ten Thousand LED Lamps', and 'Golden Sun'. Under the 'Ten Cities-Thousand New Energy Vehicles', it was originally planned to promote the use of hybrid electric, all electric and fuel cell vehicles in the public transport sector in more than ten cities in a modular manner.

By 2010, the demonstration pilot cities under this project had increased to 25. Under the 'Ten Cities-Ten Thousand LED Lamps', which is a scheme to promote common use of semi-conductor lighting products for quicker development of the industry, the LED lighting pilot cities are 37 at present. It is estimated that LED lighting will account for 30 per cent of China's general lighting market by 2015, saving more than 100 billion kWh each year. Under the 'Golden Sun' project, it is planned to provide upfront subsidies for qualified solar PV demonstration projects with a project size of no less than 500 MW in the next 2–3 years. By 2015, the newly installed capacity of PV power systems will be 2.5 GW and the annual output value of PV power will reach RMB 20 billion in the domestic market. Moreover, some scientific and technological achievements, e.g., new energy vehicle, LED lighting, clean energy and smart grid technologies were broadly applied and demonstrated during the 2008 Beijing Olympic Games and the World Expo 2010 Shanghai.

Current Status on International Cooperation in Energy and Climate Related Technologies

China has actively participated in multilateral S&T cooperation on climate change. It plays an important role in international scientific programmes and organizations. China has also actively participated in the preparations of the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports. In 2007, MOST and NDRC released the International Science and Technology Cooperation Programme on New and Renewable Energies. China also initiated some international cooperation programmes at the regional level, through which studies on global change were made, taking into account both China's unique features and the global implications.

China has strongly promoted international S&T cooperation with developed countries. To date, it has signed 103 S&T cooperation protocols with 97 countries. In 2010, the Ministry of Science and Technology of China and the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety, signed a Memorandum of Understanding on Sino-German Cooperation in Climate Protection and Electric Vehicles and an Agreement on Implementation of Sino-German Cooperation in Electric Vehicles and Climate Protection. China and the United States have agreed to invest USD 150 million together to create a joint Sino-US Clean Energy Research Center. The two countries will conduct joint research in three priority areas: building energy efficiency, clean coal/carbon capture and storage (CCS), and clean energy vehicles. China and EU have held eight conferences on energy cooperation, and in 2010, the two sides established the Europe–China Clean Energy Center. In 2007, the Chinese and Japanese governments signed the Joint Statement on Strengthening Scientific and Technological Cooperation on Climate Change, and initiated the China–Japan exchange programme on climate change research. China has actively cooperated under the Clean Energy Ministerial (CEM), and launched China (Shanghai) International Electric Vehicle Pilot City Demonstration Program.

In addition, under the framework of the Asia–Europe Meeting (ASEM), the Asia–Europe Water Resources Research & Utilization Center has been established. Together with other countries and international organizations, e.g., Australia, Italia, UK, EU, IEA, and the Carbon Sequestration Leadership Forum (CSLF), China has initiated a number of cooperative projects on carbon capture and storage. In 2010, China launched the CCS projects with Australia, Italia, EU, and other countries, which made positive contributions to China's capacity building for development of CCS demonstration projects. In 2009, NDRC of China, UK's Department for International Development, and the Swiss Agency for Development and Cooperation jointly implemented a project–Adapting to Climate Change in China–which played an exemplary role in facilitating China's scientific and technological work in adaptation to climate change. Furthermore, China has also conducted extensive S&T cooperation with UK, Italy, Japan, and the Republic of Korea in the fields including energy-saving buildings, low carbon demonstration townships, and smart grids.

China has actively carried out S&T cooperation on climate change with other developing countries too. Climate change, clean energy, and environment are the priority areas of cooperation between countries including China, India, South Africa, and Brazil. MOST organized the preparation of the Applicable Technology Manual for South–South Cooperation on Science and Technology to Address Climate Change and launched the Network/Platform for International Science and Technology Cooperation for Addressing Climate Change. MOST and the United Nations Environment Programme (UNEP) signed a Memorandum of Understanding on Framework of Technical and Institutional Cooperation on Environment in Africa (2008) and an Implementation Agreement on Joint Projects on Environment in Africa (2009), under which MOST had implemented some demonstration projects in Africa, e.g., technologies for drought early warning system and adaptation to drought, to help African countries improve their capacities to tackle climate change. In 2010, China and Brazil established the Tsinghua-UFRJ China–Brazil Center for Climate Change and Energy Technology Innovation in Tsinghua University, which enhanced the cooperation of the two countries in this field. Additionally, the China State Oceanic Administration implemented the Indonesia–China Center for Ocean and Climate.

Gaps in China's Energy and Climate Technology Research

Despite rapid progress in climate-related research, China still lags behind the world's developed countries.

It lacks supportive research in core technologies for climate change mitigation and adaptation, e.g., integrated gasification combined cycle (IGCC) technology used for coal fired power plants in the power generation industry; large wind power equipment, PV cell, fuel cell, biomass energy, nitrogen energy for developing new energy technologies; automobile fuel economy and hybrid vehicle technologies in the transport sector; energy saving and high-efficiency technologies in metallurgy and chemical industries; and optimal design of energy-saving schemes for energy-efficient buildings, among other gaps.

Main Areas of Future Research on Energy and Climate Technology in China

For mitigation, the main research areas include innovations and marketing of non-fossil energy and clean coal technologies, development of new energy saving and high-efficiency technologies in key sectors (e.g., industry, building, and transport); R&D of key technologies for forestry carbon sinks and industrial carbon sequestration; cost reduction and market-oriented applications of key technologies (e.g., carbon capture, utilization, and storage); carbon emission statistical and monitoring systems in support of achieving the binding targets of CO_2 emission and energy use intensities.

From the perspective of sustainable socioeconomic development, the main research areas include major strategies and policies on climate change; construction and comprehensive demonstration of technological support systems for low carbon and sustainable development; raising public awareness of participation in actions to tackle climate change; and international collaborative research.

Energy and Climate Technology Innovation System in India

The Government of India also attaches high priority to the promotion of R&D in the multi-disciplinary aspects of environmental protection, conservation, and development including research in climate change. Several central government ministries/departments promote, undertake, and coordinate climate and climate-related research activities and programmes in India. India's energy and climate technology innovation mainly focus on three aspects: *(i)* energy efficiency of fossil fuel use, *(ii)* smart grid, and *(iii)* renewable energy.

The Ministry of Coal, Government of India, is mainly responsible for the funding and management of the research and development of clean coal technology. The 'Strategic Plan of India's Ministry of Coal', released in 2011, clearly states the need for enhancing the research and development of coal mining, production and use technologies, in order to comprehensively improve the efficiency of coal use in India.

The Ministry of Power in India is in charge of the research and development of smart grid. In 2010, it enacted a five-year programme, 'Restructuring Plan of Accelerating Power Development and Reform', with a total investment of USD 10 billion in order to strengthen and enhance the global power transmission and distribution capacity.

The research and development of new energy and renewable energy technologies is a key focus of India's innovation. The Ministry of New and Renewable Energy (MNRE) supports research, design, development and demonstration (RDD&D) activities to develop new and existing renewable energy technologies, processes, materials, components, sub-systems, products, and services. It also conducts standards and resource assessment so as to indigenously manufacture renewable energy products and systems. The Solar Energy Research Initiative (SERI) of DST supports activities aimed at improving efficiency of materials, devices, systems and sub-systems, including innovative R&D demonstration projects. The programme also facilitates and encourages inter-institutional linkages to develop state-of-the-art products and development of critical mass of R&D strengths for solar energy research. Applications of solar energy in areas other than power generation are being explored and assessed for their potential to provide convergent technology solutions under real-life conditions. Meanwhile, the programme also demonstrates hybrid solar power systems integrated on various R&D pathways and multiple technology alternatives for distributed energy use to validate their viability to meet rural energy needs under public–private partnership mode.

In addition, MNRE has launched the National Biomass Cook Stoves Initiative, to ascertain the status of biomass cookstoves and identify ways and means for development and deployment of efficient and cost-effective biomass cookstoves in the country. The Advanced Biomass Research Centre (ABRC) project is being undertaken by the Indian Institute of Science, Bengaluru, for biomass research and to identify gaps and ways to address the issues for technology development and advanced research for promotion of biomass energy in the country. The project specially focusses on advanced research in thermo-chemical conversion, technology packages development and development of specifications, test protocols and standards for biomass energy systems.

The growing concerns about energy security and environmental pollution caused by ever increasing use of conventional fossil fuels has led to a continuing search for environment friendly renewable fuels. Biofuels, which primarily include biodiesel and bio-ethanol, have been recognized the world over as the most suitable substitutes for petro-based fuels. In the Indian context, biofuels assume special importance, particularly from the energy security point of view, as the domestic supply of crude oil meets less than 30 per cent of the demand. Several initiatives have been taken to supplement petro-based fuels with biofuels. MNRE is primarily involved in the development of a National Policy on Biofuels, besides research, development and demonstration (RD&D) on transport and stationary applications using biofuels, strengthening the existing institutional mechanism and overall coordination regarding biofuels. RD&D programme on the different aspects of hydrogen energy technologies, including hydrogen production, its storage and utilization for stationary, motive, and portable power generation applications using internal combustion engines and fuel cell technologies has been planned. A broad based programme for research, development, and demonstration of battery operated vehicles (BOV)/hybrid electric vehicles/plug hybrid electric vehicles with the objective of promoting BOVs and receiving feedback on their performance in operating conditions has also been encouraged.

The Indian Renewable Energy Programme has received increased recognition internationally in recent years. The MNRE cooperates through international bilateral/multilateral cooperation frameworks between India and other countries for cooperation in new and renewable energy. The focus of the interaction for cooperation has been to explore opportunities for exchange of scientists to share experience and for taking up joint research, design, development, demonstration, and manufacture of new and renewable energy systems/devices by R&D institutions/organizations of both countries and thereby establishing institutional linkages between institutions of India and other countries.

The Ministry of New and Renewable Energy (MNRE) has cooperated with various international organizations, including the Department of Energy of the USA for the development of biofuels; the Ministry of Climate and Energy, Government of the United Kingdom; Federal Republic of Brazil for wind resources; the Government of the Republic of

Cuba; the Ministry of Industry of the Republic of Iceland for renewable energy; Department of Resources, Energy & Tourism, Government of Australia; University of Saskatchewan in Indo-Canadian Renewable Energy Cooperation; the Ministry for Environment, Land and Sea of Italy in Indo-Italian Renewable Energy Cooperation; the Secretariat of Energy of the United Mexican States; the Department of Energy, Republic of The Philippines; Ministry of Energy, Government of The Kingdom of Thailand; the National Energy Commission, Republic of Chile; the Government of Scotland in India–Scotland Renewable Energy Cooperation; the Ministry of Industry, Tourism and Trade of the Kingdom of Spain; the Ministry of Power of the Islamic Republic of Iran, the National Renewable Energy Laboratory, United States Department of Energy on Solar Energy Research and Development;the Ministry of Enterprise, Energy and Communications of Sweden in India–Sweden Renewable Energy Cooperation; the Ministry of Electricity and Energy of the Arab Republic of Egypt, and Uruguay in India–Uruguay Renewable Energy Cooperation. In addition, interaction with USA and Japan for cooperation in new and renewable energy is being pursued under the India–US Energy Dialogue and India–Japan Energy Dialogue, respectively. Interaction with EU for cooperation in new and renewable energy is being pursued under the India–EU Energy Panel. A multilateral cooperation framework called the Asia–Pacific Partnership on Clean Development and Climate (APPCDC) enables interaction for cooperation with USA, China, South Korea, Japan, Canada, and Australia.

1.2.4 Government and Private RD&D Investment Trends in China and India

Global Innovation and RD&D Investment Trends

The rate of innovation appears to be accelerating in many clean energy technologies on the global scale. The number of clean energy patents filed between 2000 and 2008 grew by 10 per cent annually. There was a four-fold increase in renewable energy patents filed between 1999 and 2008, driven by technologies that were closest to being competitive—wind power, solar PV (but not thermal), and biofuels.

Energy gets a small slice of the research pie. OECD countries' spending on energy RD&D has been generally decreasing as a share of total research budgets over the past 30 years, as governments have preferred other areas of research, such as health, space programmes, and general university research. Defence research receives the maximum government support, and while it has also seen its share of funding decline, it remains dominant at 30 per cent. Energy's share has varied between 3 per cent and 4 per cent since 2000, after peaking in 1981, when it was over 11 per cent.

In absolute terms, RD&D budgets for low carbon technologies have been steadily increasing in IEA member countries over the past decade, from a low of USD 9.3 billion in 1997 to over USD 15 billion per year in the past three years. In 2011, the total was USD 16.8 billion. Funding has risen nearly every year since the late 1990s and received a substantial increase as part of 'green stimulus' spending programmes in 2009. Such high levels of investment channelled money into innovation centres like the US Department of Energy's Advanced Research Projects Agency, which supports high-risk, potentially high-payoff projects that are not sufficiently advanced to attract venture capital investment. However, with growing concern over budget deficits, funding levels have decreased from peak levels in 2009 (Figure 1.5).

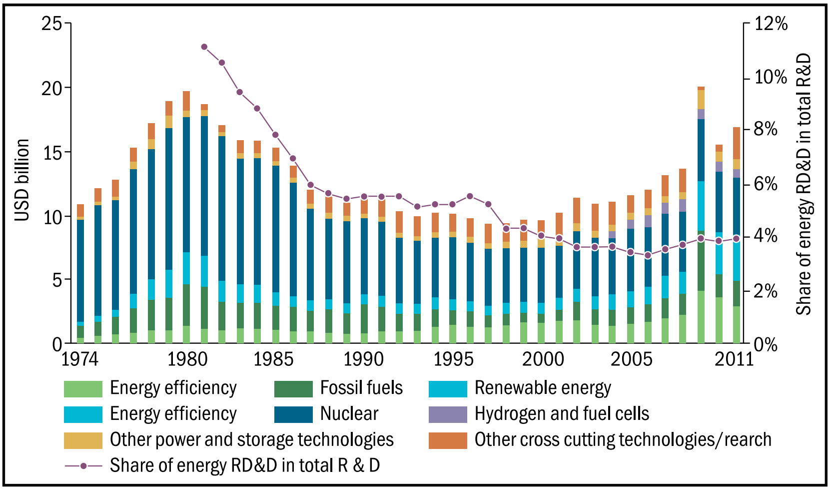


Figure 1.5 Government Energy RD&D Expenditure in IEA Member Countries (1974–2011)
Source: IEA (2013)

Nuclear fission still accounts for the largest share of investment in energy technology RD&D among IEA countries—roughly 24 per cent in 2010 (nuclear fusion accounts for 5 per cent). In general though, RD&D spending has moved away from nuclear, which accounted for over 70 per cent in the mid-1970s, towards renewable energy, cleaner fossil fuel, and emerging technologies, such as smart grids and EVs.

Renewables, hydrogen and fuel cells have seen the biggest increases since 2000. In particular, expenditureon renewable energy RD&D has risen sharply over the last decade and now accounts for over

24 per cent of the total public spending on clean energy RD&D. In general, the United States and Europe spend more on RD&D for renewables than the Pacific region or emerging economies. Data isless comprehensive for emerging economies than for IEA countries, but it is clear that RD&D is focused on nuclear energy, fossil fuels, and transmission, distribution and storage technologies, while deployment activities concentrate on renewables and energy efficiency.

Most of the 2009 stimulus funds for energy RD&D were attributed to cleaner fossil fuels research, but since then the trend has reversed and research spending on all fossil fuels and renewables is now about equal.

Cumulative spending on projects that demonstrate CCS reached almost USD 10.2 billion in the period between 2005 and 2012. This is a significant increase over previous periods, but is still far below the estimated investment needed to deliver CCS levels envisaged. Australia and Norway spend just over 30 per cent of their clean energy RD&D budgets on CCS; Canada spends 37 per cent.

Governments are also ramping up investments in EVs and HEVs, announcing ambitious targets for their sales (20 million by 2020). Enhanced RD&D will be fundamental to reaching these targets. Spending on research into energy efficiency has been fairly steady since 2000, distributed across industry, residential, and commercial buildings.

RD&D and Innovation Investment Trends in China and India

RD&D in non-OECD countries such as China and India is predominantly funded by governments, and is focused on basic and applied research rather than on development. Adaptation and improvements on existing technologies are the main source of innovation.

Data collection on RD&D investment and strategies in emerging economies needs to be more comprehensive to help decision-making and international collaboration. Several international initiatives, including the CEM, have attempted to collect data and report on energy technology RD&D in emerging economies, but most analyses focus on OECD countries. Absence of a centralized, reliable source for RD&D spending data for non-OECD countries, such as China and India makes it very difficult to compare countries' initiatives, and to estimate global public spending on clean energy RD&D.

The information, that is available, indicates that China and India are increasing their share of global RD&D and innovation.

In China and India, where governments are investing more in RD&D than other emerging economies, the private sector is also more heavily involved in RD&D. These two countries are starting to reap benefits from decades of investments in education, research infrastructure, and manufacturing capacity. China and India are already playing leading roles in developing, manufacturing, deploying, and exporting (including to OECD countries) clean energy technologies such as solar panels and wind turbines technologies.

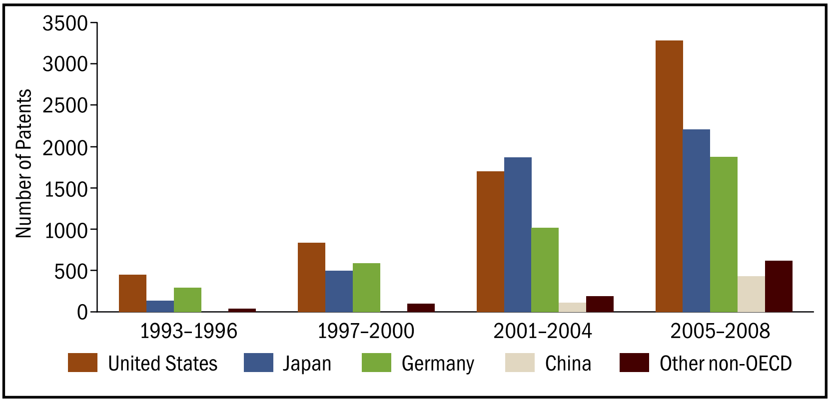


Figure 1.6 Clean Energy Patents Filed by Inventor's Country of Residence (1993–2008)
Source: IEA (2013)

Emerging economies could leapfrog towards a competitive, low carbon economy not only by applying technology developed elsewhere but also through domestic innovation. Despite the increase in RD&D spending by emerging economies, however, OECD countries hold an overwhelming majority of patents in all categories of clean energy technology, led by Japan, the United States and Germany, followed by Korea (which has had exceptionally high growth rates in recent years), the United Kingdom and France (Figure 1.6). While patents are a useful indicator of product and process innovation, they do not capture the entire landscape of innovation and knowledge protection. Intellectual property protection mechanisms include other ways of protecting innovations, such as copyrights and trademarks.

Patent data also shows that emerging economies like China, India, and South Africa are becoming increasingly active. China, in particular, has been catching up in the last few years in several clean energy technologies (except carbon capture), although it is possible that many patent filings are made by the Chinese subsidiaries of multinational enterprises (Ma *et al*. 2009).

RD&D in emerging economies is strongly focussed on renewables, with far fewer collaborative RD&D activities in industry, transport, and energy efficiency in buildings. Governments should develop clear criteria for setting priorities not only in technology areas but also in selecting partners for international RD&D collaboration.

Although India has relevant industries and a vibrant entrepreneurial ecosystem, R&D activities are predominantly government-led, and Indian research is strongly directed towards goals set by the government. High interest rates and short-term loans increase the cost of renewable energy projects in India by up to a third compared with similar projects in the United States and Europe (Shrimali *et al*. 2012). Funding constraints have been affecting all stages of the innovation process in India, particularly since the 2008 financial crisis, but the government can help address these by building partnerships and networks with the private sector, and providing incentives to drive capital investment in low carbon technologies, through supportive policies like grants, soft loans, and tax incentives.

1.3 Lessons Based on Case Studies

1.3.1 Governments Must Invest in Clean Energy RD&D and Innovation

Government support for RD&D is vital to stimulate the development of an adequate portfolio of new and improved energy technologies on a scale and within the timeframe needed. Demonstration and deployment of tomorrow's innovations are underpinned by robust funding of basic science and applied research and development in key areas today. The private sector will not do this on its own, as companies face costs associated with environmental challenges and difficulties in reaping returns from their investments and entry barriers.

Industrial priorities focus on shorter-term, incremental improvements designed to maximize returns on energy RD&D investments. A survey of 240,000 businesses in the United States involved in energy technology innovation, from small start-ups to multinational corporations, found that a large fraction of them are expected to recoup investments in only two to three years (Anadon *et al*. 2011).

To make sure new technologies are widely propagated, governments must supplement public funding schemes for RD&D (e.g., grants, loans, and tax credits) with non-RD&D support for business innovation (e.g., support for venture capital, public–private partnerships and business networks, nascent entrepreneurial activities) and targeted policies that foster demand and markets for clean energy (e.g., pricing mechanisms, public procurement, minimum energy performance standards, energy efficiency labels, and mandatory targets).

1.3.2 Structured Analysis for Determining Innovation Priorities

Based on existing analysis, countries have been favouring certain technologies without using structured analysis and documented processes to determine clear priorities, resulting in a lack of coherence in RD&D strategies. Governments should identify existing skills and knowledge, and those that are required to support the development and deployment of priority technologies. RD&D and innovation efforts should focus on a portfolio of technologies selected through a structured mapping exercise (Figure 1.7) that identifies existing domestic resources, skills and knowledge, and the policy frameworks and market mechanisms required to support the development and deployment of the desired technologies. Such a process should also help in identifying priority partners for international cooperation and improve efficiency of domestic efforts.

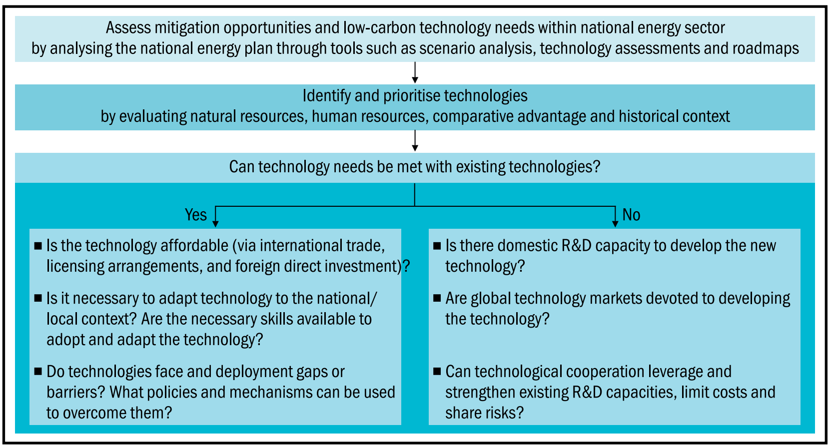


Figure 1.7 Process for Developing an Energy RD&D Strategy
Source: IEA (2013)

1.3.3 Fostering Innovation Requires Addressing the Entire Innovation Chain

The combination of direct support for RD&D (e.g., grants, loans, tax credits) with non-RD&D support for business innovation (e.g., support for venture capital, public–private partnerships and business networks, starting up entrepreneurial activities) and targeted policies that foster demand and markets for clean energy (e.g., pricing mechanisms, public procurement, minimum energy performance standards, energy efficiency labels, mandatory targets) is an important consideration for countries when designing their mix of policy instruments to support innovation. Any of these policies implemented alone would be less effective and more expensive. The key challenge is to strike a balance between the various instruments.

If demand for innovation is augmented, a continuing flow of technology developments will improve the portfolio of available CO_2 mitigation options, bring down the costs of achieving global climate goals and provide significant economic, environmental, and security benefits. However, scale, timing, and duration of policies to foster demand need to be determined carefully and modified as necessary, and should allow for gradual removal of support as technologies reach maturity, such as in the case of gas and nuclear.

1.3.4 R&D Portfolios should be Consistent with Technology Portfolios

A comparison of technology portfolio scenario studies with past and current energy R&D portfolios reveals that the latter are highly biased, with energy efficiency/conservation under-represented and nuclear R&D over-represented in comparison to their respective option values in a climate-constrained world.

Ifcurrent energy technology R&D portfolios were to represent the respective 'option value' of alternative technologies in a climate and resource constrained world, one would have to increase current R&D into energy efficiency by at least a factor of five or by some USD 6 billion PPP per year (thus not proposing a reduction in nuclear R&D). Given that improved energy efficiency has multiple public benefits beyond climate change (e.g., less energy use, reduced local air pollution, and lessened import dependence), even more ambitious increases in public energy R&D budgets for energy efficiency would be justified.

1.3.5 R&D Investments in Supply Side and Demand Side should be Balanced

Analysis of investment flowing into different stages of the innovation process reveals an apparent mismatch of resource allocation and resource needs.

Early in the innovation process, public expenditure on R&D is heavily weighted towards large-scale supply side technologies. Of an estimated USD 50 billion in annual investment globally, less than USD 10 billion are allocated to energy end use technologies and energy efficiency.

Later in the innovation process, annual market (diffusion) investment in the supply side plant and infrastructure total roughly USD(2005) 0.8 trillion, compared with a conservative estimate of some USD 1–4 trillion spent on demand side technologies. These relative proportions are, however, insufficiently reflected in market deployment investment incentives of technologies, which almost exclusively focus on supply side options to the detriment of energy end use in general, and energy efficiency in particular, foregoing also important employment and economic growth stimuli effects from end use investments that are critical in improving energy efficiency. The need for investment to support the widespread diffusion of efficient end use technologies is also clear. The demand side generally tends to contribute more than the supply side options to realize near-term and medium-term climate goals. This apparent mismatch suggests the necessity of rebalancing public innovation expenditure and policy incentives to include smaller-scale demand side technologies within innovation portfolios.

Given persistent barriers to the adoption of energy-efficient technologies even when they are cost competitive on a life cycle basis, technology policies need to move toward a more integrated approach, simultaneously stimulating the development as well as the adoption of energy efficiency technologies and measures. R&D initiatives that fail to incentivize consumers to adopt the outcomes of innovation efforts (e.g., promoting energy-efficient building designs without strengthened building codes, or carbon capture and storage (CCS) development without a price on carbon) risk not only being ineffective but also preclude the market feedback and learning that are critical for continued improvements in technologies.

1.3.6 Bad Outcomes can have Substantial Spillover Effects on Other Technologies

The experience of innovation policy related to solar water heaters in the United States is a story of policy intermittency. A key general finding is that bad outcomes are often not easily forgotten, and can have substantial spill-over effects on other technologies. This presents a challenge to the need to support experimentation and intelligent failures. The key points of this case are: *(i)* A large, high-profile failure in the early stage of the US SWH industry has proven extremely difficult to overcome; *(ii)* For several years after this failure, the technology was not trusted; *(iii)* Experience was lost with the collapse of the industry; *(iv)* Verification is essential and not expensive; *(v)* Inspection and verification have proven successful in Hawaii; *(vi)* Both R&D and incentives in the US SWH industry placed excessive focus on collector units rather than on system integration; and *(vii)* Lack of involvement of utilities and builders appears to have hurt the industry.

1.3.7 Policies need to be Strategic, Continuous, Flexible, and System Oriented

Innovation and diffusion policies for the development and introduction of heat pumps provide an interesting case study on policy learning. The assessment of innovation and diffusion policies for the heat pump systems can be used to illustrate some general policy conclusions. The key points of this case are:

- The assessment shows the need for strategic, long-term, and continuous support. First attempts to introduce a new technology failed, and continuous support was needed to overcome initial shortcomings. Technological change takes considerable time.
- The combination of policy instruments may have to change and the government's approach should be flexible. The policy intervention may initially allow uncoordinated intervention to support entrepreneurial testing, but then should be developed into credible, stable and transparent strategies that allow industry to make long-term investments.
- The policy interventions need to be system-oriented and consider both the development of the technology and its emerging market. In other words, R&D is important as a part of the policy strategy, but not enough.
- The assessment indicates the need for testing and certification processes to support technical quality and create credibility and legitimacy. R&D initiatives and subsidies require testing and certification to support stable market development.
- The support of networking to improve strategic integration and the use of learning and ensuring feedback and spill-over effects seem essential.

1.3.8 Role of Standards is Important for End-Use Products

Dynamic and continuously adjusted standards have been successful in accelerating the trend of energy efficiency improvement in many end-use products, such as room air conditioners and passenger vehicles. In these cases, the standards provided a clear direction for product development by aiming at higher energy efficiency and eliminating low efficiency products from the market.

The case study of the Japanese Top Runner Programme illustrates that ambitious policies that match market conditions and technological conditions can work well to induce remarkable energy efficiency improvements. Because such conditions depend on the country and the phase of technological development, careful design and adjustment are required for effective policy making.

1.3.9 Support for Diversity in Technology and Market Formation is Essential

The experience of wind turbine policy intervention shows the importance of applying a diversified technology portfolio. Moreover, the study illustrates the difficulties in foreseeing the drivers and trends of any given technology and the need to provide subsidies for implementation to many actors.

RD&D is fundamental but not sufficient. In many countries, wind energy innovation was initially supported through RD&D only and the innovation process was envisioned to be linear. However, the RD&D funding alone did not bring about any commercial applications.

To support technology innovation, quality assurance is essential. An important component of the innovation path of wind turbines was the development of a certification process.

Support for innovator interaction and networking is essential. However, models for interaction and networking have only gradually developed over time and have been designed differently in different countries.

Support requires a systemic approach. The case of wind energy shows that governmental policy needs to support the development of the entire innovation system, i.e., the development of turbines and their infrastructure, and also the involvement of actors, necessary networks, and institutions.

Support needs to be stable and continuous. The history of wind turbine development is long; it started in the 1880s. Many failures have occurred over time. Yet, continuous support allowed knowledge creation and learning, as well as essential market formation that paved the successful innovation path of onshore wind energy and which is now the basis for the development of offshore wind energy.

1.3.10 International Cooperation is Essential to Help Developing Countries to Strengthen National Innovation Capacity

It is also well-recognized that limited technological capabilities within developing countries create a common barrier to effective action in addressing climate change. The R&D investments of most developing countries are lower than those of most industrialized countries in absolute terms and as a proportion of gross domestic product; and the capabilities of the science and technology enterprises in these countries remain relatively weak, as illustrated by various technology and innovation indices. Collaborative R&D between developed and developing countries can help the latter adopt appropriate technologies for adaptation and mitigation by providing access to complementary skills and by supplementing their own capacity.

From the viewpoint of an industrialized country partner, collaborative R&D can be helpful since such a partnership allows for a better understanding of local needs and product opportunities that can help meet these needs. The value of a partnership with developing country entities that possess complementary knowledge is already being used by firms in industrialized countries in their strategies for 'open innovation'. Realization of the importance of developing countries' markets and the need to be close to these markets has also led to the establishment of R&D centres in these markets.

International collaboration can enable governments to conduct more RD&D at a lower cost and with less duplication, but most current collaborative activities in emerging economies focus on facilitating deployment rather than RD&D. Collaborative RD&D is often difficult, because sharing knowledge is risky, capabilities for innovation are limited in some countries, and national regulations and policies related to RD&D tend to differ.

1.4 Opportunities for Cooperation between China and India on Low Carbon Technology

1.4.1 Priority Sectors and Areas of Development of Low Carbon Technologies in China and India

As emerging economies increase their energy use and their CO_2 emissions, there is an urgent need to better understand their energy innovation policies, the magnitude of their RD&D budgets and the effectiveness of their initiatives. In the 2 degree scenario, emerging economies like China and India can make the biggest contribution to the global efforts on CO_2 abatement (Figure 1.8).

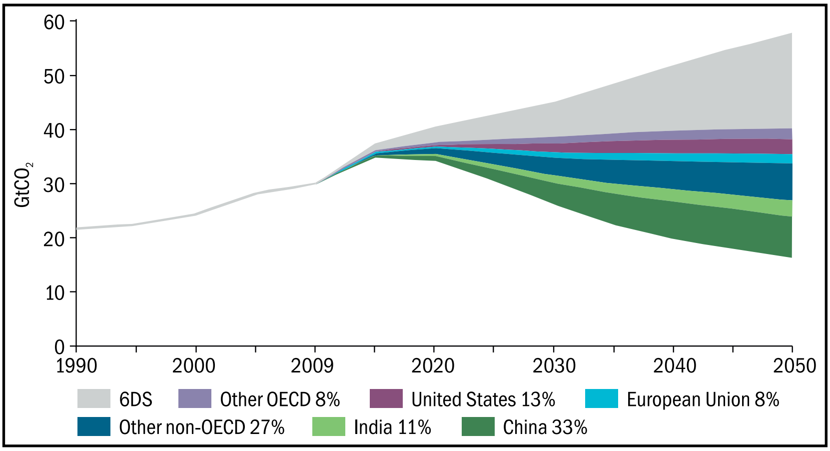


Figure 1.8 World Energy Related CO_2 Reduction by Region
Source: IEA, Energy Technology Perspective 2012, 2DS

For both China and India, the research and application of low carbon technology could focus on the following nine areas, namely, clean coal incineration and power generation technologies, energy-saving technologies in the industrial, building, and transportation sectors; wind power utilization; solar power utilization; carbon capture, utilization and storage (CCUS); nuclear; new energy vehicles and smart grid. In terms of strategic selections, China and India could put clean energy and end-use energy technologies at the core of technology development; and place CCUS, renewable, fourth generation nuclear and new energy vehicle technologies as their technological reserve.

1.4.2 Possible Areas of Cooperation between China and India

As China and India are major players in the international cooperation on energy security and climate change, and both of them face enormous challenges during the transition to a low carbon economy, there is a great potential for China and India to cooperate while tackling climate change and in the pursuit of a low carbon future. Based on the aforementioned information and analysis, China and India can undertake project- and policy-level cooperation in the areas of joint R&D of climate-friendly and low carbon technologies, adaptation, policy development, and coordination and best practice sharing, in accordance with their respective national circumstances and priorities.

The Second National Communication (SNC) of India identifies the constraints, gaps, and related financial, technical, and capacity building needs for India in terms of tackling climate change. According to India's SNC, there is a continuing need for reporting information on implementation of the UNFCCC, as well as technology needs for adaptation and mitigation, adaptation to climate change, technological, and capacity building needs. India has been promoting low CO_2 emission intensive technologies for sustainable development through programmes such as the Integrated Renewable Energy Programme. It has one of the largest programmes for promoting renewable energy in the world and there is a significant need for increasing funding of technology transfer from developed to developing countries.

The Second National Communication (SNC) of China also identifies the constraints and related needs for China with regard to combating climate change. According to China's SNC, China also needs enormous financing for tackling climate and achieving its carbon intensity target by 2020. For example, in order to achieve the 40–45 per cent GDP emission intensity target, additional resources are needed in the sectors of energy efficiency and energy mix optimization. Mitigation and adaptation technologies, as well as capacity building needs are also identified in the SNC, in the areas including energy, steel, transportation, building, meteorological observation, agriculture, coastal protection, ecological system, national GHG inventory development, and GHG emission accounting system development. Table 1.6 lists some possible areas of cooperation between China and India for adaptation, mitigation, and capacity building.

Table 1.6 Possible Areas of Cooperation between China and India

Country	Areas of cooperation				
	Mitigation		Adaptation		Capacity building
	Technology, equipment and process	Service: Planning, policy, strategy and management	Technology, equipment and process	Service: Planning, policy, strategy and management	
China	Infrastructure: Electricity, transportation and building, low carbon city planning, energy-saving best practice (energy labelling), energy strategy planning, and technology diffusion	Policy coordination on international environment and sustainable development (international negotiation on environment), climate and energy policy analysis		Policy coordination on international environment and sustainable development (international negotiation on environment), climate and energy policy analysis	Policy consultation and personnel training

India	Energy management (fossil fuel switch, coal-fired power generation, rural biomass energy utilization, short-lived climate pollutants), low carbon city development, energy efficiency improvement in traditional industries (including building materials, metallurgy, and chemistry)	International environment and sustainable development	International environment and sustainable development	Policy consultation and personnel training

1.5 Policy Recommendations

1.5.1 Increasing RD&D Investment in Clean and Low Carbon Energy Technologies

According to the Energy Technology Perspectives (ETP) 2012, over the next decade, an estimated USD 24 trillion needs to be invested in the power, transport, buildings, and industry sectors in order to achieve the 2 degree objective, which means that countries need to pursue a low carbon development path. This also applies to China and India, the two largest developing countries that are facing enormous socio-economic challenges while rapidly moving towards middle income countries. The ETP 2012 also estimates that the transition to a low carbon energy sector requires additional investment of USD 130 per person per year, on an average, between now and 2050. Investments in the transport sector represent the largest share, accounting for nearly 34 per cent of the total investments, which will globally exceed USD 8 trillion over the next decade. Over this same decade, a projected 1.7 billion new vehicles will be purchased globally. The buildings sector investments up to 2020 will reach over USD 6 trillion; just over half of this is needed in OECD regions for significant investments in retrofitting existing building envelopes and improving the energy efficiency of heating, ventilation and air conditioning (HVAC) systems, appliances, and other equipment.

Investments in the power sector are estimated at USD 6.4 trillion under the 2 degree scenario, of which China will account for nearly 30 per cent. China's economic growth is expected to remain strong over the next decade, resulting in increased investment needs across all sectors, but particularly in the power and transport sectors to meet growing demand for electricity and higher vehicle penetration rates. Table 1.7 briefly summarizes the incremental investment needed to achieve the 2 degree objective in accordance with the study undertaken by several institutes and organizations.

Table 1.7 Additional Investment for Achieving the 2 Degree Objective

Institutes	World	China
IEA, World Energy Outlook 2011	In order to achieve the 450 ppm scenario on a global scale, the cumulative incremental investment shall be USD 15.2 trillion over 2011–35	N/A
IEA, Energy Technology Perspectives 2010	In order to achieve the 450 ppm scenario (BLUE scenario), the additional investment needs to reach USD 46 trillion over 2010–50, among which USD 13 trillion has to be over 2010–30, and USD 33 trillion over 2030–50.	In order to achieve the BLUE scenario (30% emission reduction in 2050 compared with the level of 2007), a total of USD 10.2 trillion is required over 2010–50 for China (USD 7.1 trillion for OECD and USD 5.8 trillion for USA over the same period).
McKinsey, 2009	N/A	In order to achieve its mitigation target, the annual incremental investment shall be USD 200–260 billion over 2010–30 (USD 4–5.2 trillion in total).
PECE, China Human Development Report (2009–2010)	N/A	In order to achieve its mitigation target, a total of USD 9.5–14.2 trillion is needed over 2010–50 (USD 24–35.5 billion on an annual basis).

It is therefore recommended that China and India take the following actions to promote the invention, demonstration, and diffusion of low carbon energy technologies through scaling up RD&D and fostering innovation:

- Develop a coherent energy strategy, with clear priorities and objectives for the short-, medium-, and long-term. This should consider the entire innovation chain, in close consultation with major stakeholders in the public and private sectors, and be consistent with other related policy areas, such as science and technology, education, economic development, and industry.

- Triple public sector investment in technology RD&D, particularly in promising energy technologies such as CSP, advanced biofuels, advanced vehicles, and capital-intensive technologies such as CCS and IGCC, which have significant potential but still face technology and cost challenges.
- Facilitate the emergence of 'game changing' technologies—innovations that could dramatically alter the energy landscape like the shale gas extraction technology. Technology policy needs to be able to enable, identify, and support positive disruptive processes and technologies.
- Invest in cross-cutting technology areas—such as advanced materials, nanotechnologies, life sciences, green chemistry, and information and communication technologies—because breakthroughs in energy technology often depend on progress in other fields. For example, chemistry research helps increase the efficiency with which energy is generated, transmitted, stored, and used. Advanced materials research is essential to develop and produce more efficient photovoltaic products, lighter vehicles and better batteries, and enable ultra-supercritical coal-fired power plants, hydrogen storage, and fusion power. China and India can examine how research advances in other fields could cross-fertilize innovation and accelerate energy technology development.
- Expand international technology collaboration to increase and leverage public and private resources and improve efficiency of national energy RD&D investments.
- Improve public and private RD&D data quality, completeness, transparency, and mutual sharing among domestic organizations and institutes.
- Provide support for business innovation in addition to RD&D-related government-run programmes (e.g., support for venture capital, public–private partnerships and business networks, nascent entrepreneurial activities) and create explicit links between research programmes and market needs to encourage cost reductions, information sharing and technology transfer.
- Combine public funding programmes with policies that foster demand (e.g., pricing mechanisms, public procurement, minimum energy performance standards) in order to attract private investment, enable continued learning and cost reductions, help available technologies penetrate the market faster, and improve the long-term cost-effectiveness and feasibility of climate policy. This will require mechanisms to enhance government

coordination, stakeholder involvement and competencies in public administration.

1.5.2 Integrating the Invention, Demonstration, and Diffusion of Low Carbon Technologies into National Long-Term Socio-economic Development Programmes and Strategies

Integrating low carbon technology development and economic development policies is a must if both China and India want to transit to a low carbon future. It requires strong leadership, common political vision, and solid cooperation among ministries and governments at different levels. Implementing low carbon technology development policies can facilitate low carbon development in developing countries in particular. This includes not only the development and diffusion of new and existing technologies, but also collaboration between countries and different actors. Efforts to stimulate low carbon technology development should also focus on building the skills to adopt imported technologies.

Fortunately, both China and India already have their national climate change programmes and strategies in place; they also have the political will to pursue a low carbon technology future. However, both of them need to translate the concept and political commitment of invention, demonstration, and diffusion of low carbon technologies into nationally appropriate policies, programmes, and even laws and regulations with clear objectives, implementation measures and timeframes, and integrate them into their respective national long-term socioeconomic development programmes and strategies.

1.5.3 Using and Strengthening Various Financial Instruments to Promote Low Carbon Technologies in China and India

Actions to promote low carbon technologies in both China and India will require enormous financial resources and put more pressure on the government budget. The sources of expenditure for promoting low carbon technologies can consist of the government budget, private sector investment, and the financing of financial institutions. Therefore, sufficient, effective, and diversified financing for low carbon technology development is crucial for ensuring the invention, demonstration, and diffusion of low carbon technologies in China and India.

For both countries, financing for low carbon technologies are twofold. On the one hand, both governments are facing enormous socio-economic challenges of higher development priority like poverty alleviation, employment, and equity, besides a sole transformation to a low carbon society; on the other hand, both governments need a huge amount of additional financial resources to kick off the development of low carbon technologies. Therefore, both governments should use reformed fiscal and financial instruments for promoting low carbon technologies. Some of these reformed instruments are explained below.

Transfer Payment

Transfer payment can be used as a major fiscal tool for financing low carbon technologies. The transfer payment with a special purpose fund will help maximize the dividend of tax revenue transfer payment. Both governments can redirect the transfer payment of some fiscal revenue to relevant departments for low carbon technology development by setting up a special low carbon financing fund or establishing special nationwide low carbon financing programmes in existing funds (e.g., the Clean Development Mechanism [CDM] Fund of China). Besides fiscal measures, both China and India can also use traditional financial instruments for low carbon development.

Public Fund Direction Instrument

Based on the experiences related to the national policy funds or special funds (e.g., the CDM Fund and the Emerging Industries Venture Initiative of China), China and India can set up special 'green funds' as the parent fund dedicated to supporting the development of clean technology investment enterprises and investing in low carbon private equity fund, so as to channel more social capital to green and low carbon sectors. There are a lot of successful cases at home and abroad in the co-financing of public and private sectors under government guidance. In addition, China and India should consider reducing the income tax for grants of private enterprises in low carbon development sectors, in order to incentivize the private sector's participation in granting.

Carbon Financial Instrument

The international carbon market used to play a very positive role in promoting social funds to support low carbon programmes, but it has been in the downturn recently under the impact of the international economic recession and the adjustment of the CDM. The domestic carbon market is a market-oriented measure and plays a significant role in raising funds for low carbon development, forming a long-term emission reduction mechanism and encouraging enterprises to participate in carbon emission reduction. The fiscal revenue from the auction of carbon emission credits can be utilized as a major financial source for China and India to develop a low carbon economy. Meanwhile, both China and India can borrow experiences from other countries to encourage the development of financial products, such as forward carbon trading, carbon options, carbon futures, and the securitization of carbon financial products.

Traditional Financial Market

There are already some innovative products of green credit to finance low carbon development programmes in China, such as energy conservation and emission reduction fixed asset loans, energy conservation and emission reduction working capital loans, contract energy management financing, carbon asset mortgage credit, and international carbon (CDM) market. Both China and India may consider providing a government guarantee for low carbon programmes, cooperating with local banking and credit systems, and adopting the PPP model more often to use the credit market and these innovative credit instruments as a financing channel for developing low carbon technologies. In addition, climate bonds may become a major source of climate change financing, and an instrument for investors in low carbon sectors to avoid policy risks in the future. The respective Governments of China and India may support enterprises in low carbon economic sectors in bond issuance and reduce their financing costs with government guarantee. Venture capital investment and private equity investment are also key sources of climate funds. Providing risk management services for sectors related to low carbon economic investment can effectively reduce the risks of low carbon investment and attract more funds from the private sector. The Governments of China and India can cooperate with insurance companies to provide risk guarantee or insurance services for low carbon programmes or investment.

International financing is also an important instrument for financing low carbon technologies. As two major developing countries, attracting international funds is a priority for China and India to finance low carbon technologies. International financial sources for both central and local governments to develop low carbon technologies can be multilateral (e.g., the World Bank and the Asian Development Bank) and bilateral (e.g., Agence Française de Développement, KFW Bankengruppe, and Japan International Cooperation Agency).

Concessional loans and grants can constitute a major financial source of the aid from international bilateral and multilateral organizations to develop low carbon economy in both China and India. The green credit of international organizations can provide proper financial and technical support for development banks and commercial banks in developing countries, help them with capacity building, overcome the obstacles facing the private sector when investing in climate related sectors, and then provide extra financing sources for local governments. In addition, China and India can provide more incentives for investment in low carbon economic sectors suitable to their own development characteristics, and attract foreign capital to promote the development of low carbon technologies with different forms of convenience and preferential policies.

1.5.4 Formulating and Implementing Sectoral Strategies to Promote Low Carbon Technology Development and a Low Carbon Future

Promoting the development of low carbon technologies and realizing a low carbon future in both China and India requires a combination of national, local, and targeted sectoral strategies in a systematic way. This includes industrial policy, investment policy, innovation and R&D policy, labour skill policy, and resilience and climate adaptation policy.

In terms of industrial policies, both China and India can:

1. In the power sector, reduce electricity demand by use of more efficient appliances, introduction of more fuel efficient power plants and changes in the mix of power plants;
2. In the transport sector, increase fuel efficiency of vehicles, promote mass transport for passenger movement, facilitate non-motorized transport and developing goods transport by railways;
3. Among industrial sectors, reduce emissions through change in technology in the steel, cement, oil and gas sectors, and reduce energy needs of commercial buildings; and
4. In the forestry sector, increase the forest and tree cover, the stock, volume and density of existing forests.

1.5.5 Strengthening Governance and Developing Capacity to Monitor, Implement and Enforce Low Carbon Technology Development Policies Effectively

The capacity of a country to develop and adopt low carbon technologies is very crucial to its low carbon development. This includes developing capacity and human resources in technical and managerial areas and in assessment and monitoring at all levels of government. Mechanisms are also necessary for broad multilevel governance and stakeholder engagement, knowledge base enrichment, awareness raising, human resource development, compliance and enforcement capacity, and monitoring and assessment. This also involves the private sector, civil society, academies, and ordinary citizens.

Another important aspect is to formulate effective low carbon technology capacity development policies. Shifting to a low carbon development path requires new skills, particularly of workers who need to shift from 'brown' to 'green' industrial practices. Labour market policies and skills development programmes can: *(i)* identify the capacity and skills needed through surveys and other instruments; *(ii)* inform people of available training and education opportunities; *(iii)* provide income support, such as unemployment benefits, to help workers adjust; and *(iv)* engage with enterprises to upscale their workers as an integral part of their business development.

1.5.6 Expanding International Cooperation on Low Carbon Technology Development

Successfully transiting to a model of low carbon development in the long run requires the engagement of all countries. The international community can play a crucial role in helping developing countries make such a transition, especially by providing advanced low carbon and climate-friendly technologies and related know-how. Recognizing the concern of developing countries on the high cost of developing and deploying low carbon technologies, international cooperation can and should ensure that developing countries have access to external and domestic sources of green and low carbon financing and investment, technology, and innovation. In addition, donors need to integrate low carbon technology development and deployment into all development cooperation initiatives and activities, and ensure that they support partner developing countries in their pursuit of specific low carbon growth goals.

Expanding international cooperation on low carbon development can offer many opportunities to help accelerate the transition to low carbon development in developing countries. For example, according to the study from Putting Green Growth at the Heart of Development by OECD in 2012, 'As part of the broader flows of official development finance or environment, climate change finance is set to increase substantially throughout the next decade as developed country governments and private sector agents scale up resources to meet the target of USD 100 billion annually by 2020 as pledged by industrialized countries under the Cancun Agreement of the UN Framework Convention on Climate Change (UNFCCC). A key to effective use of such funding is to ensure it delivers outcomes with multiple co-benefits or sustainable development.'

In this connection, China and India can pursue international cooperation on promoting domestic low carbon technology development from the following three perspectives: *(i)* securing low carbon finance and investment, through better targeting use of official development assistance (ODA), other types of official development finance and private investment; *(ii)* promoting green technology innovation through cooperation, joint R&D and capacity building for endogenous low carbon technological innovation and adoption, as well as to protect intellectual property rights and enable conditions for successful technology transfer; and *(iii)* promoting cooperation and exchanges between national and international think tanks and research institutes on low carbon strategy and policy design, as well as laws and regulations development, and carbon market creation.

1.5.7 Strengthen Institutional Arrangement

In order to implement low carbon technology development strategies and policies, a supportive institutional set up is necessary for each of the two countries. For instance, both China and India can establish intergovernmental agencies or state-owned companies, or invite private sectors to promote low carbon technology and know-how transfer between developed and developing countries, and even among developing countries. The South–South Global Assets and Technology Exchange (SS-Gate) in Shanghai jointly established by the United Nations Office for South–South Cooperation (UNOSSC) in the UNDP and Shanghai United Assets and Equity Exchange (SUAEE) in 2006 is a good example in this case. The SS-GATE is a virtual and physical platform where entrepreneurs in developing countries can interact and obtain needed technology, assets, and finance in a secure environment. It facilitates the realization of actual business transactions through a market mechanism, offering both online and offline beginning-to-end supporting services. It operates through a global network of participating organizations and institutional members. The SS-GATE aims to provide transparent, fair, transactional, and sustainable development exchange platform[1] that benefit all Southern countries and contributes to achieving the Sustainable Development Goals. To date, it has facilitated the transaction of several technology transfer projects between developing countries.

The previous paragraphs provide a spectrum of policy options that can help develop a low carbon future for China and India. However, it is recommended to consider the following principles when designing related strategies and policies on low carbon technologies in China and India:

1. Strategies and policies need to be incentive compatible, so that they create incentives for people to self-regulate themselves. They should promote technological and institutional innovation so that efficiency continuously improves over time. The development and introduction of low carbon technology is an essential element of a low carbon future. There is an urgent need to scale up and expand investment in the research and development of such technologies. This will not only require supportive policy framework for research and development, but also interventions that facilitate adoption and absorption of new technology. Venture capital funds that take equity risk could contribute to successful commercialization of innovations.
2. Policies and implementation strategies should recognize that actions will have to come from multiple levels in government, as well as industry, institutions, and individuals. Since many actions take place at the national and local government levels, not only the analysis and formulation of action plans, but also capacity building will have to be tailored to these levels. Implementation should also harness the creative potential of non-governmental actors, particularly business, professional associations, and the civil society at large;
3. Policies should facilitate coordination so as to reduce transaction costs in the implementation of low carbon strategies. While setting priorities, both 'co-benefits' and 'consequential losses' need to be considered, as also cross-cutting effects across sectors of the economy; and
4. Policies should take into consideration uncertainties as well. In the context of climate change, such uncertainties could be uncertainty about current and cumulative greenhouse gas emissions, the

[1] South-South Global Assets and Technology Exchange (SS-Gate), January, 2014. Available at http://www.ss-gate.org

time patterns of global warming, collective action at the global level, uncertainty about technology development, behavioural responses of the emitters, and the impact of global warming on local ecosystems.

1.6 The Way Forward

Low carbon development means a new approach to and an opportunity of continued economic growth while ensuring that natural assets, the environment, and the interests of human well-being are safeguarded. Embracing low carbon development can secure a strong, stable, and sustainable future for both developed countries and in particular, developing countries. Governments that place low carbon development at the core of their socio-economic development strategies can achieve sustainable economic growth and social stability, protect the environment, and conserve resources for generations to come. Balancing development with environmental protection and sustainable natural resource management is crucial to avoiding natural resource depletion, tackling climate change, and maintaining social security. This is also particularly true for developing counties due to their acute exposure and vulnerability to environmental risks, such as climate change.

Both China and India are moving on the right track for low carbon development with strong political willingness, fairly well-designed domestic policies, and international engagement. The key to China's and India's low carbon technology future is through innovation, development, and commercialization of new technologies and focusing on indigenous solutions. In addition, technology transfer from developed countries and joint R&D with developed countries can also help China and India leapfrog to cleaner development patterns and become leaders in rapidly emerging economic sectors like renewable energy. However, both China and India need to overcome a series of social and economic barriers in order to achieve a low carbon future, for instance, meeting poverty reduction needs, expanding energy services, ensuring energy security, maintaining and increasing employment rate, reducing environmental pollution, protecting biodiversity, while moving themselves down a low carbon development path. The difficulty for both China and India as emerging economies in developing, deploying, and adopting low carbon technologies is due mostly to the additional cost associated with it and in some cases technical barriers to implementation. Besides, collaboration and open stakeholder involvement from various sectors including government, industry, academic, and civil society between the two countries is essential in framing and coordinating policies and measures between them, so that low carbon technology development policies can be implemented to promote sustainable development, spur innovative business, and meet the poverty reduction needs of the two largest developing countries in the world.

CHAPTER 2

INNOVATIVE FINANCING FOR LOW CARBON DEVELOPMENT

2.1 Introduction

Cities are the centres of economic activities. They are also the world's biggest consumers of energy and major greenhouse gas emitters. Therefore, promoting urban planning and respective policies for climate-friendly cities can effectively improve energy efficiency, reduce greenhouse gas emission, and facilitate the realization of the goal of a global response to climate change. A recent research on low carbon cities shows that cost-effective policies to reduce energy consumption can ensure the reduction of greenhouse gas emission in cities by 40 per cent by 2020 (Gouldson *et al*. 2012). Without doubt, low carbon investment in cities' response to climate change can promote local economic growth, create jobs, and then stimulate the development of a low carbon economy with structural transformation. Measures to reduce greenhouse gas emission and adaptation to climate change will, however, increase the pressure on the budget of local governments and raise extra financial demands, including: (*i*) adaptation-related expenditure and financial demands; (*ii*) reduction-related expenditure and financial demands; (*iii*) expenditure and financial demands as the result of carbon-related energy price increase; (*iv*) expenditure and financial demands related to capacity building. The current size of investment in low carbon development to meet the needs of the development of low carbon cities is yet far from adequate. One of the main reasons for this is the insufficient investment in low carbon development in cities. Though financial inadequacy for the development of low carbon economy is universally common, it is particularly prominent in developing countries which are more vulnerable economically. However, it is also in developing countries that urbanization rates and urban expansion soar. Therefore, how to prevent the lock-in effect[2] and effectively finance low carbon development in cities becomes an important question.

[2] In general, the lock-in effect refers to the fact that the energy consumption and pollution level of fixed asset investment programmes, once determined, are hard to improve upon within a certain period due to existing technical restraints. Therefore, high-polluting and energy-consuming investments will bring about lasting negative impacts on energy conservation, emission reduction and low carbon economic development within a certain period.

Local governments normally enjoy a certain degree of discretion in areas such as urban planning and infrastructure construction, and to some extent, play a guiding role in the design and development of green and low carbon cities. The development of low carbon cities mainly involves transport, construction, energy, and waste management—the financing for which is closely related to the financial source of local governments. A sound financing scheme will effectively boost the growth of low carbon economy or vice versa. As can be judged from the division of rights and obligations between the central and local governments in China, the latter bears quite a percentage of government expenditure. Responding to climate change and developing low carbon economy have brought about new challenges to the management and use of the fiscal revenue of cities and the attraction of extra funds. These challenges include: (*i*) identifying financing needs in low carbon sectors and breaking financing bottlenecks; (*ii*) determining the structure and form of financing mechanisms and providing conveniences for low carbon financing; (*iii*) determining and giving full play to the roles of public—the Central government, local governments, and the connection between the two—and private sectors, and providing conveniences for low carbon financing; and (*iv*) determining which specific policies and conveniences the local government need to provide in order to attract more investment in low carbon sectors.

This chapter provides an overview of the financing management and innovation for low carbon development in cities and furthermore, a comparatively comprehensive reference basis for future research on specific issues. As summarized in Table 2.1, we believe that efforts to improve the financing capacity of local governments for the development of a low carbon economy can be done in three respects: (*i*) to improve the ability to obtain extra financial sources, that is, expanding the size of disposable funds through the scale effect; *(ii)* to reform the existing fund management and use different modes to improve fund-use efficiency, that is, realizing the same low carbon development objective with less money through the technology effect; and *(iii)* to incentivize the private sector in low carbon development to save some public funds, that is, the substitution or structure effect. There are only a few articles published on the research of low carbon financing for cities. Based on the abundance of research on climate financing, the Research Centre for Climate and Energy Finance of CUFE have conducted a special systematic research on city financing. This chapter not only summarizes the greening of fiscal instruments and the reform of financial instruments, but also classifies fiscal and financial instruments on the basis of scale effect, technology effect, and substitution effect, and analyses, one by one, the feasibility of financing instruments for developing low carbon economy in cities based on relevant international experience. Foreign enterprises and direct investment of enterprises are excluded in this research, for we believe they are up to the policy signals sent by the central and local governments, and thus are not entirely financing instruments for low carbon economy.

Table 2.1 Summary of Financing Means for Local Governments to Develop Low carbon Economy

Effect	Form	Content/Case
Scale effect	Directly provide extra financial sources	The improvement of existing policies concerning taxation, fees, and financing means and policy innovation
Technology effect	Improve the existing fund use and management mode	Strengthen the management of existing special funds for low carbon economy; reform the transfer payment mode
Structure or substitution effect	The private sector invests in relevant low carbon economic sectors to save government expenditure which can be used in other low carbon economic sectors	CDM or voluntary emission reduction programme; enterprises are more active in emission reduction in the carbon trading market

2.2 The Challenge of Budget Increase for Cities in Response to Climate Change

Developing a low carbon economy will not only ensure energy conservation and emission reduction in cities, strengthen their ability to adapt to climate change and extreme weather, but also promote sustainable development of cities and maintain their lasting competitiveness and appeal. More and more cities are actively developing a low carbon economy, which will surely raise more demands on expenditure. Infrastructure mainly involves sectors of transport (highway and railway), telecommunications, energy and power, and water treatment and supply. The International Energy Agency (IEA) predicts that to provide for universal modern energy access by 2030, a cumulative investment of USD 1 trillion is required, with an annual average of USD 48 billion (IEA 2011).

Effective, convenient, and diversified financing for low carbon economy is the key to ensuring the low carbon development and transformation of cities. However, cities vary in emission reduction, development phase, economic structure and scale, comparative advantages, and development trends; therefore, the challenge of budget increase for them to develop a low carbon economy also differs. What is more is that there is no unified amount or rate of extra financial demand. The analysis of financial demands shall be made on a case-by-case basis. Table 2.2 summarizes the financial demands and annual emission reduction of some low carbon programmes or low carbon development plans of cities, from which we can see that the financial demands vary greatly according to the emission reduction size of each programme and the sectors involved—such as transport, construction, and energy. Low carbon economy covers a wide range of industries and technologies, and most countries do not have a unified statistical scope for it, resulting in diverse definitions of expenditure on low carbon economy. Therefore, because of different scopes and data available, expenditures of low carbon economy with different research statistical sources are not entirely comparable.

Table 2.2 Summary of Financial Demands of Current Major Low Carbon City Programmes and Development Objectives

Low carbon City Programmes	City	Financial demand (USD 1 million)	Annual emission reduction (ktCO_2)
Convenient public transport transfer measures	Vancouver	39.2	1.8
The comprehensive goal of reducing carbon dioxide emission by 60% by 2025	London	40,000	N/A
Congestion charge management system	London	244	120
The public bike system	Paris	132	18
Solar water heater of buildings	Montreal	1.96	1.34
The city wind power system	Toronto	1.21	0.38

Sources Compiled from KPMG (2011), Merk *et al.* (2012), and Kennedy *et al.* (2010)

The comparison of low carbon issues of cities is not the scope of this chapter. However, we analyse the expenditure of local cities in low carbon sectors in a comprehensive manner; first, the budget expenditure of major cities in the world on low carbon development is compared; second, an analysis of the expenditure in low carbon relevant sectors in provinces and municipalities directly, under the central government in China, is carried out.

2.2.1 Expenditure Analysis of Current Low Carbon Development Sectors of Major Cities in the World

The sources of expenditure of cities to develop low carbon economy include the government, investments of the private sector, and financing of financial institutions. Since most low carbon industries and service sectors are still at the early stage of development with immature technology, low degree of marketization, and high cost of operation, they bear higher investment risks than traditional industries for the private sector. Government support and assistance will effectively reduce the above investment risks. The use of public funds can effectively boost the growth of low carbon industries and reduce the uncertainties of investment. Compared with the financing of the private sector and financial institutions, data of government expenditure is readily available. We focus on the analysis of government expenditure structure of major cities in low carbon development.

First, if we consider the source of government expenditure to develop low carbon economy in cities, such expenditure is normally shared by the central and local governments. Also, because of different structures and systems of different countries, the division of low carbon expenditure between the central and local governments of different countries in the world varies greatly. Thus, as far as government expenditure is concerned, low carbon financing for local governments is complex, not typical and not entirely comparable. Figure 2.1 summarizes the expenditure percentage of the Central government and local governments in fixed-asset investment sectors for environmental protection and developing green economy in 20 developed countries. We can see that in France, Germany, Hungary, Ireland, Israel, South Korea, the Netherlands, Norway, Poland, and Switzerland, more than 90 per cent of the fixed-asset investment in the environmental protection field comes from local governments, making them typical countries in which local governments dominate the government expenditure on low carbon city development. In Austria, Belgium, Denmark, Italy, and Portugal, the figure is between 20 per cent and 45 per cent, making them typical countries in which local governments and the central government share nearly equally the expenditure in environmental protection sectors. It is only in Greece, Iceland, Spain and the UK, that the expenditure of the central government—including state governments in some countries—exceeds that of local governments on fixed-asset investment in environmental protection sectors, accounting for more than 50 per cent of the total expenditure. In particular, in Iceland, the expenditure of the central government is more than 80 per cent. In these countries, the Central government dominates the government expenditure on low carbon city development. On the whole, the government expenditure on low carbon economy in most countries mainly comes from the local government. On an average in OECD countries, capital expenditure of local governments in the environment low carbon field takes up about 75 per cent of the total—combined expenditure of the central and local governments (OECD 2010). If we cannot change the current division structure and size of low carbon expenditure of the central and local governments in the short term, it will pose extra demands and challenges for the financing capacity of local governments to develop a low carbon economy.

Second, considering the importance of local government expenditure in the financial supply for low carbon economy, we further analyse the percentage contribution of the local government on low carbon economy in the total expenditure. As the priority sector and other restraints vary, cities differ a lot from each other in terms of the percentage of expenditure in low carbon sectors in the total expenditure; the expenditure composition of major cities in low carbon sectors also differs. According to the present scenario, local government expenditure in low carbon and green economic sectors accounts for the majority of all the local government expenditure in some European Union (EU) countries while in others, the expenditure in low carbon sectors only takes up a small percentage of the total local government expenditure. Table 2.3 gives the various types of low carbon expenditure of the Central and local governments.

Table 2.3 Types of Low Carbon Expenditure of the Central and Local Governments

Types	Characteristics	Representative Countries
Expenditure mainly coming from local governments	Over 90% of fixed-asset investment in environmental protection and low carbon sectors comes from local governments	France, Germany, Hungary, Ireland, Israel, South Korea, the Netherlands, Norway, Poland, and Switzerland
Expenditure coming from Central and local governments	The fixed-asset investment expenditure of local governments in environmental protection and low carbon sectors accounts for between 20% and 45%	Austria, Belgium, Denmark, Italy, and Portugal
Expenditure mainly coming from the central government	The expenditure of the central government (including state governments in some countries) exceeds that of local governments on fixed-asset investment in environmental protection sectors, accounting for more than 50% of the total expenditure	Greece, Iceland, Spain, and the United Kingdom

Source Author compilation

Figure 2.2 shows that local government expenditure policies can be divided into two categories according to the percentage of expenditure in low carbon economic sectors against the total local government expenditure. The first category is the low carbon development potential category comprising building, transport, water, waste and other environment sectors; these have a direct bearing on green/low carbon development. The second category accounts for other development activities. In Los Angeles, Montreal, and Toronto, the expenditure on low carbon economic construction accounts for over 40 per cent of the total local government expenditure which enables local governments to implement low carbon measures. In particular, in Montreal and Toronto, over 30 per cent of local government expenditure is spent on the construction of local transport facilities. Hence, we can say that the local government expenditure policies, in these two cities, lean towards or prioritizes a certain low carbon economic sector. The local government expenditure of Los Angeles is more equally distributed to major low carbon economic sectors; hence, we can say that the local government expenditure policies lead to a balanced development of low carbon economy. In Paris and San Francisco, about 20 per cent of the local government expenditure is spent on low carbon and green economy, making the local government expenditure policies of these two cities at the medium level. In particular, most of the local government expenditure in Paris goes to the construction and transport sectors and in San Francisco, the local expenditure on transport construction takes up two-thirds of the total local expenditure on low carbon economy, with the rest one-third equally distributed to

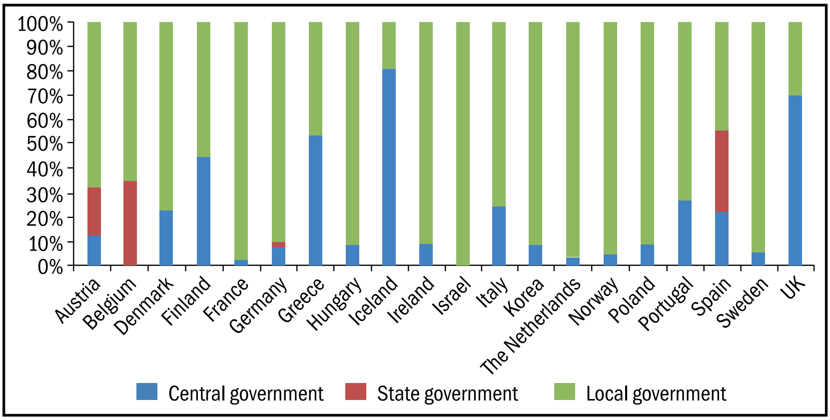


Figure 2.1 Percentage of Central Government Expenditure and Local Government Expenditure on Fixed-Asset Investment in the Environmental Protection Sector in Major OECD Countries (2009)
Source: Merk *et al.* (2012)

water conservancy facilities and waste disposal. Last but not least, in London, New York, and Melbourne, the local government expenditure on low carbon and green economy accounts for less than 10 per cent of the total local government expenditure, and in Chicago, it is about 14 per cent. The expenditure on low carbon economy in these cities takes up a small percentage of the total local expenditure.

The above analysis only tries to categorize the relationship between local government expenditure and low carbon economic development based on the percentage of local government expenditure—in relation to total local expenditure—in the pursuit of a low carbon economy. It shows, only to some extent, the importance attached by the local government to low carbon economy in its expenditure policy, and cannot be used to tell the determination of local government to develop low carbon economy. For example, though London has only a small percentage of expenditure on low carbon economy, it has developed a comparatively comprehensive and ambitious low carbon economic plan and greenhouse gas emission reduction plan; it is also one of the most active cities in the world in its response to climate change. As mentioned above, each local government and their respective country have their own systems, development goals and phases, so there is no unified standard to measure the financing needs of local government to develop low carbon economy. However, on the whole, in most countries, local governments face a bigger financing challenge for the development of low carbon economy than the central government. The main reason is because in most countries, the expenditure on

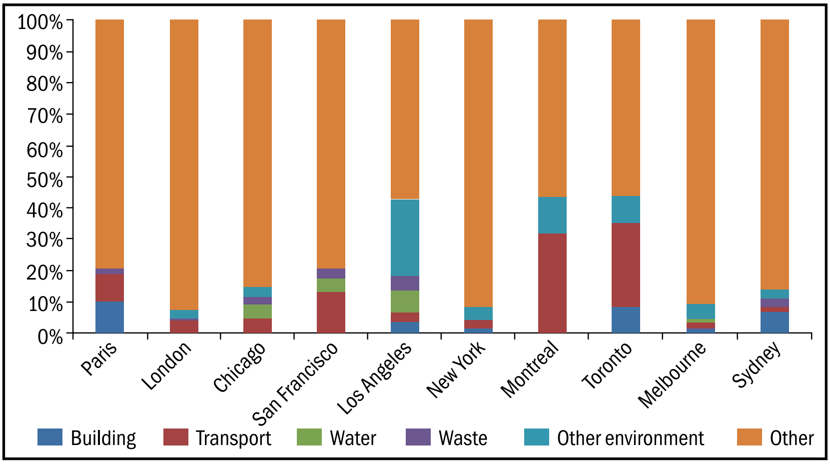


Figure 2.2 Structure of Local Government Expenditure in Major Cities: The Percentage of Expenditure on Low Carbon Economy and Other Expenditure (2010)
Source: Merk *et al.* (2012)

low carbon economy mainly comes from local governments, and is restricted by factors such as systems; it is unlikely and infeasible to change that structure within the short term.

2.2.2 Analysis of the Expenditure Challenge Facing Local Governments in China to Develop a Low Carbon Economy

Limited by data availability, this section mainly studies the administrative units at the level of province and municipality directly under the central government and autonomous region, to analyse the expenditure challenge facing local governments in China to develop low carbon economy. There are two main challenges here. The first is that the revenue-expenditure ratio of the central and local governments is not balanced and second, local governments bear most of the expenditure in low carbon economic sectors.

First, as to the overall structure of fiscal revenue and expenditure, local governments in China face a bigger expenditure pressure than the central government. To better support the construction of a socialistic market economy, China has launched a tax reform in 1994, including the reform of the tax distribution system for the central and local governments. Since the tax reform in 1994, more and more fiscal revenue has gone to the central government (Zuo 2007). As shown in Figure 2.3, the percentage of fiscal revenue of the Central government has risen from 22 per cent in 1993 to 55.7 per cent after the reform in 1994, and has been maintained within the range of 49 per cent to 55 per cent. Though the percentage of fiscal revenue of the central government in the total fiscal revenue has somewhat shrunk; e.g., the figure in 2011 fell below 50 per cent (49.4 per cent) for the first time since 1998. Compared with the percentage of fiscal revenue of local governments in the total fiscal revenue, the ratio of fiscal expenditure of local governments to the total expenditure[3] is still much bigger than

[3] China divides the rights and responsibilities between the central and local governments according to the different roles of government in economic and social activities and then determines the expenditure based on the rights and responsibilities of the government. The central fiscal expenditure includes expenditure on national defence; expenditure on armed forces and police; expenditure on administrative management at the central level and all sorts of operational expenditure; expenditure on major construction; and expenditure on national economic restructuring, regional development coordination, and macroregulationand control. Local fiscal expenditure includes the expenditure on local administrative management and all sorts of operation expenditure, expenditure on infrastructure construction and technological reform coordinated by local governments, expenditure to aid agricultural production, expenditure on urban maintenance and construction, expenditure on price subsidies, etc.

that of the central government. As shown in Figure 2.4, the percentage of fiscal expenditure of local governments in the combined fiscal expenditure of central and local government has been increasing in recent years, from 65.3 per cent in 2000 to 84.9 per cent in 2011. The increasing expenditure–revenue ratio has constituted a certain potential threat for the overall financing capacity and the default risk of local governments.

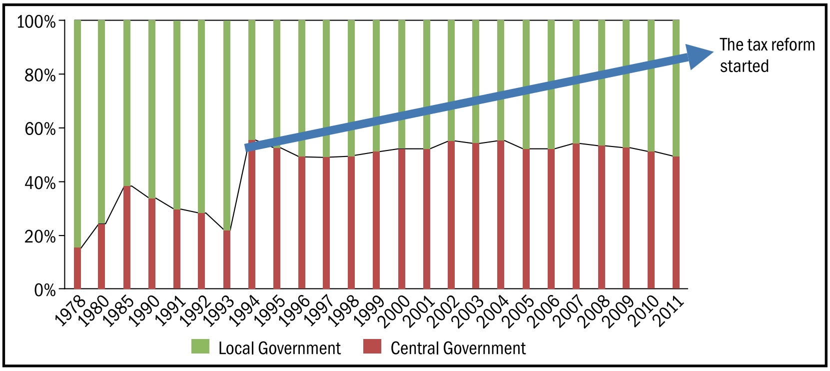


Figure 2.3 Fiscal Revenue Percentage of the Central and Local Governments (1978–2011)
Source: National Bureau Statistics of China (2012).China Statistical Yearbook 2

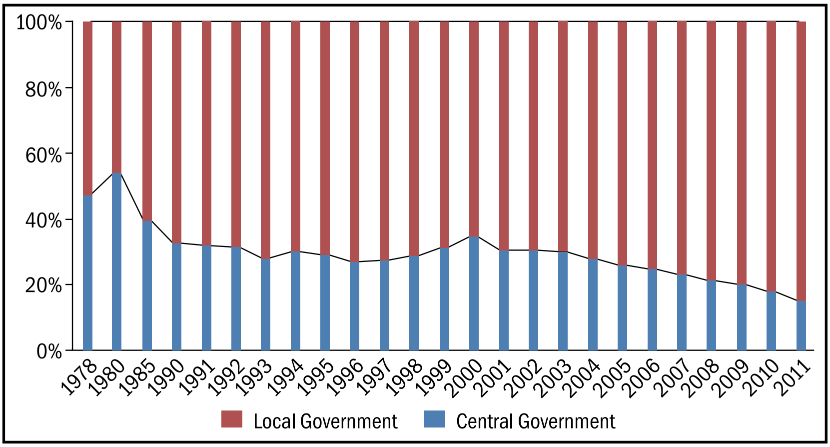


Figure 2.4 Fiscal Expenditure Percentage of the Central and Local Governments (1978–2011)
Source: China Statistical Yearbook (2012)

Secondly, the pressure of increasing overall fiscal expenditure on local governments to create a low carbon economy will present a big challenge for future local governments also. Based on the current statistical scope and available data (sorted on the basis of the data derived from the China Statistical Yearbook 2012), we summarize the expenditure sectors related to local low carbon economic development in Table 2.4. As shown in Table 2.4, most of the expenditure in low carbon sectors in China is borne by local governments; the expenditure of which in low carbon economic sectors such as urban and rural community affairs, energy conservation and environmental protection, transportation, agriculture, forestry and water affairs, and land and meteorological services, takes up almost the majority of the combined expenditure of the central and local governments on related industries. To provide extra financial source and improve the existing fund use and management mode, fund use efficiency will be the key to ensuring financial support of local governments to the development of low carbon economy.

Different areas have different economic structures and development phases; their capacity to finance and pay also varies. Figures 2.5 and 2.6 show that the per capita expenditure in low carbon sectors of local governments in China can be distinguished by their geographical characteristics and development types—measured against the per capita GDP—to some extent. For instance, municipalities directly under the central government such as Beijing, Shanghai, and Tianjin are economically developed, and have higher per capita GDP, and thus a higher capacity to pay for low carbon development. Qinghai, Tibet, and Ningxia have a smaller per capita GDP, but the per capita expenditure in low carbon sectors in these areas is high due to the small population. Compared with these areas, the per capita expenditure in low carbon sectors in other areas is between 1,500 Yuan/person and 2,500 Yuan/person. Among them, the per capita expenditure in low carbon sectors in Xinjiang, Chongqing, Hainan, Liaoning, Jiangsu, Shaanxi, Jilin, Heilongjiang, Gansu, Shanxi, and Guizhou is above the national average of 2,090 Yuan/person, while that in Yunnan, Zhejiang, Fujian, Sichuan, Hunan, Guangdong, Guangxi, Anhui, Hubei, Jiangxi, Shandong, Hebei, and Henan is below the national average level, with the lowest level in Henan (1,184 Yuan/person).

We conclude that the local governments in China are facing financing pressures and challenges with regard to low carbon development. With the comprehensive deepening of low carbon development, infrastructure construction and renovation, and the completion of major objectives of energy conservation and emission reduction, the need for financial support in all aspects will be increasing. Local governments which have smaller per capita investment in low carbon sectors will face more low carbon financing pressure. Providing feasible short-term and medium- and long-term financing instruments to local governments will be the key to ensuring the low carbon transformation of local governments in China. The following two sections will focus on the analysis of fiscal and financial instruments that can bring extra financing sources for local governments to develop low carbon economy.

Table 2.4 Expenditure Structure of the Central and Local Governments for Low Carbon Development (2011)

Sector/ Area	Central Government (in 100 million Yuan)	Local Governments (in 100 million Yuan)
Urban and rural community affairs	11.62	7,608.93
Energy conservation and environmental protection	74.19	2,566.79
Transportation	331.11	7,166.69
Agriculture, forestry, and water affairs	416.56	9,520.99
Land and meteorological services	231.61	1,289.74

Note Since for construction expenditure, the data in the China Statistical Yearbook 2012 corresponds to the housing security expenditure, we cannot separate the construction input (urban planning) and social security input. So, we will not include construction expenditure in the low carbon expenditure in this chapter.

Source Based on the China Statistical Yearbook 2012

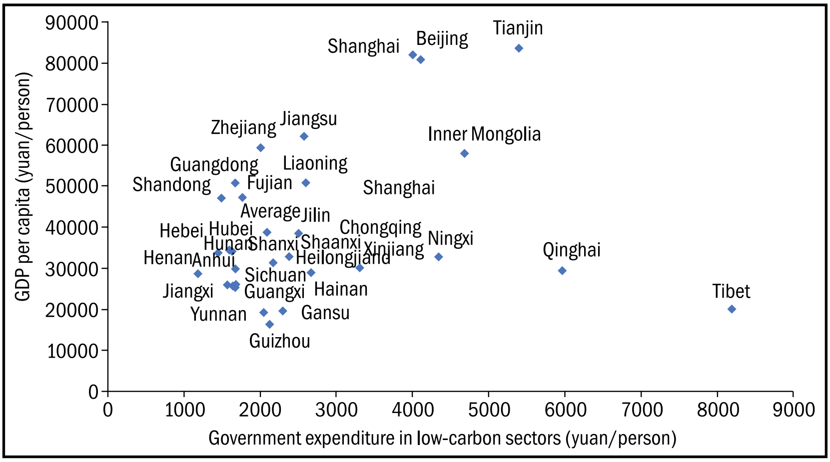


Figure 2.5 Comparison of Per Capita GDP and Per Capita Low Carbon Expenditure in China in 2011

Source: Based on the China Statistical Yearbook 2012

Notes: (1) The population refers to the year-end population. (2) Low carbon expenditure includes: energy conservation and environmental protection, agriculture, forestry and water affairs, transportation, land resources and meteorological services, and urban and rural community affairs. Since for construction expenditure, the statistical scope in the China Statistical Yearbook 2012 is the housing security expenditure, we cannot separate the construction input (urban planning) and social security input. So we will not include construction expenditure in the low carbon expenditure in this chapter. (3) Low carbon expenditure of major cities below the provincial level is excluded in this analysis due to data inadequacy.

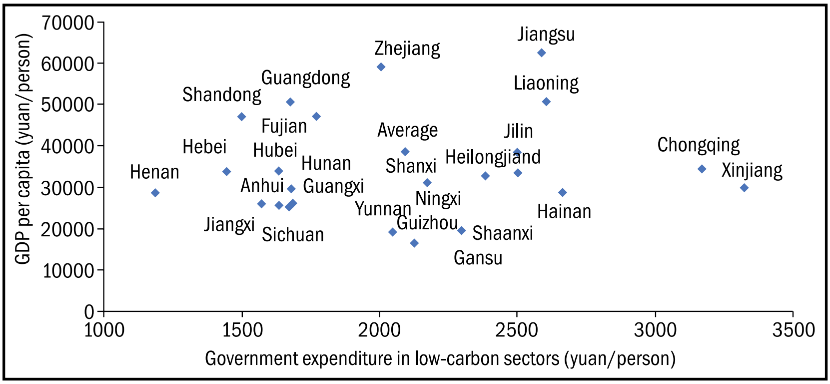


Figure 2.6 Comparison of Per Capita GDP and Per Capita Local Low carbon Expenditure in China in 2011, excluding Beijing, Tianjin, Shanghai, Ningxia, Qinghai, Tibet, and Inner Mongolia

Source: Based on the China Statistical Yearbook 2012

Notes: (1) The population refers to the year-end population; (2) Low carbon expenditure includes: energy conservation and environmental protection, agriculture, forestry and water affairs, transportation, land resources and meteorological services, and urban and rural community affairs. Since for construction expenditure, the statistical scope in the China Statistical Yearbook 2012 is the housing security expenditure, we cannot separate the construction input (urban planning) and social security input. So we will not include construction expenditure in the low carbon expenditure in this chapter; (3) Low carbon expenditure of major cities below the provincial level is excluded in this analysis due to data inadequacy.

2.3 Fiscal Instruments for Low Carbon Financing in Cities

The bottleneck faced by the local governments in financing low carbon growth may be alleviated through reform and innovation of fiscal and financial instruments. This section focuses on how the existing fiscal instruments of China can help local governments fund low carbon growth in a better way. It will place emphasis on two aspects: *(i)* the reform (greening) and innovation of the existing fiscal instruments, which explore viable low carbon financing available to the local governments in view of the types of fiscal policies; and *(ii)* the management of the existing fiscal revenue and reform of the existing distribution policies (including the fiscal expenditure of the Central and local governments and transfer payment, etc.), which deals with the low carbon financing from the perspective of the efficiency and direction of the use of the fiscal revenue.

The former aspect aims to increase the funds available for low carbon growth, while the latter aspect can not only increase such funds, but also improve the efficiency of its use. As fiscal instruments, both aspects can effectively provide additional, stable, and effective funds for the local governments in their low carbon growth strategy.

Existing international experience can provide sound reference for the design and reform of the Chinese fiscal instruments for the time being. Table 2.5 is a summary of the key fiscal instruments which may be applied to the low carbon financing of local governments by the key sectors related to low carbon economy. According to the sources of local governments' funds, such instruments include taxes and fees, as well as transfer payments of the central government.

It is worth emphasizing that the existing international experience may not necessarily be applicable to China due to the differences in national conditions. Hence, adaptability of policies to suit the local context is important. In view of the sources of the local governments' fiscal revenue, as shown in Table 2.5, this section will first strive to analyse the status quo of each fiscal instrument in China, and then move on to the reform and innovation of each fiscal instrument and the methods of fiscal revenue management in light of the international experience, with a view of providing the local governments with better financing services in their efforts to develop the low carbon economy.

Table 2.5 Summary of the Fiscal Instruments for the Low Carbon Financing of Local Governments by the Sources of Fund and the Key Sectors

Instrument	Transportation	Building	Waste Recycling and Disposal	Energy
Taxes	Consumption Tax, Vehicle and Vessel Tax	(Property Ownership Tax)	(Property Tax)	(Energy Tax) (Carbon Tax)
Fees	(Congestion Fee) Parking Fee (Highly Travelled Road Fee)	(Construction Fee) Land Transfer Fee (Development Fee) (Excessive Plot Ratio Fee) (Other Fees)	Property Management Fee	Electricity Surcharge
Transfer Payment of the Central Government	Current Account Expenditure Subsidies Special Funds [Earmarking of Tax Revenues]			

Note Policies within parantheses are those which have been put in place in other countries but have not yet been adopted or widely applied in China.

2.3.1 Taxation

Taxes are an important source of revenue for central and local governments. According to the distribution methods of tax revenue, the taxes of China can be divided into central taxes (that is, those due to the Central government in their entirety), local taxes (that is, those due to the local governments in their entirety), and those shared by the central and local governments (with the distribution ratio varying from tax to tax). Table 2.6 is a summary of the revenues from different taxes in China in 2011. It shows that the central government's tax revenue in the year 2011 stood at RMB 4,863.1 billion, which is RMB 7,525 billion more than the RMB 4,110.6 billion of the local governments, reflecting an advantage of the central governments in terms of the tax revenue. It follows that, in an effort to increase the funds of the local governments in developing the low carbon economy, there is a need to green or innovate in the types of taxes. 2.2

The tax revenue of the local governments in China, first of all, derives from the taxes shared with the central governments. These taxes include three types of taxes: firstly, the taxes related to the production and operation activities, namely, the business tax and value added tax.[4] These taxes cover, relatively, a wide range of sectors and their tax rates are generally speaking, universal. China is now implementing a policy of deducting or exempting the value added tax for some low carbon industries and products, but in terms of the local governments' revenue, it is rather difficult to increase the tax revenue of the local (and central) governments by reforming or adjusting these taxes for the special purpose of low carbon growth (e.g., raising the value added tax rate for some sectors with high level of carbon intensity). Also, the feasibility of such a measure is low, both in the short and medium term. Second, there are taxes related to income, namely, the personal and corporate income taxes. China is now implementing an income tax deduction or exemption policy for enterprises in certain sectors, such as the energy conservation and environmental protection and clean energy sectors. This policy can effectively promote the development of the low carbon economy and low carbon cities. However, from the perspective of providing effective and additional funds to the local governments for a low carbon economy, the feasibility is relatively low. Third, another source of taxes is related to the use and sale of land, including the city maintenance and development tax. These taxes cover a relatively smaller range of population groups and economic sectors and are mostly directly related to the use and sale of land in

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4 China is now experimenting with the practice of changing business tax into value added tax for the transportation industry and a part of the modern service industry in eight provinces or municipalities directly under the central government, such as Beijing and Shanghai.

Table 2.6 Composition of Chinese Fiscal Revenue in 2011

Head	Sub-head	Revenue of the Central Government (in RMB 100 million)	Revenue of the Local Governments (in RMB 100 million)
Total		51,327.32	52,547.11
Subtotal of tax revenues		48,631.65	41,106.74
Central tax	Domestic consumption tax	6,936.21	
	Value added tax and consumption tax imposed on imported goods	13,560.42	
	Value added and consumption tax rebate offered to exported goods	-9,204.75	
	Vessel tonnage tax	29.76	
	Vehicle purchase tax	2,044.89	
	Customs duty	2,559.12	
Revenue shared by the central and local governments	Domestic value added tax	18,277.38	5,989.25
	Business tax	174.56	13,504.44
	Corporate income tax	10,023.35	6,746.29
	Personal income tax	3633.07	2421.04
	City maintenance and development tax	169.37	2,609.92
	Stamp tax	425.28	616.94
	Other tax revenue	2.99	1.16
Revenue due to the local governments in its entirety	Resource tax		595.87
	Housing property tax		1,102.39
	Urban land use tax		1,222.26
	Land value increment tax		2,062.61
	Vehicle and vessel tax		302.00
	Farmland occupation tax		1,075.46
	Deed tax		2,765.73
	Tobacco tax		91.38
Revenue from fees	Subtotal of the non-tax revenues	2,695.67	11,440.37
	Special revenues	361.40	2,695.01
	Administrative charges	404.02	3,635.36
	Fines	38.76	1,262.63
	Other revenues	1,891.49	3,847.37

Source China Statistical Yearbook (2012) the development and expansion of cities. We believe that by adjusting the rates of these taxes, we can effectively inhibit over-expansion of the cities on the one hand, and increase the tax revenue on the other hand, thus providing additional funds for the local governments based on the existing tax revenue distribution ratio between central and local governments.

Next, the tax revenue of the local governments are mainly those related to the use and sale of land, including the housing property tax, farmland occupation tax, land value increment tax, and urban land use tax. The adjustment of these tax rates can also lead to the inhibition of over-expansion of the cities, protection of the farmland and increase in the local governments' income. Meanwhile, the emission-based vehicle and vessel taxes have a direct bearing on the cost of vehicle use, and therefore, their tax rate adjustments can bring a considerable amount of additional revenue to the local governments, while curbing the pollution resulting from vehicle exhausts and promoting energy conservation and emission reduction.

Internationally, a majority of the Organization for Economic Cooperation and Development (OECD) countries derive their local governments' tax revenues from property tax. Property tax has an impact on land use, urban plot ratio, and the speed of urban expansion. Hence, it has an overall impact on the planning of low carbon cities. However, the tax rate, tax base and target of the property tax vary from country to country. For example, France introduced, in 2010, a tax policy which imposed a certain low density tax on building projects whose plot ratios were lower than the statutory level; the City of Austin in the State of Texas, USA, levied tax on motor vehicles for their use of public facilities based on the assessed per-household mileage of the vehicles, which played an effective role in preventing low density of the city.

The low carbon city development financing, related to the property tax, also includes the tax incremental financing (TIF). TIF is basically applied to promote the development of an underdeveloped area in a city or an urban area which is in need of large-scale renovation. It works by first raising the overall value of a designated area through investment and then earmarking the income from the property tax, so generated, to cover the preliminary investment of investors in such area. For example, Chicago earmarked 10 per cent of its property tax revenue for TIF, which covers 25 per cent of the city's territory. However, public opinion on the effect of TIF is divided. Some believe that the TIF fund may be used for already developed urban areas, and therefore, exacerbate the imbalance of development in cities.

Moreover, some countries have adopted tax deduction or exemption measures for some taxes (including value added and income taxes) for green/low carbon projects. France is an example. In recent years, the country has offered value added tax deduction or exemption policies for the use of and investment in distributed PV power generation. We propose that China further expands the coverage of such tax deduction and exemption and incorporates more low carbon city development projects into such coverage, so as to effectively lower the cost of investment. Also, considering land tax, in contrast to the property tax using the price of housing property as the tax base, the land tax uses the price of land as the tax rate. However, given its limited scope of application and relatively more complicated management, it does not fit in well with the national conditions of China at the moment, and we will not make detailed analyses on this tax herein.

Finally, the newly created taxes related to low carbon development are also an important source of fund for the local governments. At present, some developed countries—e.g., Finland, Switzerland, and the UK—are imposing a certain percentage of carbon dioxide emission tax (carbon tax) on carbon dioxide emission from fossil fuels. China is also actively studying and preparing the levying of the carbon tax; the environment tax has already been written into the Twelfth Five-Year Plan of China and will be put into effect in due course. In addition, China can take the financial trading tax,[5] in combination with the existing financial product taxes, as a medium-to-long-term policy option, and use a part of the revenue from this tax to provide additional funds for the low carbon development of Chinese cities. At present, some European countries—e.g., France, Poland, Sweden, Finland, and Belgium, etc.—have already put the financial trading tax in place and used part of their revenues from this tax for the purpose of low carbon economic development. The financial trading tax is not only beneficial to the stability of financial markets and the reduction of malicious speculation behaviours; it is also capable of providing sufficient funds for government budgets.

In addition to studying the types of taxes for the purpose of providing funds for local governments in the low carbon growth area, we can also study the revenue from the taxes shared by the central and local governments, with the aim of adjusting the distribution

[5] The financial trading tax was first proposed by James Tobin, a Nobel Prize winner for economics in 1972. It is therefore also dubbed as the 'Tobin tax'. It refers to the globally uniform trading tax imposed on the spot foreign exchanges. The forms and targets of the financial trading tax vary from country to country.

ratios of such taxes and enabling the local governments to have more disposable income in their green/low carbon development efforts. In this respect, we can consider earmarking the additional tax revenue transferred by the central government to the local governments for low carbon development or environmental protection efforts of the latter. Moreover, apart from greening of the existing taxes, we must also take into consideration the impact of distribution and use of revenue from the newly created taxes in the future—e.g., the environment tax and the carbon tax—on the local governments' low carbon financing efforts. We may also consider distributing more tax revenue of the central government to the local governments. However, given the fact that the adjustment of tax rates and the distribution ratios require a relatively lengthy administrative process, the above analysis can basically be incorporated into the feasible medium-to-long-term policy packages which aim to fund local governments in their efforts.

2.3.2 Fees

As opposed to taxes, fees are more flexible in the law-making procedures. They have a relatively short cycle from the policy design at the top level to their implementation, and are more flexible in their earmarked use. Table 2.6 shows that the revenue from fees accounted for a relatively big proportion of the non-tax revenue of the Chinese government in 2011, and an absolute majority of such revenue was attributed to the local governments. Therefore, reforming the existing fees—such as increasing the pollutant discharge fee and the road toll fee—and introducing new fees are both important sources of funds for the local governments in their low carbon financing efforts. However, what is worth noting is the fact that the current reform in the fiscal systems and policies of China clearly aims to replace fees with taxes. An excessive use of fees as a means of financing is, to some degree, in conflict with the overall direction of the tax system reform. Nevertheless, as a fiscal instrument which is relatively easy to be implemented in the short term, a well-designed fee system for low carbon growth can effectively provide additional funds for the local governments in the short run. This section refers to existing cases of developed countries to discuss some feasible fee systems which do not contradict the overall fiscal system reform of China—or which are in relatively small conflict in the short term—for low carbon growth. In the international community, the fee policies in favour of local low carbon growth are now relatively concentrated in the housing and transportation areas, and the principal financing instruments in response to the pollutant discharge—including the use of energy and the emission of greenhouse gases—are emissions trading and taxes. We will discuss emissions trading in carbon financing in Section 4.

Regarding fees in favour of low carbon growth, we can, first of all, collect different amounts of fees from real estate developers in a one-off way in view of the geographic locations of their projects. Such fees can urge developers to make effective use of the land resources and provide additional revenue at the same time. For example, the extension of the subways of Copenhagen, Denmark, was funded by the fees collected from the real estate development projects in the Orestad district of the city; the US and Canada both levy different amounts of fees on urban developers to fund the development of public facilities in the cities (Burge 2010). These fees are different from the traditional fees, because they require the project developers to bear the cost of overall city development outside the territory of their projects, so they have some referential value for the low carbon financing of local cities in China. Another example is the St. Paul district of Brazil which increases local fiscal revenue by selling the right to elevate existing houses, stipulating that new buildings whose plot ratios exceed the prescribed level must pay for such right before starting construction. China can also take into consideration the practice of allowing developers to outrun the statutory plot ratio yet levying additional fees from them for it. This cannot only enrich the diversity of the real estate market, but also provide an effective source of funds for the low carbon growth of the cities.

Second, we can collect transportation fees, in order to reduce the use of motor vehicles and thereby reduce carbon emissions and local pollution in cities. A relatively wide means is to collect congestion fee, which is levied against motor vehicles at the peak of traffic. London, Stockholm, Singapore, and Milan have all began to collect this fee and have effectively reduced the emission of carbon dioxide (about 19.5 per cent) (Beevers and Carslaw 2005). In particular, in 1875, Singapore began to levy a road congestion fee at the rate of 3 Singapore dollars per day on vehicles (excluding those meant for public transportation) which enter the 6-square-kilometre downtown area under control. In the United States, the Congress of the City of New York adopted a resolution to collect congestion fees in the Manhattan Borough on March 31, 2008. According to the resolution, a congestion fee would be imposed on vehicles in the area ranging from the 60th street in the Manhattan Borough all the way southward to the Wall Street business community from 6 a.m. to 6 p.m. every day, at the rate of USD 8 per day for saloon cars, USD 21 for trucks, and USD 1 more for taxies as surcharge. Meanwhile, the tax credit given to garages in this area was cancelled. In addition to these measures, Singapore and Milan levy additional high emission fees for vehicles with a high level of emission. With respect to the use of fees collected, London applies the congestion fee to the development of urban public transportation means. Finally, New York and Los Angeles impose even higher parking fees in the highly congested areas, which effectively lessened traffic congestion. It is recommended that China collects similar congestion fees (from parking or moving vehicles) or impose progressive fees on vehicles according to the level of their emission, and use the revenue so generated for construction and maintenance purposes in the low carbon transportation sector.

2.3.3 Transfer Payment

Transfer payment, in a broad sense, refers to the government's behaviour in allocating the fiscal revenue to the particular areas of expenditure. The current transfer payment model between the central and local governments in China is characterized by a uniform collection of fiscal revenue in the first place and distribution of the revenue to the local governments or SOEs in the second place. Therefore, transfer payment can be seen as an important source of funds for the local governments' low carbon financing. A form of the transfer payment which supports low carbon financing of the local governments is the development subsidy by the central government, inside or outside its budget. As a reward, the local governments or the project developers undertake to maintain the use fee of the facilities developed at an appropriate level recognized by the central government, so as to provide cost-effective, low carbon urban services. For example, South Korea began to implement its First Five-Year Action Plan for Green Growth in 2009. The plan gave a subsidy of about 20–30 per cent of their project expenses to green urban development projects (undertaken jointly by the public and private sectors); this figure however might rise to 50 per cent for rail transportation projects, and even 50–80 per cent for environmental protection service projects. Such transfer payment models characterized by central collection and payment is relatively easy to manage. The transfer payment of the central government needs to better match the low carbon urban development projects and better coordinate with the funding of the local governments in both time and space, so as to maximize the effect of fiscal expenditure. It is recommended that China experiments with a joint coordination mechanism between the Central and local governments in the field of green/low carbon expenditure.

In contrast to the central payment model, the earmarking style of the transfer payment generally refers to a management model under which the revenue from a particular tax or fee is subject to special management and is used to corresponding areas in its entirety. Take the revenue from the energy or carbon tax for instance. Some developed countries have put the revenue under independent management and used the total of such revenue directly for the development and maintenance purposes in the clean energy and low carbon growth areas. Earmarking is beneficial not only for the maximization of the dividend of the transfer payment, but also important for the double dividend effect in the environmental protection area, which is to promote—green/low carbon—economic development and employment while protecting the environment. At present, the earmarking style of the fiscal management mechanism is not widely applied in China. However, we can transfer part of the fiscal revenue to the sectors where low carbon growth is more likely to happen by establishing special low carbon financing funds at the local level or setting up projects which support local low carbon financing under the existing funds (such as the CDM fund). The low carbon financing in the form of funds will be discussed later. Finally, the current transfer payment mechanism may consider giving more compensation to the areas which have suffered structural economic loss in the short term due to their efforts to develop the green, low carbon economy. This will stimulate the local governments' enthusiasm in developing the low carbon economy in cities.

Apart from the transfer payment, direct investment from the central government can also lighten the investment burden of the local governments, and in turn, bring about more disposable income to the local governments, which can be used to promote the low carbon economy. For this purpose, we need to further clarify the rights and responsibilities of investors in the environmental protection area, adjust the investment behaviours of various investors in the low carbon economic investment area (including the central government, local governments, and enterprises), and regulate low carbon investment activities. As Wang Wenxiang[6] pointed out, there are many shortcomings and defects in the method and scope for the division

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6 Wang,Wenxiang, 'Environmental Protection Investment: Too Heavy Burden for Local Governments, Expenditure of Central Government to be Increased', *China Economic Herald*, 10 May 2012. Available at http://www.ceh.com.cn/ceh/llpd/2012/5/10/112169.shtm

of rights and responsibilities among investors in the environmental protection sector, and further improvement is needed. The rights and responsibilities division among investors in the low carbon development and environmental protection areas must follow the principle of fairness, justice, and efficiency, and delineate the scope of rights and responsibilities between the government on one side and the enterprises and individuals on the other side and between the central government on one side and the local governments at various levels on the other side. Wang (2012) further suggests a way to divide the rights and responsibilities between the Central and local governments in the low carbon investment field.

The division of rights and responsibilities between the central and local governments must follow the principles of benefit, efficiency, and of matching the investment rights and responsibilities of the governments at various levels with their corresponding financial strengths. According to these principles, we must reasonably divide the rights and responsibilities between the central and local governments as well as among the provincial, municipal, county, and township governments. This means, firstly, according to the principle of benefit, we must have the central government undertake the rights and responsibilities with respect to the investment in low carbon growth and environmental protection areas across regions that would generate cross-regional benefits. It must also have a bearing on national economic and social development and ensure that the local governments undertake the rights and responsibilities with respect to the regional or local investment in the low carbon growth or environmental protection areas which generates regional or provincial benefits and have a bearing on the local economic and social development. Secondly, according to the principle of efficiency, we must allow the government, which is most efficient in making the low carbon and environmental protection investment, undertake the rights and responsibilities with respect to such investments. From the practice of China, we find that the Central government is more efficient in undertaking major cross-regional or cross-territorial low carbon or environmental protection projects, while the local governments are more efficient in undertaking regional low carbon or environmental protection investment activities. Moreover, the current practice shows that, with respect to the low carbon or environmental protection investment which are undertaken jointly by the Central and local governments and which benefit the regions concerned and the country at the same time, the Central government shall delegate the investment rights and responsibilities to the local governments and only give the latter financial support and subsidy to the extent corresponding to the level of benefit being accrued to the whole country. In view of the financial strength of the governments at various levels, we propose that, between the central and local governments, we must moderately increase the rights and responsibilities of the central government in the low carbon or environmental protection affairs, and that, between the local governments at various levels, we must gradually increase the rights and responsibilities of the provincial and municipal governments and constantly reduce the obviously excessive burden on the county and township governments.

2.4 Financial Instruments for Urban Low Carbon Financing

Apart from the fiscal policies, financial instruments are also key policy means of the local governments in low carbon financing. According to the types and nature of the financial instruments and in reference with the existing international cases, this section discusses how local governments reform and innovate with the help of existing financial instruments to enhance their ability to finance low carbon economy and expand their channels of financing in this respect. Table 2.7 summarizes all the key financial policy means analysed in this section.

2.4.1 Innovated Public Fund Direction Instrument

In the low carbon growth of a city, public funds may play a crucial leading role. First, it can effectively serve as a stable source of funds for projects in the low carbon economy. Second, it can further guide more private funds into the sector. The direction of the public fund can find its expression in policy funds, the green direction funds of the local governments, the fiscally supported guarantee funds, public–private cooperation, etc. Moreover, with proper guidance of public policies, the public fund can effectively enhance the enthusiasm and direction of the private grant. This section will introduce these public-fund-directed financing models one by one, and in view of the local governments' needs in financing, discuss the feasibility of the public fund direction instrument in providing additional funds for the local governments in their low carbon financing efforts.

Table 2.7 Summary of Financial Instruments Employed by Local Governments in Low Carbon Financing

Type	Content
Innovations in public finance	Policy funds
	Fiscally supported guarantee funds
	Special green funds for local governments
	Local financing platforms
	Public–Private Partnerships (PPP)
	Private grants
Carbon financial instrument	International carbon market
	Domestic carbon market
	Other market-based innovations
Innovations in traditional finance	Traditional credit
	Carbon assets pledge credit service
	International carbon factoring service
	Bonds
	Option tools
	Risk management tools

Policy Funds

The cooperation between the national policy funds and the local governments can effectively promote low carbon projects and reduce the risk of the projects. At present, China has no low carbon development funds in the strict sense of the term, but has some special funds which are dedicated to activities and projects in the field. For example, it established the China Clean Development Mechanism (CDM) Fund in August 2006 to support undertakings addressing climate change. The sources of fund of China CDM Fund include the government revenue derived from the transfer of certified emission reductions (CERs) of the CDM projects, fiscal appropriations, operating revenue of the fund itself, as well as donations from organizations and individuals at home and abroad. In addition to these sources, there is still the electricity price mark-up imposed by the government on electric power in favour of renewable energy for the purpose of promoting development and application of new energies. The revenue from this price mark-up, in combination with the special renewable energy development fund allocated by public finance, supports the development and utilization of renewable energy through the renewable energy development fund. Since 2012, the electricity price mark-up in favour of the renewable energy has increased from RMB 0.004 to RMB 0.008 per kilowatt hour. A rough estimate put the revenue from this change at RMB 20–30 billion.

Moreover, local governments can enhance their guidance in the low carbon investments in their territories through the venture capital investment plans of emerging industries. For example, in the emerging industries' venture capital investment plans launched under the Twelfth Five-Year Development Programme, the central government allocated a part of its industrial technology R&D fund together with the local governments' fund and the social capital, by contributing to their registered capital.

Since the Guiding Opinions on Standardized Establishment and Operation of the Venture Capital Investment Direction Funds was issued in October 2008, many local governments have set up governmental venture capital investment direction funds. The governmental investment direction funds refer to policy-based funds which are established by the government and operated in a market-oriented way. They aim to lead social capital into the venture capital investment field by supporting development of the venture capital investment enterprises. Their operation follows the principle of government guidance and market-oriented operation and their principal operation models include subscribing shares, providing guarantee for financing, making follow-up investment, offering investment guarantee, providing risk subsidies, etc. The governmental investment direction funds can give impetus to the fiscal fund in generating the leverage effect and guide the private capital into the industries which are to be intensively developed. They mainly invest in enterprises which are in the early or medium stage of their growth, or in other words, in the seed or growth stage of their development. For instance, the venture capital investment direction fund of Shanghai, founded in March 2010, had a fund of RMB 3 billion; by partnering as a parent fund with 12 venture capital investment funds, it leveraged capital in the total amount of more than RMB 4 billion.

Box 2.1 is a case in which the central financial organization of the EU partnered with the governments of its member countries to set up affiliated funds with the aim of providing additional sources of funds for the local governments in their efforts to develop a low carbon economy. We propose that the Chinese government, on the basis of the existing fund management models mentioned above and through the central government's fund, enter into partnerships with the local governments, local funds or fund management organizations to provide joint financing models in their efforts to promote a low carbon economy.

Box 2.1: Cooperation between Central Financial Organization and Local Government

The European Investment Bank (EIB) cooperated with the European Commission in adopting the EU Structural Funds to leverage the private investment in the low carbon city projects. A relatively typical financing mechanism in this respect is shortened as JESSICA. JESSICA ensures that the public sector makes investment in a paid way and provides fund for projects which cannot obtain fund from the commercial sector. It does not replace other existing financing forms in the public sector, such as grant, but is a supplement to them and balances the risk and return in a better way for investors. JESSICA requires participation of the government decision makers, so it can provide the local governments with greater policy space and obtain more professional information from the commercial sector.

From the partnership between JESSICA and the British government, we see that the organizational structure of JESSICA can be divided into two parts: the Holding Fund, which is managed by the EIB and is responsible for formulating overall strategies; Urban Development Fund (a general reference rather than the exact name), which is responsible for receiving the fund from the Holding Fund to handle specific projects by using the fund management experience and skills of the private sector for the purposes of promoting low carbon growth and maximizing the benefit of the projects. By applying for fund from the Urban Development Fund, the applicant of a project ensures normal, smooth implementation of the project concerned.

One of the funds which participate in the management of JESSICA is London Green Fund. The Fund was founded in November 2009 with registered capital of 100 million pounds to help the CO_2 emission reduction in London. Of the capital, the ERDF project of London contributed 50 million pounds; London Development Agency contributed 32 million pounds; and London Waste and Recycling Board contributed 18 million pounds, all aiming to help London in the carbon dioxide emission reduction projects. As manager of London Green Fund, the EIB provides different urban development funds with capital to support their cyclic economy and energy efficiency programs.

Fiscally-supported Guarantee Funds

Providing guarantee for projects with fiscal support can effectively lower the risk and raise the expected rate of return of projects. As shown in Table 2.8, the practice of providing guarantee with public fund is already present, although it has seldom been used in the low carbon growth area. We propose that the local governments adopt similar guarantee mechanisms to provide guarantee services for the low carbon economic sectors in their investment activities.

Table 2.8 Domestic Practice of Providing Guarantee with Public Fund

	Business tools
Jinan Export Guarantee Fund	The fund is totally funded by the municipal treasury and operated in accordance with the principle of being deposited in a special account, subjected to uniform management, released as per certificates, operated in a closed-end way, settled case by case, used without compensation and recovered in its entirety. In the four years of its founding, the fund has accumulatively provided guarantee for 497 loans in relation to 200-plus export enterprises, with the amount of guarantee amounting to RMB 318 million.
Beijing SMEs Credits Re-guarantee Co., Ltd	Apart from the pro rata, general, joint, cede, and double guarantee, the company has presented the new business trust plan and the business start-up loan, providing short-term finance for small enterprises in the early stage of their growth. According to the amount of financing, the products in favour of small enterprises are divided into two types, namely, the 'authorized guarantee as gift and the 'loans released upon guarantee'. The line of the credit under the 'authorized guarantee as gift' is RMB 1 million, which is to be examined and approved by the Bank of Communications. After examination and approval in batch, the re-guarantee company will provide guarantee of joint and several liability at a certain proportion of the amount of the credit. The line of the credit under the 'loans released upon guarantee' is RMB 1–5 million, which is to be guaranteed with joint and several liability by a cooperative guarantor (which shall be determined jointly by the re-guarantee company and the bank) in the first place and re-guaranteed by the re-guarantee company at a certain proportion of the amount of the credit in the second place and examined and approved by the bank via the fast track in the end.

Special Green Funds for Local Governments

The practice of the local governments jointly establishing funds with the development financial institutions and investment companies to promote infrastructure construction for low carbon cities and development of low carbon industries is already present. At the same time, there are an increasing number of cases in which social capital takes the initiative to launch low carbon-related private equity funds, such as Zheshang Nuohai Low Carbon Fund. Following this trend, the local governments can refer to the model of the governmental venture capital investment direction fund to establish special green direction funds, with the goal of guiding more social capital into the green, low carbon domain. As a parent fund, the green direction fund is committed to supporting development of the venture capital investment enterprises in favour of clean technologies and making contributions to the low carbon private equity funds. Like the governmental direction funds, the green direction fund can subscribe shares, provide guarantee for financing, make follow-up investment, provide guarantee for investment, offer subsidies for risk taking, etc., in its operation.

Local Finance Platforms

The establishment of local financing platforms can effectively facilitate and convenience the local governments in their efforts to develop new financial instruments. Given the popularity of the practice of financing the infrastructure construction through urban development investment companies, in this section, we will focally analyse the issue of facilitating local governments in issuing low carbon bonds and the establishment of local low carbon centres.

It is important to ask how cities can be enabled to obtain low carbon growth loans in better and more convenient ways that can finance low carbon development via the issuance of bonds. This is an important part of innovation in low carbon financing in the traditional financial market. At present, the local governments, including those of the OECD countries, still have a rather limited use of both the loans and bonds to serve this purpose. Some countries expressly ban local governments from raising fund through bonds, while others allow them to seek short-term loans yet prohibit them from seeking long-term loans in fund raising. However, a study by Della Croce *et al*. (2011) shows that infrastructure development can leverage the size and efficiency of the financing through loans or bonds more effectively. In fact, the size of a city's borrowings and the revenue of the city have the following relationship—the more (expected) revenue the city has, the more credit the city can obtain, hence, the more convenient it is for the city to finance via loans and bonds. With respect to the low carbon financing via the issuance of bonds, a financing form of relatively greater referential value to China is that the central and local governments jointly issue green bonds to finance the low carbon projects at the local level. For instance, the World Bank facilitates cities in middle- and low-income countries in their green bond financing efforts, but on the condition that the central governments of these cities cooperate and provide guarantee for them.

A study of the Climate Bonds Initiative shows that, considering the relatively wider area of emission reduction and climate change response, there are more than 1,000 climate themed bonds at present across the world; these bonds are created by 207 issuers in the size of about USD 174 billion. Companies (including listed companies and non-listed SOEs and private enterprises) account for 82 per cent of these bonds, followed by banks and financial institutions (13 per cent), project bonds (3 per cent), and municipal bonds (2 per cent). In addition, there are 204 billion US dollar worth bonds of which 50 per cent of the income and activities are related to the climate economy. Except the bonds issued by companies in the low carbon field, China has rarely used special climate bonds. Therefore, the development financial institutions of China can borrow the experience of multilateral financial institutions on the international arena to issue climate bonds to other financial institutions and institutional investors, in a bid to increase the capital put into the climate change domain. In the future, acceleration of investor participation and market expansion rely on three important conditions: *(i)* standardization and third party certification; *(ii)* certain scale to be met; and *(iii)* assistance of the public fund in enhancing the rating of climate bonds. Climate bonds can play a role in providing sources of fund for the local governments in developing the low carbon economy. Firstly, by financing local low carbon projects via the climate bonds issued by the central government or organizations and secondly, financing the local low carbon projects via the climate bonds issued directly by the local governments. Although these options are relatively hard to be operated in China for the time being, they can be proposed to policy-makers as medium-to-long-term policy options, given the international experience and the popularization and constant scale-up of the climate bonds at present.

Finally, what is worth noting is the fact that there is always relatively little existing experience in the innovation of financial instruments. In combination with the uncertainty of the low carbon growth projects in terms of the technical and managerial experience, it adds to the risk of investors. In an effort to effectively share the technical and managerial experience in this area, the municipal government of Amsterdam joined hand with local banks to set up the Green Finance Lab (Box 2.2), with a view of promoting exchanges among different sectors, driving low carbon investment, and lowering the risk of investment effectively. We propose that China, too, establishes such a financing platform to provide holistic support to both national and local low carbon financing efforts.

Box 2.2:Green Finance Lab of Amsterdam

In an attempt to effectively promote exchanges of experience among various sectors and lower the risk and cost of investment in the low carbon growth area, the municipal government of Amsterdam joined forces with the Dutch bank ABN AMRO to have set up the Green Finance Lab. As an important part of the sustainable development plan of Amsterdam and of the Green Deal between the Amsterdam government and the central government of the Netherlands, the lab is committed to exploring new forms of financing for the purposes of helping Amsterdam successfully transform into a sustainable city and providing a platform of exchange and cooperation for the public and private sectors.

The lab provides reference for investors from different angles (e.g., research, financial, governmental, and private investment, etc.) and consult with investors for the sake of the best forms of investment.

Public–Private Partnerships (PPPs)

As an important supplement to public finance and private finance is an important source of fund for local governments to effectively develop the low carbon economy. As this economy further develops, it requires more and more capital. To finance the low carbon growth only through the public sector is not sustainable in terms of both time and budget, and excessive government support cannot effectively promote industrialization and commercialization of the low carbon growth. It is therefore not conducive to the reduction of cost, impeding normal development of the low carbon economy. The PPP led by the government is nowadays quite widely adopted in a majority of the OECD countries, but varies greatly in content and organizational structure from country to country. It covers a wide range of forms ranging from the simplest government-entrusted management contract to the private finance initiative.[7]

Under this model, the private sector can effectively participate more in the design and early analyses of the projects; in return, the private sector can utilize capital in the long run (Box 2.3), rather than undertake the contracted government work in strict accordance with contract in the traditional way. This is very helpful in dispersing risks and lowering the cost of investment. Table 2.9 summarizes cities which employ the PPP form of financing successfully. Box 2.4 presents a success story in the innovation of low carbon financing where the local governments and private enterprises provide guarantee jointly.

Another example is the Infrastructure Credit Guarantee Fund (ICGF) of South Korea, managed by the Korea Credit Guarantee Fund. It aims to provide guarantee for low carbon projects, funded jointly by public and private sectors. The fund of the ICGF comes from three sources—the government fund, the guarantee fee, and the return of investment. Guarantee for low carbon projects is capped at 100 billion Won, or 200 billion Won in some special circumstances, with the annual rate of guarantee standing at 1.5 per cent. The ICGF provides effective support for the low carbon green city and overall green

[7] OECD, Les Partenariats Public–Privé: Partager les Risqueset Optimiser les Ressources.Paris: OECD 2008.

growth programmes of South Korea. Another typical form of the PPP financing is the energy management contract.

Box 2.3: Private Finance Initiative Supported by the Local Governments

The Birmingham District Energy Scheme is a comprehensive regional low carbon growth scheme which primarily aims to provide more efficient and cleaner energy by way of reconstructing the network and generating thermal power jointly. In order to finance the scheme better, the Parliament of Birmingham entered into cooperation with the Cofely District Energy Ltd to establish the Birmingham District Energy Company in 2007, in the hope of fuelling the private sector's enthusiasm in investment and fulfilling the area's low carbon growth goals. The Broad Street project under the scheme can ensure an annual reduction of 4,000 tonne carbon dioxide. In addition, the energy conservation projects at Ashton University and Birmingham Children's Hospital have been started in 2009 and 2010, respectively.

Box 2.4: Construction of the Eco-friendly Sports Stadium in Nice, France

The eco-friendly sports stadium project in Nice, France, required a whole cycle of work—design, financing, construction, use and maintenance, etc. The project aims to build a self-sufficient sports stadium where the balance of energy supply and consumption are in positive numbers. As an important element of the overall sustainable development goals of Nice, the stadium uses a large quantity of wood structures and a unique ventilation design relying on natural wind. Although the project was hard to execute under the traditional financing models, it succeeded under the PPP form of financing, where the public and private sectors signed a 30-year long contract. The preliminary cost was relatively high, but considering the relatively long term of recovery, the investors of the project took energy conservation into consideration in the overall planning and design in an effort to ensure a stable return in the long run.

Private Grants

Different from loans, grants normally do not aim at returns, but are generally used to support development of public goods. The sources of grants include domestic (individuals and organizations) and international (bilateral and multilateral banks, individuals or enterprises, and foreign governments) donations. In China however, an absolute majority of the grants comes from international donations. Grants can effectively drive implementation of the projects which are conducive to development of the low carbon economy and the public (infrastructure) facilities, and is a primary source of finance for local governments.

Table 2.9 Summary of Cities Employing the PPP Form of Financing

Sectors	Cities	Countries
Public biking system	Paris	France
	Lyon	France
	London	The UK
	Barcelona	Spain
	Seville	Spain
	Oslo	Norway
	Stockholm	Sweden
	Brussels	Belgium
	Dublin	Ireland
	Berlin	Germany
Architectural energy conservation	London	The UK
	Paris	France
Waste disposal	Sydney	Australia
	Gothenburg	Sweden

Source C40 Best Practices Projects. Available at http://c40.org/home

Charities and related NGOs have also provided a part of the climate fund, which comes from private donors and enterprises in the form of charitable foundations' donation, corporate social responsibility initiatives, NGO activities, etc. Philanthropy in developed countries is relatively sounder; the size of donation and the number of charitable organizations there are both far bigger, relatively speaking. A considerable number of organizations are concerned about climate change; this can be corroborated by existing statistical data in this respect. For instance, according to an estimate of the California Environmental Associates, foundations in America provide around 21 million US dollars for projects in relation to climate change every year (CEA 2007).

Domestic grant generally comes from the private sector's donation. Private donation can further constitute an important source of fund for the local governments' low carbon financing. The philanthropy in China in relation to climate change has just begun and its fund is generated mainly from donations by enterprises, social groups, and individuals, through which money is channelled into the climate change area in the form of green public offering of funds and corporate social liability initiatives, etc. The green public funds of China include China Green Foundation and China Green Carbon Foundation, etc. The sources of these funds' capital are mainly the donation by naturalized persons, legal persons or other organizations at home and abroad, governmental funding and value increase of the funds themselves. According to estimates by China Charity and Donation Information Center, the total donation in kind and currency accepted by China within its homeland and abroad amounted to about RMB 84.5 billion in 2011, with 4.62 per cent of the donation streaming into the eco-environment field.[8] However, enterprises are the key force in the philanthropy of China, with private enterprises making the greatest contribution. The China Green Foundation enjoyed total revenue of RMB 324 million in 2011, with RMB 315 million coming in the form of grants.[9]

Some countries give tax advantages (income tax) to enterprises or individuals for their grants made to low carbon growth in their area. From the donators' point of view, to spend part of their income in the form of donation, enables them to pay less income tax and therefore spend less in comparison with the circumstance where they do not donate (that is to say, their spending when they do not donate would be greater than the sum of the income tax and the grant when they donate). We recommend that China gives 100 per cent or even a higher rate of tax advantage to individuals or enterprises who give grants to the low carbon growth area, in an effort to fuel the enthusiasm of donation in the private sector.

2.4.2 Carbon Financial Instruments[10]

International Carbon Market

At present, the CDM market is the main mode and source through which we have access to capital in the international carbon market. The international carbon market used to play a very active role in promoting flow of social capital into low carbon projects. However, affected by the recent international economic situation and adjustments of the CDM mechanism, the international carbon market is very sluggish. After 2012—as an alternative for the CDM mechanism has not yet been determined—the financial flows in the

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[8] Beijing News,'Giving China 2011: Per Capita Donation in China Stands at Only 62.7 Yuan', June 2012. Available at http://news.anhuinews.com/system/2012/06/29/005050344.shtml

[9] China Green Foundation, 2011 and 2012 Audit Report. Available at http://www.cgf.org.cn/jiandu/

[10] Section 4.2 is mainly based on information from websites of major carbon exchanges, such as Lanhong, carbon finance and business innovation, 2012; TuYongqian, Carbon Finance Laws Recreation, extracted from 3rd edition, 2012

international carbon market provided to developing countries may be substantially reduced. However, for China, the international carbon market remains significant, because China is an important participant in the CDM market and the largest carbon credit provider. Although the scale of financing that the international carbon market could now provide for China to develop the low carbon economy is a drop in the bucket compared to its fund demand, yet the role of the CDM is not only to provide climate funds for China, but also to facilitate smooth development of infrastructures necessary for developing its domestic carbon market.

Domestic Carbon Market

The domestic carbon market, as a market-based means, is of great significance in raising low carbon development funds for the local governments, forming long-term emission reduction mechanism, and encouraging enterprises to participate in carbon emission reduction.

With positive actions by the Chinese government and support from the international community, the National Development and Reform Commission issued a notice at the end of October 2011, allowing Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong, and Shenzhen, to carry out carbon emissions trading pilot projects. The pilot projects are actively exploring the mode for development of the carbon market, but are all at a preliminary stage. Beijing, Shanghai, and Guangdong launched their carbon emissions trading pilot projects on March 28, 2012, August 16, 2012, and September 11, 2012, respectively.

Fiscal revenue from auction of carbon emissions quota can be used as a significant source of funding for local governments and the central government to develop a low carbon economy. However, as shown in Box 2.5, these policies tend to take some time for adaptation and transition, and will not bring significant fiscal revenue in the early stages of implementation. Nevertheless, local governments and the Central government should also have early consultations on use of the fiscal revenue from auction of carbon emission quota so as to determine allocation, management, and use of the revenue while pushing forward the development of the carbon market piloting projects.

Box 2.5: Auction of Carbon Emissions Quota

The EU ETS mechanism has covered the energy sector as well as high carbon-intensity industrial enterprises. The annual carbon dioxide emissions from these two sectors account for about half of all carbon dioxide emissions in the EU and 40 per cent of all EU greenhouse gas emissions (carbon dioxide equivalent). Since its official launch in 2005, the EU carbon trading system has gone through adaptation in the first phase (2005–07) and is in the second phase (2008–12) featuring explorations and improvements. Beginning from the third phase, EU ETS will fully strengthen and make unified use of the carbon emissions quota auction mechanism and strive for reducing EU carbon dioxide emissions by 21 per cent by 2020 compared to the level in 2005. In addition to the EU carbon trading system, existing carbon trading systems or carbon trading systems planned to be launched in the near future have also adopted a certain degree of auction. For example, the Regional Greenhouse Gas Initiative (RGGI) adopted the 100 per cent quota auction at its most initial stage; Western Climate Initiative (WCI) adopted auction of at least 10 per cent of the carbon quota; New Zealand carbon trading system, as a whole, took the form of auction and provided free quotas for industrial sectors which may have carbon leakage; the carbon trading system that Australia plans to implement in 2015 also stands ready to give priority to auction of carbon quotas and distributes free emissions quota to high energy-consumption industries.

The domestic carbon market in China is expected to provide an impetus to domestic enterprises' emission reduction actions in the future. Also, since enterprises are actively involved in energy conservation and emission reduction activities, resources used by the local governments for energy conservation and emission reduction are reduced to a certain degree; as a result, the additional source of resources for local governments to spend on other areas of the low carbon economy is guaranteed. In addition, positive development of voluntary emission reduction can generate CCERs for carbon market transaction on the one hand, and promote transformation and upgrading of local infrastructures and industrial construction technologies on the other hand, thus, contributing to the development of local low carbon economy and serving as a substitute for fiscal expenditure of local governments.

Other Market-based Innovations

China's financial market is not mature as a whole. Its carbon financial market has just begun. Therefore, the government needs to learn from international experience to encourage developments of carbon financial products. At the current stage, the four continents of the world have had their own hallmark carbon exchanges. Exchanges from emerging markets such as India and Brazil have much earlier introduced financial derivatives such as carbon futures and carbon options. The internationally typical carbon financial trading tools include carbon forward transactions, carbon options, carbon futures, and securitized carbon financial products. Table 2.10 depicts the emissions trading and carbon financial products in Europe, America, Australia, and Asia.

Table 2.10 Major Foreign Emissions Trading and Carbon Financial Products

Regions	Name	Carbon finance
Europe	European Climate Exchange (ECX)	Future option products of EUA, ERU and CER forward
	European Energy Exchange (EEX)	Electric available goods, Electricity, EUAs
	Nord Pool (NP)	Electricity, EUA, CER
	BlueNext Exchange	Available products and derivatives from EUA and CER
	Climex Exchange	EUAs, CERs, VERs, ERUs and AAUs
America	Green Exchange	EUAS, CERs, RGGI, SO_2 and NO_x quota and California Carbon Emission Quota CCAS, in addition there is the VER/VCU, RECs
	Chicago Climate Exchange (CCX)	Six kinds of greenhouses offset project trade credit of North America Brazil
	Chicago Climate Futures Exchange (CCFE)	Future contract of standard and settle accounts of discarded discharge quota and other environmental products
Australia and Asia	Australian Climate Exchange (ACX)	CERs, VERs, RECs
	Australian Securities Exchange (ASX)	RECs
	Australian Financial and Energy Exchange (FEX)	Environment, etc., exchange products and over-the-counter services
	Singapore Mercantile Exchange (SMX)	
	Singapore Asia Carbon Exchange (ACX-change)	Long-term contract of carbon credit future goods and share options or the already signed and issued CERs or VERs (voluntary emissions reduction) auction
	Multi Commodity Exchange of India (MCX)	Two carbon trade credit carbon product contracts: CERs and CFIs (Carbon Financial Instruments)
	National Multi Commodity Exchange of India Ltd	CERs

Carbon forward transaction means that a contract is signed on a carbon emission reduction project (such as a CDM project) before the project is launched to stipulate future carbon emissions trading price, quantity, and time. There are two pricing modes, namely, fixed pricing and floating pricing. Fixed pricing means that the carbon emissions right has a fixed price for the future closing which does not fluctuate with the market. The floating pricing consists of the base price and the EU reference price and is based on the lowest floor price, plus a floating price pegged to the quota price. As far as the CDM projects China participates in are concerned, most of the signed CER forward contracts stipulate a locked price. Although this avoids the risk of price fluctuations, it loses out on shared profits when prices go up in the international market.

Table 2.11 provides a brief description of the major international options and futures products. Carbon futures means buying futures contracts to replace carbon credits (such as EUA) on the spot market so as to hedge EUA price against inflation to achieve the purpose of avoiding and transferring price risks. Therefore, carbon futures have the function of price discovery. In the global carbon market, carbon spot trading accounts for a very small proportion, the futures represent the mainstream. In the carbon futures trading, management fees, transaction fees, and clearing fees are generally charged.

Table 2.11 Major International Options and Futures Products and Their Features

Products	Characteristic Description
ECX CFI	The ICE Futures Europe ECX Futures Contracts (ICE ECX Futures) are designed to facilitate the trading, risk management, hedging and physical delivery of emission allowances in the EU ETS.
EUA Futures	This product was uniformly formulated by the European Energy Exchange that carries out centralized business. It is the standardized contract that stipulates that in the future, at a set time and place, the quality and amount of the carbon emission index shall be handed over. The price shall be reached through in-house open price bidding by the Exchange.
CER Futures	Can avoid the CER price substantial fluctuation risk.
EUA Options	Entrust the holder/buyer with rights to the selected performance of this contract within the shared option by or before the due date, and buyer/seller with the obligation of fulfilling the contract.
CER Options	Achieve call option or put option value through CDM.

Carbon options are the carbon-derivative trading tools developed on the basis of carbon futures. Take CER options as an example; when the CER prices are expected to go up, the CER sellers will buy call options to hedge against the risk of future price increases. If future CER prices go down, CER sellers will gain benefits by exercising the call option.

On the contrary, when the future CER prices are expected to fall, the seller will buy put options to lock-in profits.

Securitization of carbon financial assets means that investment banks or other financial institutions put carbon assets into a carbon assets pool. This is then utilized for cash flow generation by using carbon assets pool as a guarantee to issue securities in the financial markets for raising funds. The respective assets in the assets pool could consist of CDM projects, carbon emission right pledge loans from commercial banks, finance lease of carbon emission right, corporate payments receivables related to carbon emission, and bank profiteering. Securitization of carbon financial assets has improved the liquidity of the carbon assets and transferred risks, thus being conducive to the development of the carbon financial derivatives market.

With increase in the world's carbon emissions trading, major trading countries will establish the emissions trading system one after another. China should also actively develop a carbon derivatives market, and use diversified modes of the derivatives market to provide better services for trading in the carbon financial market. At the current stage, although China has established a number of carbon emission right exchanges and a number of carbon futures exchanges, carbon derivative financial instruments suited to China's market have not yet been developed. The carbon financial services provided by financial institutions in China are now mainly focusing on consulting, carbon emission right purchase agents, and transaction settlement.

2.4.3 Innovation of Traditional Financial Market Instruments

China's financial industry is still in the early stages of development and its credit market is the most important source of funding for enterprises in the country. However, in the field of climate financing, the role of the traditional financial markets has not yet been fully played, and climate-related projects are not the most popular areas for investment. Although the China Banking Regulatory Commission has vigorously promoted green credit, green loans still account for only an insignificant proportion of total lending. Having said this, however, it is important to note that the debt-financing and equity-financing market is developing rapidly, although still relatively small. In many cases, the development of an urban low carbon economy still faces difficulties in seeking financing from the traditional financial markets. To promote the provision of more climate funds by traditional financial markets, we must rely on clear investment signals, complete policies, improved vigour and vitality of financial intermediaries, and innovations in financial instruments. This section is dedicated to analysing how traditional financial market instruments could more effectively provide financial support for local governments to develop low carbon economy.

Traditional Credit

At present, bank loans are the main financing channels for Chinese enterprises with the loan balance of financial institutions in 2011 standing at RMB 54.8 trillion. In the credit market, banks actively strengthen credit support for an energy-saving and low carbon economy, as well as environmental protection. The number of energy-saving and environmental protection projects supported by the banking sector in 2011 registered a year-on-year growth of 28.79 per cent (loan balance for these projects grew by 25.24 per cent) and loans for strategic emerging industries stood at RMB 363.46 billion, recording an increase of 36.5 per cent (Yang 2011). The increase in the loan balance of 2011 in the banking financial institutions for energy saving and environmental protection was greater compared to that of 2010, surpassing the increase of loan balance of the previous year (as shown in Figure 2.7). By the end of 2011, the relevant loan balance of six financial institutions including the National Development Bank, Industrial and Commercial Bank of China, Agricultural Bank of China, Bank of China, China Construction Bank, and Bank of Communications stood at more than RMB 1.9 trillion. According to statistics, loans for energy-saving and environmental protection projects by financial institutions in 2009 stood at RMB 856 billion, accounting for

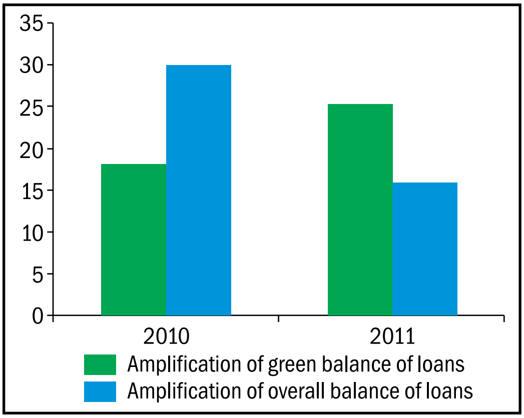

Figure 2.7 Increase of Green Loan Balance and Total Loan Balance of Financial Institutions (2010–11)
Source Financial Statistical Report of the People's Bank of China; China Banking Association's Annual Social Responsibility Report of China Banking Industry

8.93 per cent of total loans. From the above data, we can see that although loans in the field of energy saving and environmental protection increase rapidly, compared to the traditional industries, loans for energy saving and environmental protection projects and low carbon industries still account for a small proportion.

However, due to non-uniform definition and statistics, total green credit (or energy saving and environmental protection loans) still has no public statistics. Although the Social Responsibility Report of China Banking Industry released by the China Banking Association disclosed incomplete statistics of credit or credit balance for energy saving and environmental protection in recent years, yet the disclosed data from 2006 to 2009 and that from 2010 to 2011 are in different names (transformed from 'credit volume' to 'credit balance'), resulting in incomparability of data from different years.

There have been some innovative products for green credit to provide financing for urban low carbon development projects.

Fixed asset loans for energy saving and emission reduction refer to loans granted by the banks for investment in fixed assets of energy-saving and emission reduction projects, including energy efficiency improvement projects, new energy and renewable energy projects, sewage treatment and water treatment projects, desulfurization and de-nitrification projects, solid waste disposal project, energy-saving and emission reduction equipment production projects (Box 2.6). These loans serve clear purposes, belong to the field of energy saving and emission reduction, and conform to the 'Green Credit Guidelines' of the China Banking Regulatory Commission.

Box 2.6: Fixed Assets Loans for Energy Saving and Emission Reduction by Industrial Bank

The Industrial Bank has summarized the risks that all kinds of fixed assets loan projects for energy saving and emission reduction should focus on. For professional service projects on energy conservation and emission reduction, banks should focus on whether the technical maturity, completeness of service contracts for energy conservation and emission reduction, and the total project cost and benefit allocation proportion are in line with market conditions. For resource recycling projects, banks should focus on market risks in terms of raw materials supply of wastes, technical maturity, and commercial operation conditions for comprehensive utilization of resources, product quality and distribution channels, etc. For exclusive production projects for energy saving and environmental protection, banks should focus on avoiding blind investment due to operations according to market concept, which leads to the risk of overcapacity.

In the process of implementing the street lamp reconstruction project of Chang'an Town, Dongguan, in Guangdong Province, the contractor of the project, a trade company with limited liability, needed to purchase in bulk electricity-saving appliances from an enterprise in Shenzhen. The contractor lacked procurement funds, and thus could not carry out the bulk purchases. By adopting the buyer credit mode, the Industrial Bank issued the energy-saving equipment manufacturer a special buyer credit line with the contractor as the borrower. The loan was earmarked for purchasing the electricity-saving appliances. The maximum loan period was not to exceed three years. The energy-saving equipment manufacturer was responsible for a variety of after-sales services and provide equipment repurchase guarantee during the repayment period. This did not only support the client in its efforts to expand sales capacity but also improved the economic benefits of the contractor and the local environmental quality.

Business processes of the fixed asset loans for energy saving and emission reduction include business acceptance, due diligence, professional accreditation, review and approval, contract signing, loans issuance, after-loan management, etc. Though the energy saving and environmental protection industry is one which enjoys strong government support, risk assessment and control is also very critical. According to the experience of the Industrial Bank, for professional service projects for energy conservation and emission reduction, banks should focus on whether the technical maturity, completeness of service contracts for energy conservation and emission reduction and the total project cost, and benefit allocation proportion are in line with market conditions. For resource recycling projects, banks should focus on market risks in terms of raw materials supply, technical maturity and commercial operation conditions for comprehensive utilization of resources, product quality and distribution channels, etc. For exclusive production projects for energy saving and environmental protection, banks should focus on avoiding blind investment due to operations according to market concept, which leads to the risk of overcapacity of exclusive products related to energy conservation and environmental protection.

Working capital loans for energy saving and emission reduction refers to loans issued by banks for operation and working capital turnover of energy saving and emission reduction projects (Box 2.7). The product differs from fixed asset loans for energy saving and emission reduction in the use of the loans, namely that the loan is used to invest in fixed assets or used to support liquidity.

Box 2.7: Working Capital Loans for Energy Saving and Emission Reduction by the Industrial Bank

A Shandong soda ash producer had a production capacity of 2.2 million tonnes of soda ash and 420,000 tonnes of calcium chloride. The producer employed a limestone vertical lime kiln to produce quicklime, and then make the quicklime react with water to generate calcium hydroxide. The calcination process not only consumed a lot of coke and electricity, but also generated a lot of carbon dioxide and calcium carbide sludge as the by-product. The producer wished to improve the original soda ash production process by using its independently developed ammonia alkali method for the soda ash preparation process by taking calcium carbide sludge and carbon dioxide as the main raw material. The project could produce 400,000 tonnes of soda ash and recycle the calcium carbide sludge and carbon dioxide it generated. The implementation of the project was short of funds and needed medium-and long-term financing matched with the payback period of the project and timely access to new production line for starting production. The Industrial Bank provided the producer a five-year project loan matched with the cash flow structure of the project, which was earmarked to support the project. After completion, the project achieved comprehensive utilization of 3.29 million cubic metres of calcium carbide sludge, saved 115,000 tonnes of standard coal, and reduced 31.6 tonnes of carbon dioxide emissions. This not only prevented pollution from the piling up of calcium carbide sludge, but also achieved reduction in greenhouse gas emissions and environmentally friendly disposal of solid wastes.

Contractual energy management financing means that energy-conservation service companies apply to banks for financing construction and operation of contractual energy management projects, use their shared energy-conservation benefits as the primary source of repayment, and pledge future project income or employ other guarantee types (Box 2.8).

Box 2.8: Contractual Energy Management Financing Model of Tianjin Climate Exchange

Tianjin Climate Exchange established the six contractual energy management financing modes on a pilot basis. These are (i) guarantee insurance, energy-saving project factoring, income buyout, mortgage financing, financing leasing and trust scheme'.

Guarantee insurance refers to the insurance that insurance companies provide to fund providers of contractual energy management projects for after-the-contract energy management project risk assessment. The insurance provider contracts energy management project funds for energy-conservation service companies after assessing risks of the project. The subject matter of the insurance includes technical risks, operational risks, and credit risks of contractual energy management projects. If the energy service companies cause economic losses to the fund provider due to their acts or omissions, the insurance companies shall be liable for the economic losses.

Energy-saving projects factoring refers to establishing a contractual relationship among energy-using units, energy-conservation service companies, and financing banks. Under the contract, the energy-using units and energy-conservation service companies transfer present or future receivables arising from the energy management contracts to the banks. At the same time, the banks provide services including project financing, sales sub-account management, accounts receivable collection, credit risk control, bad debt guarantees, etc.

Income buyout means that fund providers acquire the earnings resulting from the contractual energy management project during the energy-conservation sharing period from the energy-conservation service companies. The energy-conservation service companies achieve discounted future income by transferring the right to earnings of the project. After the income buyout, the energy-conservation service companies still need to fulfil obligations including maintenance and training according to the energy management contract. At the same time, the energy-conservation service companies need to make compensations when the future energy-saving benefits do not meet the contracted value according to the income buyout contract.

Mortgage refers to loans the energy-conservation service companies have gained by mortgaging equipment and energy-saving technologies for projects. As a traditional financing mode, the scope of collaterals for mortgage in contractual energy management projects is innovated, taking energy-saving benefits as a kind of collateral. In case of maturity of the loan, the energy-conservation service companies must repay the loan in total, or the bank has the right to dispose of the collateral as compensation.

Finance lease means that the energy-conservation service companies rent their invested equipment for contractual energy management projects from the financial leasing companies, and pay the equipment rental fees by energy-saving benefits within the energy-conservation service period. When the energy-conservation service companies have repaid the total price of the equipment within the energy-conservation service period, the financial leasing companies shall transfer the ownership of such equipment to the energy-conservation service companies. Finance leases can help save equipment funds for contractual energy management projects when developing the projects.

Trust plan means that trust companies use large-scale contractual energy management projects or similar project portfolios as the future source of revenue and launch trust products for trust plan client groups. The raised funds are used for the development, operation, and maintenance of contractual energy management projects; energy-saving benefits of the projects shall be shared between the energy service companies and clients.

The six financing modes are explorations and innovations that the Tianjin Climate Exchange has made on contractual energy management project financing and have corresponding demonstration projects.

Carbon Assets Pledge Credit Service

Under the carbon assets pledge credit service, commercial banks provide credit to applicants with carbon assets owned by the applicants as pledge. When the owners have registered CDM projects, commercial banks can accept CER mortgage and provide short-term liquidity loans to owners (see Box 2.9 for an example). The service cannot only help enterprises make good use of future carbon assets, but can also assess the value of the carbon assets of the project through bank professionals, help enterprises improve operation and management efficiency of the CDM project, and increase missions reductions. However, there are some uncertainties about carbon assets and value of future carbon assets is difficult to assess. Therefore, banks run high risks in carrying out this service, and it is rare to see services purely with future carbon assets as mortgage to gain credit.

Box 2.9: Carbon Assets Pledge Guarantee Credit Service

The first credit service purely with carbon assets as pledge guarantee (free from other guarantee conditions) was provided by the Industrial Bank in April 2011 for Xingyuan Hydroelectric Ltd in Minhou County, Fuzhou City. The 20 MW small hydropower project run by the company was registered in the United Nations as a CDM project in June 2010; it is expected that the annual emission reductions stands at 43,600 tonnes. The company signed an emission reduction purchase agreement with the Sweden Carbon Assets Management Co., Ltd. and is expected to receive an income from carbon sale annually. To make good use of future carbon assets, have access to funds for optimizing operation, and management of the small hydropower project to increase future emission reductions, the company applied to the Industrial Bank for carbon assets pledge and used income from carbon revenues as the collateral.

International Carbon Factoring Service

The service means that banks sign a contract with seller enterprises; the seller enterprises transfer receivables resulting from transaction carried out in the form of credit sale to the banks, and the banks provide comprehensive financial services for the seller enterprises—including financing, receivables management, receivables collection, and credit risk guarantees (Figure 2.8). The core of factoring service lies in the transfer of receivables. For those CDM project development enterprises with issued CERs, the CERs income rights in their hands can be seen as receivables. If banks or other financial institutions could provide for CDM project development enterprises, a factoring financing with recourse, and the CDM project development enterprises sell CERs earning rights to the banks, then they can receive payment of the receivables in advance (see Box 2.10 for an example).

Local governments could make use of the credit markets and innovative credit instruments such as financing channels for the development of a low carbon economy in a number of ways. First of all, local governments can consider providing government guarantees for low carbon projects in order to reduce project risks and increase the capacity for securing loans. Second, local governments could cooperate

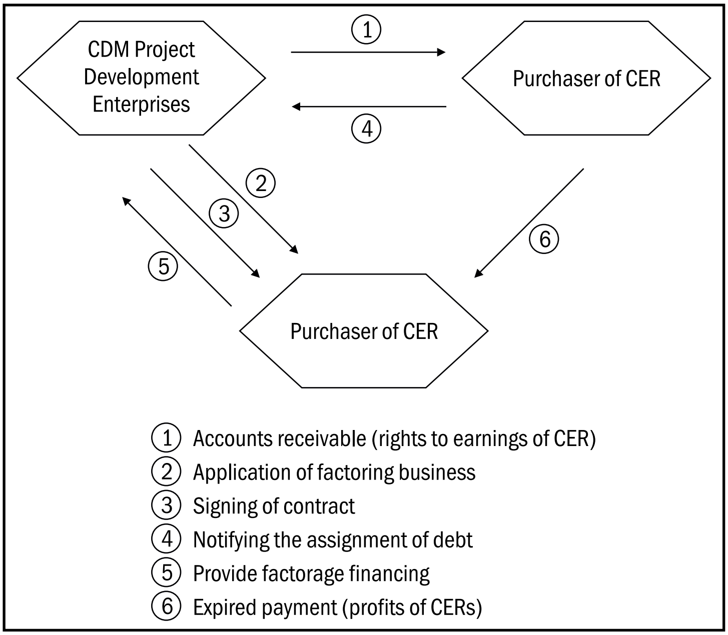

Figure 2.8 Carbon Factoring Business Process

with local bank credit systems to provide financing for local low carbon projects. Third, local governments could consider the PPP mode as described previously, together with cooperation from the local bank credit system, thereby, increasing the capacity of the bank credit system of the central government to obtain loans. Finally, while the nation is actively developing green credit, local governments can have a try at implementing green credit policies with national or local bank credit institutions on a pilot basis, to encourage the application of innovative green credit products. It is suggested that successful cases of banks (for instance, the Industrial Bank) positively engage in low carbon development activities and extend green credit, so as to support local investment projects while enjoying the local government guarantees.

Box 2.10: International Carbon Factoring Financing by Shanghai Pudong Development Bank

Shanghai Pudong Development Bank provided international carbon factoring financing service for the hydropower project registered in United Nations with the largest domestic installed capacity (200,000 kilowatts) and the largest single-unit carbon emission reduction. The bank has developed a system based on international carbon (CDM) factoring financing. The system includes special project financing [International Finance Corporation (IFC) energy efficiency loans, AFD green intermediate credit] through an international carbon (CDM) trading financial adviser, international carbon (CDM) factoring or international carbon asset pledge financing using international carbon (CDM) settlement products, etc., to maintain its leading position in the domestic commercial banks.

Bonds

In the field of green and low carbon economic development, climate bonds cannot only become an important source of climate change financing, but also serve as a tool for investors in the low carbon field to avoid policy risks. The bonds are particularly suitable for providing long-term capital support for construction of infrastructure to cope with climate change, and play an important role in the climate field. Theoretically, climate bonds can be of various types. Although early-stage incremental investments are huge, cost recovery can be achieved during the infrastructure operation period, particularly in construction, energy, industrial, and transport sectors. It is estimated that from 2010 to 2020, global cumulative investments of about USD 10 trillion will be required to promote the development of low carbon energy. According to the 6:4 ratio between debt and equity in previous financing cases, it takes about USD 6 trillion in bank loans or bonds.

Enterprise (company) bond market has gradually become one of the sources for urban and local developments. Green bonds reached USD 6 billion in 2011, accounting for about 3 per cent of the total size of the 'green bonds', among which, the financing scale of new energy enterprises by issue bonds increased by four times, reaching USD 4.3 billion (accounting for 72 per cent); the rest are mainly concentrated in the transportation industry. Currently, the feasibility of China's local governments to issue bonds is not high, but the local government can support local enterprises engaged in the field of low carbon economy to issue bonds, and use government guarantees and other incentives to reduce interest rate of the bonds, thereby reducing the cost of corporate financing. Good corporate financing and investments in the field of low carbon development can generate a certain degree of substitution effect, saving part of the expenditures for local governments to support the development of low carbon economy.

Option Tools

China's venture capital and private equity (VC/PE) market has witnessed rapid developments in recent years, as enterprises related to climate change and low carbon technologies enterprises tend to be start-ups or SMEs, making VC/PE markets a very critical source for climate funding. In 2011, the VC/PE total investment in clean technologies stood at USD 1.72 billion, witnessing some increase compared with USD 1.27 billion in 2010, but this was mainly because of the overall rapid development of the VC/PE market from 2010 to 2011. In fact, the clean technology industry accounts for 4.25 per cent in all areas of investment, a decline from 8 per cent in 2010.[11] In the clean energy industry, there are only three disclosed financing cases in the first half of 2012 with a total financing of USD 28.7 million, a sharp year-on-year decrease of 81 per cent and 95 per cent, respectively, in terms of both number of cases and financing amount.[12]

In the stock market, only four companies went public in the domestic capital market in 2011, raising USD 3.68 billion. Although there were fewer companies which got listed compared with 2010 (seven companies got listed), the scale of financing has increased by 41 per cent.[13] Since 2012, some clean technology industries have not been optimistic in the capital markets as a result of production overcapacity, shrinking international market, and other factors. According to statistics from China Venture, in the first half of 2012, a total of five enterprises in the clean energy industry succeeded in initial public offering (IPO) in the global capital market with a total financing amount of USD 99,800,000, a year-on-year sharp decrease of 17 per cent and 65 per cent, respectively, in terms of both number of cases and financing amount. At the same time, it frequently occurs that the IPO of new energy enterprises, especially solar energy companies, get stranded.[14]

As it is true for corporate bonds, enterprises in the low carbon industry are often in infancy in terms of development of a business or an industry and there are high uncertainties and risks on investment returns. Local governments should support local green enterprises to go public and support financing modes such as local private equity. Success of the enterprise in going public will not only improve corporate profitability and generate additional fiscal revenue for local governments, but also generate a certain degree of substitution effect and save a certain degree of local government expenditures in the field of low carbon economy.

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12 ChinaVenture.Availablefromhttp://report.chinaventure.com.cn/r/f/606.aspx

13 Qingke Research Center, 2012.2011 Annual Research Reporton IPO of Chinese Enterprises. Available at http://www.zero2ipogroup.com/research/reportdetails.aspx?r=97ca0fd5-a904-426c-b217-7148682bbf2c

14 ChinaVenture.Availablefromhttp://report.chinaventure.com.cn/r/f/606.aspx

Risk Management Tools

Agricultural insurance, weather index insurance, clean technology insurance, and catastrophe insurance are mature hedging instruments that the international insurance industry has developed for climate financing. Risk management services for sectors related to low carbon economy investments could effectively reduce risks of low carbon investments to attract more private funds, generate the substitution effect, and bring extra funds for local governments to support the development of low carbon economy. For example, as clean energy technologies have not been tested by the market, there is the need to seek channels for risk transfer. Current practices in the field of clean technology insurance include a series of insurance products that Munich Reinsurance Group has launched for clean energy technologies (Box 2.11). Local governments can cooperate with insurance companies to jointly provide risk guarantees or insurance services for low carbon projects or investment.

Box 2.11: Clean Energy Technology Insurance Solutions by Munich Reinsurance

Clean energy technology insurance solutions by Munich Reinsurance involve a variety of products that may affect clean energy projects, such as solar module performance insurance, possible loss insurances for wind and power plants, performance insurance for products (such as lithium ion batteries, concentrated solar power generation, LED, heat-protecting glass, etc.), insurance for hydropower plants, etc. These insurance products can free clean technology equipment manufacturers and developers from measurable and predictable losses resulting from product performance or objective conditions. For example, Munich Reinsurance can provide insurance to manufacturers who have insured PV module products and photovoltaic power plants with a production capacity of more than 20 MW. Such an insurance product ensures that investors can maintain a stable cash flow in the event that products operation runs worse than expectations. When providing manufacturers with product performance insurance, Munich Reinsurance has set requirements on a number of indicators, including technical performance, manufacturing process stability, and monitoring and auditing procedures for the manufacturing process. In September 2011, Ping An Insurance and Munich Reinsurance signed a cooperation agreement to jointly provide insurance solutions for the renewable energy industry in China.

In 2011, Munich Reinsurance once provided a performance guarantee solution for PV modules of Eco Supplies Solar AB, a Sweden PV manufacturing supplier. When its PV modules could not achieve the expected output power, a 25-year compensation payment was provided; at the same time, the agreement also guaranteed that solar modules should reach 90 per cent of output power in the first 10 years and 80 per cent of the output power in the rest of the 15 years. In December 2012, Yingli Green Energy signed the components quality guarantee insurance agreement with a dedicated insurance corporation under Munich Reinsurance. This agreement covered the polycrystalline silicon components sold during the period from October 1, 2012 to September 30, 2013.

2.5 International Financing

Developed countries offer funds to developing countries against climate changes from a public budget, which is the representation of 'common but differentiated responsibilities'. It is estimated that in 2011, about USD 97 billion was transferred from the developed countries into developing countries, of which USD 21 billion was provided from the public budget of developed countries, accounting for nearly 22 per cent. Such an amount of capital was offered to the developing countries including China by a capital mechanism under the conventional multilateral channels and bilateral channels. According to the statistics acquired at present, Asia has accepted the most capital from developed countries. In 2009–10, 40 per cent of climate fund was transferred by multilateral financial institutions and 26 per cent from bilateral financial institutions went to Asia; however, there is no definite amount of the total capital flowing into China.

At present, although some institutions have presented certain statistics on China's acceptance of climate funds from developed countries, it is difficult to make an accurate estimation on the overall capital scale due to different statistical calibres, and there is no accurate, complete, and full statistical data on local governments' acceptance of international capital to develop low carbon economies. At the end of 2011, foreign government loans of USD 33.3 billion and loans from international financial institutions of USD 35 billion were used in China. The State Administration of Foreign Exchange and the Department of Foreign Capital and Overseas Investment of National Development and Reform Commission have presented some statistics on China using capital from multilateral and bilateral financial institutions from different perspectives; however, there is no disclosed statistics data on the amount of capital involved in climate change programmes. According to the Twelfth Five-Year Plan, in terms of foreign capital and overseas investment, China estimates loans of USD 23.38 billion provided by foreign governments and international financial institutions on favourable terms. Resources obtained from these sources were mainly invested in activities including agriculture, forestry, water, transportation, energy conservation, health, education, and ecological construction during the Eleventh Five-Year Plan period.

As the basic beneficiary of these sectors is the local government and all these sectors constitute the main departments for developing low carbon economy, improving the inflow of international capital is an important aspect for local governments to facilitate low carbon economy financing.

However, at the same time, the outbreak of the American subprime mortgage crisis and the European sovereign debt crisis in 2008 and 2010 caused the European and American countries to implement fiscal tightening measures. The world economy is slowly picking up, which has directly affected the implementation of transfer climate capital to developing countries. Meanwhile, in recent years, with the growth of China's economic strength, developed countries are less willing to offer funds for China's development and many countries have announced cutting of funds for assisting China's development, which would surely affect the supply of international climate funds. How to improve capital utilization efficiency within the limited capital supply is also an important factor for local governments to consider for low carbon development financing.

2.5.1 Key Institutions Providing Financial and Technical Support

Effective international funds that facilitate local governments to develop low carbon economy financing are mainly from multilateral and bilateral institutions. This section will briefly summarize some of the international institutions that have closely cooperated with China.

Bilateral Financial Institutions and Bilateral Banks

Bilateral financial institutions (BFIs) refer to institutions, founded and led by a government. They offer assistance to developing countries or emerging markets or invest in development programmes or plans. They mainly include bilateral development agencies, bilateral banks, bilateral climate funds, and export credit agencies. BFIs are the most important media for transferring international public climate funds and 25 per cent of the world climate capital in 2010 was transferred by BFIs (UNEP 2011). According to the OECD database, from 2006 to 2009, about 18 OECD members had provided financial support to China in the relevant climate change sector by the bilateral channel, accounting for 78 per cent of OECD members providing assistance for China's development. In China, the active bilateral development agencies/ bilateral banks include the French Development Agency (AFD), the Kreditanstaltfür Wiederaufbau (KfW), the Japanese International

Cooperation Agency (JICA), etc. Since its entrance into China in 2004, AFD has supported a large number of programmes relating to climate change through cooperation and offering loans. Up to April 2010, the total investment in China was over 700 million Euros. While offering financial support, AFD attaches great importance to include capacity construction, technical assistance, leveraging private capital for joint financing, etc., in the capital design. Nevertheless, AFD is now offering less and less funds for China in the form of grants. In the climate financing sector, the technical assistance for financial institutions and exploration or licence for innovative financing models has become a more important channel for bilateral cooperation. JICA and KfW have similar mechanisms to carry out programmes; however, they intend to provide less assistance for China's development, which can be shown in the total funds provided, the numbers of programmes developed, and the financing instruments used in recent years. Therefore, China should actively turn to technical communication cooperation and non-assisting loans and make full use of the technologies and funds brought by BFIs.

As the main bilateral institutions have changed their strategy and composition for providing funds for China, the local government should actively strengthen communication and coordination with bilateral institutions so as to jointly study and affirm the feasibility and specific content of joint financing for low carbon programmes. It is suggested that China sets up a state-level platform to facilitate communications between bilateral institutions and local government and inject the additional cost for local governments to facilitate low carbon economy financing.

In additional to bilateral financial institutions, there are a few bilateral funds which support low carbon development programmes. The German International Climate Initiative (ICI) and Japan Fast-start Fund (JFSF) have several programmes, which deal with emission reduction and alleviation, respectively. Among these, ICI has approved 21 programmes from 2008 to 2012 in total, covering a total amount of USD 53 million; JFSF has only supported one programme, covering an amount of USD 20,000. It can be seen that the bilateral climate fund is not an important source of China's climate fund, and China is also not a target of the international bilateral climate fund. Nevertheless, in view of the financial gap in the whole China and the local government in developing a low carbon economy, the local government should strengthen the communication and contact with bilateral funds so as to get more additional funds for developing such an economy.

Multilateral Financial Institutions

Multilateral financial institutions (MFIs) refer to the international financial institutions as founded and led by three or more governments and their members, which not only include the developed countries which donate money, but also include the developing countries which borrow money. MFIs mainly offer loans and grants to developing countries, and provide financing for private sectors by means of creditor's rights, equity, and guarantee. In recent years, they have obtained fruitful achievements in the climate change sector and could lever a part of external capital, in addition to their own investment.

The World Bank (WB) has also actively taken measures against climate changes in 130 countries and obtained a series of achievements. In 2008, WB promulgated the Strategic Framework for Development and Climate Change (SFDCC) and listed the highlights from 2009 to 2011—increasing financing in suitable sectors, facilitating the carbon market development, and promoting the application of climate risk insurance. In 2011, the state support and country partnership strategy plan as approved by WB Group had taken climate change as priority and the International Bank Reconstruction and Development (IBRD), International Financial Corporation (IFC), and Multilateral Investment Guarantee Institution (MIGI) subordinated to WB Group transferred part of international capital to China. By the end of October 2012, IBRD and the International Development Association (IDA) have offered loans to China with the amounts of USD 21.38 billion and USD 10.21 billion, respectively.[15] A part of the funds were invested in renewable resources, urban transportation, urban construction and environment, etc. In addition, WB is also the trustee of the Global Environment Facility (GEF) and cooperates with China in climate financing and technical assistance by GEF. To be specific, in the climate change sector, WB programme database shows that the relevant programmes carried out in China totalled USD 1,352 million (including the programmes where only part of the capital was invested in the climate change sector), and was mainly carried out by IBRD/IDA and GEF.[16]

The local government should also strengthen the cooperation with multilateral financial institutions. In addition to the bilateral financial institutions, multilateral climate fund is also an important

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15 http://data.worldbank.org.cn/country/china#cp_fin

16 World Bank Database.Available at http://web.worldbank.org/external/programs/main?pagePK=217672&piPK=64778441&theSitePK=3535340&menuPK=3535699&category=regcountries&regioncode=3&countrycode=CN&sortby=PROGRAM_NAME&sortorder=ASC

channel for climate capital transfer who is mainly from the grants of the countries, international tax revenue, loan, fund from capital market and charitable donation, etc. At present, the multilateral fund winning greatest concern is the capital mechanism under the United Nations Framework Convention on Climate Change (UNFCCC), mainly including the Global Environmental Facility (GEF), Adaptation Fund (AF), and Green Climate Fund (GCF). Besides, the agencies of the United Nations, multilateral development banks, the EU, and some bilateral institutions have also set up climate funds. However, on the whole, the multiple climate funds supporting China's climate change programme are mainly GEF and the Special Climate Change Fund (SCCF) that have supported a few programmes. The other multilateral funds have not carried out any programmes in China. In the future, China should more actively participate in the negotiation with multilateral climate funds, in particular, the GCF that will play an important role in the future. It is suggested that the Central government should set up a joint coordinated mechanism with local governments to promote communication between the local governments and multilateral funds and create more financial channels for the local governments.

2.5.2 Grant

Grants are also important instruments for international institutions adopted to support China's climate change programmes, in particular, the technical assistance and competency construction programmes. For instance, the 'Provincial Energy Efficiency Development Program' of WB/GEF with a grant amount of USD 13.4 million is jointly carried out by Shanxi, Shandong, and Jiangxi. The three provinces shall carry out the study on energy-saving supervision and monitoring system, energy information scheduling supervision and data processing analysis system, energy-saving technique service system supervision and management system, and energy-efficiency evaluation management system on newly built industrial programmes and energy-saving finance and tax system by using GEF grant. The programme will, by virtue of internationally advanced energy-saving experience and management ideology, improve the competency construction and system study of provincial governmental authorities so that the energy efficiency system, mechanism, experience, technologies, and programmes could be widely accepted and then taken as a model for national energy-saving work.

As for international development financial institutions, grants would always be used with other public fiscal mechanisms so as to lever more private capital. Compared with the traditional sectors, private investors are not enthusiastic about investments in the climate change sector due to its higher risks. Public funds would help the private investment programme to realize the balance between risks and returns by intervention of certain forms. To be specific, such forms may include grant, loans on favourable terms, risk alleviation instruments, insurance, loss sharing or market integration, etc. The leverage rate may reflect the utilization efficiency of public funds from one side. However, there is no uniform calculation method to determine the leverage rate of public funds/mechanism levering private capital. The Great Britain adopts the representation leverage index in climate investment fund (CIFs), equalling to the proportion of CIF investment and investment of other institutions (including the investment of multilateral financial institutions, private institutions, national public fund, non-governmental associations, etc.).

Grants could offer the direct additional fund for low carbon development; nevertheless, the international grant is rather limited, and the assistance to China for facilitating low carbon economy by means of grants is declining; therefore, there is a certain uncertainty and the government cannot regard grants as a source of low carbon economy financing in the medium and long run.

2.5.3 Loans on Favourable Terms

Loans on favourable terms and grants have constituted the main funding sources of international bilateral and multilateral institutions to support the low carbon economy construction and development in China. The report on green product innovation shows that international development financial institutions has offered certain amount of loans on favourable terms—mainly the sovereign loans for China's pollutants discharge reduction programmes. Such loans are characterized by low interest rate, long maturity, and having a grace period.

Box 2.12: Wuhan Government Office Building Energy Saving Renovation Program Implemented by AFD

The Wuhan Government Office Building Energy Saving Renovation Program implemented by AFD is the first programme that supports energy-saving by means of a sovereign loan in China. It is to renovate 30 public buildings in Wuhan, covering a total area of 620,000 m^2. Every year, 15,000 tonnes of CO_2 emission would be reduced. AFD will offer sovereign loans on favourable terms with an amount of 20 million Euros in the form of on-lending from the Ministry of Finance to Wuhan, with an upper interest rate of 5.94 per cent, maturity of 16 years, and a four-year grace period. At the same time, Wuhan municipal government will invest 1 million Euros and offer incentive on taxes, etc.

2.5.4 International Green Credit

Although commercial loans have not shown much interest in the climate change sector, there have been some special green credit products for the carbon emission reduction programme. The green credit as provided by international institutions may offer suitable funds and technique support for development banks and commercial banks in developing countries to help their competency construction, resolve the obstacles in private sector investing in relevant climate sectors, and offer additional sources of finance to local governments. Multilateral and bilateral financial institutions, such as WB, AFD, and others, have carried out a series of cooperation initiatives with the financial institutions in China (UNEP 2011). The provider of green credit helps cooperative banks to formulate their own climate strategy and climate financial asset portfolio and assist them with reducing credit risks, which would in turn promote the financing of private green investment in full compliance with climate friendliness standards and support the enterprise's green investment. The cooperation between international development financial institutions and domestic commercial banks could also help them to discover investment opportunities and select industries with highest returns and encourage clients to invest in the low carbon sector by offering loans. At the same time, development financial institutions could also offer grants for competency construction and technique support to help the banks to carry out green credit business.

Box 2.13: Intermediate Credit Programme under Sino-German Financial Cooperation

As of 1987, multiple intermediate credit programmes have been arranged under Sino-German Financial Cooperation. The Ministry of Finance executes the agreement with KfW and then Chinese banks would be responsible for on-lending. The Export-Import Bank of China acts as the on-lending Chinese bank for energy saving/renewable energy loans under Sino-German Cooperation for International Climate Protection. In 2012, KfW provided new capital with 42 million Euros for carrying out a green intermediate credit programme, which was specially used for supporting the energy saving and emission reduction of small and medium-sized enterprises in China—China Citic Bank and Chang'an Bank were the on-lending banks. At present, the annual interest rate of such loans is 3 per cent, with a maturity of 12 years, including a three-year grace period.[17]

[17] For details, refer to the Ministry of Finance website available at http://wzs.ndrc.gov.cn/gwdk/wgzfdkgbxx/t20110422_407371.htm

Among these, IFC has begun to explore cooperation with local governments in energy efficiency financing on the basis that the China Utility-Based Energy Efficiency Finance Program (CHUEE), developed by the International Financial Corporation (IFC), has achieved success at an earlier stage, so as to popularize the practice of promoting energy efficiency financing by adopting risk sharing facility in more areas. In 2011, IFC executed the memorandum of understanding on energy saving and emission reduction financing programme with the Hongzhou municipal government to set up risk-sharing mechanisms so as to support renewable resources, water resource utilization and clean technology application, etc. At the end of 2012, IFC initiated CHUEE (China Utility Based Energy Efficiency Finance) Jiangsu Program with the cooperation of Clean Fund (International Department of Ministry of Finance, Finance Department of Jiangsu Province). The programme commits to invest RMB 462 million (including RMB 372 million invested by IFC) to lever the Bank of Jiangsu and enlarge the energy saving and emission reduction loan scale by offering loss risk sharing for the Bank of Jiangsu when it provides energy saving and emission reduction loans—this will foster domestic private enterprises to engage in energy efficiency, renewable energy, and relevant equipment manufacturing programmes in Jiangsu province. The Bank of Jiangsu has offered such loans to an amount of RMB 924 million.

Box 2.14: China Utility-based Energy Efficiency Program (CHUEE) of International Financial Corporation and Green Credit Products of Cooperative Banks

CHUEE is co-developed by IFC and the Chinese government and co-funded by GEF, Finland government and Norway government. It is the new financing model specially designed for Chinese enterprises to improve energy efficiency, use clean energy, and develop the renewable energy programme.

The basic principle of CHUEE is that ICF, with the cooperation of commercial banks provides a partial risk-sharing facility and helps banks to evaluate the risks and business opportunities of energy efficiency and renewable energy industry. At the same time, IFC would motivate GEF (grant) as the primary loss bearer of IFC. However, the responsibilities of the banks are not relieved while they are motivated, as the banks would share the primary and secondary losses. If there is any loss, the banks will share such losses and its balance sheet will be affected thereby. While effectively stimulating the banks to provide energy efficiency loans, CHUEE has not greatly reduced the banks' duties in verifying the loan programmes. At the same time, IFC offers a package of technical assistance, including market research, engineering technology, programme development and equipment financing, etc., and assists banks to develop the potential energy efficiency programme, verification and evaluation of energy efficiency programmes, creation of energy administration network and provision of technical consultation, etc. Two domestic commercial banks participating in CHUEE Phase I have rapidly enlarged the loan portfolio of energy-efficiency programmes by making use of the loss-sharing facility.

Two phases of the CHUEE programme as designed by IFC have provided the risk-sharing facility with an amount of USD 215.5 million, including a USD 16.5 million grant by GEF as the primary risk sharing facility of bank's loans. By the end of 2011, the cooperated banks of CHUEE had provided loans with the amount of nearly USD 700 million and supported more than 160 energy efficiency and renewable energy programmes.

The innovation of CHUEE lies in its ability to exert the function of public funds to the greatest extent and lever more market funds, including the capital of the banks and IFC, which is mainly reflected in the application of GEF grants. WB, while evaluating the CHUEE programme in 2010, believed that the basic probability of default that GEF would compensate such losses is 4 per cent; nevertheless, as of today, there no loan loss has occurred. GEF's grant has repeatedly shown its leverage role in releasing, collection and reuse, levering the banks' capital and greatly supporting the energy-efficiency financing.

The Chinese cooperative banks of CHUEE have also launched special businesses with such support. Take CHUEE Loan (Phase II) of Industrial Bank for example; CHUEE Loan (Phase II) is mainly for the energy-efficiency programme, renewable energy programme, and emission-reduction programme so as to improve energy efficiency and reduce greenhouse gas emission. Among these, the energy-efficiency programme is the programme with updated equipment, optimized design and energy recovery and use, etc., as the means and with the purpose of saving primary energy such as coal, oil and natural gas and secondary energy such as electricity and stream, etc.; renewable energy programme refers to the production and use of non-fossil energy such as wind energy, solar energy, water energy, biomass energy, geothermal energy and ocean energy, etc. and pure emission-reduction programme is the programme as implemented under clean energy mechanism framework with greenhouse gas reduction. The main revenue of the programme is mainly from sales of certified emission reduction.

As an important source of international funds, green credit could effectively promote the development of domestic green credit. Green credit may have two functions as a financing source for local governments to facilitate low carbon economy growth: firstly, provide the additional source for local governments to finance directly (that is, size effect); secondly, green credit may drive the private sector to invest more so that the local government may save the investment expenditure (that is, substitution effect).

2.5.5 Risk Management Instruments of International Financial Institutions

Multinational Investment Guarantee Agency (MIGA) provides political risk guarantee for foreign private investors, including expropriation risk, currency transfer limit, default, war and civil disturbance and offers investment promotion services for its members so as to increase their capacity in foreign capital attraction and then facilitates the investment of foreign investors to flow into developing countries. MIGA's main contributions to coping with the climate change sector are to provide guarantee for green infrastructure investment of developing countries and thus, help developing countries with renewable energy competency construction, encourage resources protection, improve allocation efficiency and improve the health and environment and offset the greenhouse gas emission. Up to 2012, MIGA had provided guarantee for 39 programmes and is providing guarantee for seven programmes at present in China, with a total amount of USD 160 million. Most of the programmes are in the infrastructure sector such as water and waste processing.[18] Using MIGA to provide financing guarantee for local governments to carry out low carbon economy programmes could effectively reduce the programme risk and improve the capacity to obtain loans.

In addition to insurance instruments, official export credit, guarantees, factoring, credit rating, derivatives and letters of credit could also become risk management instruments in the green financial sector. Besides, public funding may set up a series of financial instruments, conduct joint investment with public capital through multiple forms, and attract the private capital to invest in low carbon industry with higher risks by some loss sharing facilities. At present, some international public funds have encouraged banks to provide green credit in the form of primary loss sharing facility or supported the development of emerging low carbon service industry by guarantee deposits. These instruments could be introduced to China and contribute to lowering the climate financing risk rating and promote capital flow. Therefore, the central government is required to further strengthen risk management cooperation with international institutions on investment in low carbon sector so as to provide supreme and more comprehensive risk management instruments for the local government in low carbon financing, and reduce investment risks and promote more investment in the low carbon sector.

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[18] http://www/miga.org/

2.5.6 Strengthen the Cooperation between Local Government with Other State and Local Governments

The local government should strengthen cooperation and communication with other countries and funding authorities to get more support in the form of loans for the low carbon programme, grant and cooperation, etc. In addition, the local government should improve the investment convenience in the low carbon economy sector that suits their own development, and adopt different forms of facilities and favourable policies to attract foreign investment to facilitate local low carbon economy growth. Besides, local government should intensify the cooperation with local governments in other countries and attract more foreign enterprises to invest in low carbon economy. For instance, Wuhan government in Hubei Province strengthened the cooperation with Bordeaux Region (Acquitaine) in France on comprehensive low carbon economy growth through Cooperation Agreement Framework on Sino-French Sustainable Urban Development and successfully attracted investment. The investment of some international corporations such as Peugeot Citroen (low emission and electromobile, etc.) has driven local employment and low carbon economy development. Meanwhile, Wuhan, as the pilot city, has benefited from the Cooperation Agreement Framework on Sino-French Sustainable Urban Development and the government office building renovation programme carried out by AFD in the form of sovereign debt.

2.6 Conclusion

Adequate provision of effective, convenient, and diversified financing for a low carbon economy is an important guarantee for low carbon development and transformation in cities. The funds needed for low carbon economy growth in cities mainly include investment of government and private sectors, and financing from financial institutions.

This chapter has firstly made a comprehensive analysis of financing sources and challenges for local government to facilitate low carbon economy growth. There are great challenges for Central and local governments in financing capacity and capital utilization efficiency in the future while facilitating low carbon growth. Whether the local government could improve their financing capacity within a period of time is an important premise and guarantee for successful development of low carbon economy. Secondly, this chapter has analysed the contributions of existing fiscal and financial policies of the local government in improving their low carbon financing capacity from additional funding source and capital management and utilization efficiency. Based on the specific instrument category, Table 2.12 has summarized the feasibility of reform time of different fiscal and financial instruments and specific financing effect (scale, technologies, and structural effect). It may effectively increase the additional funding sources for local government to facilitate low carbon economy growth, capital management and utilization efficiency, and lever more investment from the private sector by speeding up the implementation of feasible policies within a short time and coordination of reform and development of medium- and long-term feasible policies.

Table 2.12 Summary and Analysis of the Financing Effect and Feasibility of Financing Instruments of the Local Government

Item	Name	Short/ Long-term Feasible	Scale Effect	Technical Effect	Substitution or Structural Effect
Fiscal instrument	Tax revenue	Medium- and long-term (m–l term)	X		
	Fees	Short term	X		
	Transfer payment of central government	Short and M–L term	X	X	
Financial instrument	Public fund direction	Short and m–l term	X		X
	Carbon financial instrument	Long term	X		X
	Traditional instrument innovation	Short and m–l term	X	X	X
International source	Fund (grant and loans etc.)	Short and m–l term			X
	Risk management	Short and M–L Term		X	X

On finance, local government faces two aspects of challenges in low carbon financing—imbalance between the fiscal revenue and expenditure of central and local governments—the local government faces much greater pressure in fiscal expenditure than the central government; the relevant expenditure in low carbon economy sector is mainly assumed by the local government which has the increasing pressure on overall fiscal expenditure. Additional funding, improving the existing capital use and management model, and enhancing the capital-use efficiency are crucial for the local government to successfully offer capital support for low carbon economy development. On reform and innovative fiscal instruments, the special suggestions mainly include:

- On tax policy, tax reduction and exemption for business income taxes in certain industry (such as energy saving and environmental protection, clean energy, etc.), adjustment of tax rate relating to land use and sales (including urban maintenance and construction tax, house duty, farmland occupation tax, land value increment tax and urban land use tax, etc.), adjustment of tax rate relating to emission-based vehicle and vessel taxes and newly added relevant taxes (environment tax, carbon tax, financial transaction tax, etc.)
- It is suggested to adjust the revenue sharing proportion in case local and central governments share the tax revenue so that the local government could have more disposable revenue to invest in local green low carbon economy growth. It is also advised that the newly added taxes (environment tax, carbon tax, financial transaction tax, etc.) should also take the revenue use and distribution into full consideration, in particular, the influence on low carbon financing of local government.
- Fiscal instruments such as reform of existing fees (such as increasing pollutant discharge fee and road toll, etc.) and introducing the new fees that may be easily implemented within a short term shall be taken as the additional funding source by the local government. The international experience that could be learnt from this includes: *(i)* collecting different development fees in lump sum from real estate developers based on different locations, *(ii)* asking developers to assume the cost relating to overall city development in addition to the location where the project lies, *(iii)* urging developers to use land resources more effectively while providing additional capital, and *(iv)* collecting congestion fees from vehicles in congestion areas at peak hours.
- Transfer payment is an important source for local government on low carbon financing. One form of supporting financing transfer payment in local low carbon development sector is that the central government will give certain construction fee subsidy for low carbon programmes carried out by the local government with the capital in and out of the budget. Besides, the transfer payment of the Central government should match the local programme of the cities that develop low carbon programmes and coordinate with the relevant

payment of local governments in time and space so as to maximize expenditure efficiency. It is suggested to pilot a joint coordination mechanism between the Central and local government in the low carbon sector, or transfer part of the fiscal revenue to the relevant sectors that are good for low carbon development by setting up special local low carbon financing funds, or establish programmes supporting the local low carbon financing programme in existing funds (such as the CDM Fund).

Financial instrument is also an important source for the local government to facilitate low carbon economy financing. The specific policies and suggestions on fully exerting the enthusiasm of financial instruments and guiding the private investment mainly include:

- Exert the key guiding role by public funds. Some cities have had certain practice on policy funds (such as the CDM Fund), government investment guiding fund and fiscal support guarantee, etc. which would be popularized in more areas in the future.
- Provide services and conveniences for local government to develop innovative financial instruments by setting up a better financing platform. In addition to loans, more explorations include local government issuing low carbon bonds, carrying out public and private cooperation programmes by urban construction and investment companies, jointly setting up urban low carbon investment fund through government and social capital and providing guarantee for low carbon programme jointly financed and invested by public and private sectors through establishing the infrastructure credit guarantee, etc.
- The fiscal revenue from market instruments could be an important funding source for local and central governments to develop low carbon economy. The use of these policies always needs time to refine and transit and would not bring outstanding fiscal revenue at the beginning of such policy implementation. The local and central government should negotiate revenue use of carbon financial instruments as earlier as possible and confirm the revenue distribution, management and use while strengthening the carbon financial instrument pilot.
- Encouraging the innovation and application of existing financial instruments. At present, the financial sector in China is still at the primary stage. To stimulate the traditional financial market to provide more funds, it must rely upon accurate investment signals, perfect policies, improvement of vigour of various financial

mediums and innovation of financial instruments (including credit, bonds, equity, risk sharing, etc.)

- Actively making use of the international capital is also an important means for cities to facilitate low carbon financing. The significance of international funds for cities lies in the international management and operation experience brought for local government and local financial institutions by relevant cooperation programmes and capital use rather than limited to the funds. With the technical assistances brought by funds, the city's knowledge and business competence in energy-saving technology and low carbon industry have also been improved. The local government should strengthen the cooperation and communication with other countries and funding authorities so as to earn more support such as loans for low carbon programmes, grant and cooperation, etc. Besides, the local government should improve its own investment facilitation in the low carbon economy sector that suits its own development, and adopt various facilitation and favourable policies to attract more investment that may facilitate the local low carbon economy.

This chapter only analyses the financing issue with cities to facilitate low carbon economy as a whole; it is necessary to make the analysis on specific feasibility with regard to different city conditions and instruments. At the same time, we would like to stress the following aspects: firstly, the innovation of low carbon financing instruments and financing capacity of local government are closely related to central policies. Only stable, definite, and anticipated policy signals and development direction from the Central government can offer the necessary guarantee and premise for the local government in low carbon financing. Secondly, there is no unified statistics instrument on low carbon financing in China, which is against policy decision-making analysis and formulation; therefore, it is necessary to set up a unified low carbon financing database (including low carbon financing of the local government). Lastly, the ultimate purpose of low carbon financing is to develop green and low carbon cities and reduce emission. At present, fossil energy and some high-energy consuming industries are subsidized; how to reduce the subsidy is also one of the important issues to improve the low carbon financing.

Appendix A: Summary of GDP Per Capita and Low carbon Expenditure Per Capita of Provincial Administrative Region in China, 2011

Province	Low Carbon Expenditure Per Capita	GDP Per Capita
Beijing	4,112.355	80,510.9
Tianjin	5,403.1	83,448.56
Hebei	1,444.636	33,859.16
Shanxi	2,169.914	31,276.23
Neimenggu	4,683.706	57,862.84
Liaoning	2,602.213	50,711.16
Jilin	2,498.427	38,440.36
Heilongjiang	2,379.369	32,816.9
Shanghai	4,010.079	81,772.17
Jiangsu	2,583.19	62,174.34
Zhejiang	2,003.075	59,159.53
Anhui	1,633.797	25,637.82
Fujian	1,767.151	47,204.78
Jiangxi	1,567.695	26,073.27
Shandong	1,497.053	47,070.51
Henan	1,184.629	28,686.65
Hubei	1,631.333	34,098.58
Hunan	1,677.952	29,822.25
Guangdong	1,673.789	50,653.07
Guangxi	1,670.527	25,233.3
Hainan	2,663.164	28,753.5
Chongqing	3,166.941	34,297.26
Sichuan	1,679.789	26,120.1
Guizhou	2,125.626	16,437.88
Yunnan	2,043.729	19,204.28
Tibet	8,187.603	19,974.61
Shaanxi	2,498.637	33,432.11
Gansu	2,295.072	19,578.78
Qinghai	5,969.692	29,400.36
Ningxia	4,340.918	32,875.28
Sinkiang	3,319.811	29,927.2
National Average	2,089.519	38,701.24

Source Author's calculation based on China Statistical Yearbook 2012

CHAPTER 3

INFORMING SUB-NATIONAL ACTIONS: CASE STUDY OF FREIGHT TRANSPORT IN GUIYANG

2.3

3.1 Introduction

Greenhouse gas (GHG) in ambient air mainly consists of H_2O, CO_2, N_2O, CH_4, and O_3. According to relevant research reports, in recent years, the increase of GHG in the atmosphere has exerted significant influence on global climate (Miralga *et al*. 2009), and the damage to ecosystems caused by global warming will pose a huge threat to human security and well-being (Lichterman 1999) in the future. The increasing GHG concentration in the atmosphere is attributed to the exploitation and consumption of fossil fuels. With the rapid development of the automotive industry, the GHG emissions of motor vehicles (mainly consisting of CO_2, CH_4, and N_2O) account for a large share of fossil fuel based GHG emissions. Take CO_2 for example, the global CO_2 emissions from motor vehicles account for 20 per cent of the fossil fuel based CO_2 emission (IEA 2008). The figure is even higher in developed countries. In the US, the current CO_2 emission from the transport sector accounts for 33 per cent of the total (Kromer *et al*. 2010). In Europe, the share of CO_2 emission from motor vehicles is 26 per cent. Although we still lack official data on China's GHG emissions, the data from the International Energy Agency show that in 2005, China's CO_2 emission from motor vehicles accounted for 8 per cent of the total emission, and the figure is expected to reach 11 per cent by 2030 (MOE 2007). Studies also find that in some cities in China, the GHG emissions from motor vehicles account for 85 per cent of the total emissions (Wu and Zhang 2008). Statistics show that in 2010, there were 199 million motor vehicles in China, of which 22.02 million or 20 per cent were freight vehicles. With high annual mileage, freight vehicles contribute significantly to CO_2 emissions, and therefore, the development and deployment of CO_2 emission reduction technologies for these vehicles in China will have a positive impact on urban GHG emission control and climate change mitigation.

Besides development of emission reduction technologies, there is a need for improvement in fuel quality supported by policy instruments such as fuel standards. In recent years, in addition to technical improvement in traditional internal combustion engine (ICE) passenger vehicles, studies on freight vehicle CO_2 emission reduction technology conducted in China have mainly focused on the research and development of new energy vehicles. However, the contribution of such technologies to CO_2 emission reduction is yet to be seen through scientific research. Moreover, relevantly mature technologies for CO_2 emission reduction in freight vehicles still await observation and application—there are still no scientific reports on the total volume of CO_2 emissions from freight vehicles in China, so analysis of the effectiveness of CO_2 emission reduction and control technologies for freight vehicles remains to be seen.

In order to address research gaps, the analysis in this chapter selects freight vehicles as the main control objective. The outcomes of CO_2 emission reduction technologies for freight vehicles are examined. The study calculates CO_2 emissions from freight vehicles with different technologies, vehicle types, fuel-switching and fuels in order to understand emission reduction as a result of different plans through optimized combinations. It evaluates the prospects for the application of different emission reduction technologies for the freight transport sub-sector in China.

The study was designed to analyse the current situation and characteristics of motor vehicle pollution in the urban area of Guiyang; determine the constraints that prevent motor vehicles to reduce pollution; ascertain the factors contributing to the current pollution from motor vehicles; and uncover the crucial problems caused by the current motor vehicle pollution. It was also designed to gather and make use of sufficient information to understand the pollution trends, to be able to formulate and suggest effective controls and counter-measures to the relevant government agencies for their decision making and policy making concerning motor vehicle CO_2 emission control. Thus, it contributes to the achievement of the country's climate change mitigation targets.

3.2 Methodology and Approach

3.2.1 Investigation of Freight Vehicle Transportation in Guiyang

Through investigation of freight companies, the freight market, and freight stations in Guiyang, the study sorts out the types, operating rules, and current operation status of freight vehicles in Guiyang, and analyses the existing problems in freight transport.

3.2.2 Study of the Characteristics of CO_2 Emission from Freight Vehicles

The characteristics of the emissions of different types of freight vehicles in the urban area of Guiyang can be analysed by testing the motor vehicle exhaust emissions. The freight vehicle CO_2 emissions can be estimated by using different models.

3.2.3 Study of CO_2 Emission Inventory from Freight Vehicles

The study of the emission inventory on the scale of urban roads in Guiyang was conducted based on the IVE (international vehicle emission) model and actual remote sensing data (known as the Honghuan vehicle exhaust pollutant analysis model). The factors affecting freight vehicle CO_2 emission were calculated based on the relevant research findings regarding the driving patterns of motor vehicles in the road network of the urban area of Guiyang. The CO_2 emission inventory was established based on the number, driving patterns, and IVE models of these vehicles.

3.2.4 Prediction of CO_2 Emission Volume from Freight Vehicles

The changes in the number of freight vehicles in the urban area of Guiyang in the next 10 years (2011–20) was predicted by using long-range alternative planning system (LEAP) 2011 as the measuring instrument and using 2010 as the base year. The total CO_2 emission volume from the freight vehicles for the same 10 years (2011–20) was forecasted based on the calculation of fuel consumption.

3.2.5 Recommendations to Reduce Freight Vehicle CO_2 Emissions

The characteristics and key influencing factors of freight vehicle CO_2 emission in Guiyang was understood based on the results from the IVE model. An estimation of the results of freight vehicle CO_2 emission reduction under different scenarios was done. Based on the above estimation, recommendations on freight vehicle CO_2 emission control in Guiyang are made.

3.2.6 Study Region

The study region was the urban area of Guiyang, with an area of 2,403 sq. km. For details about the study region, please refer to Figure 3.1.

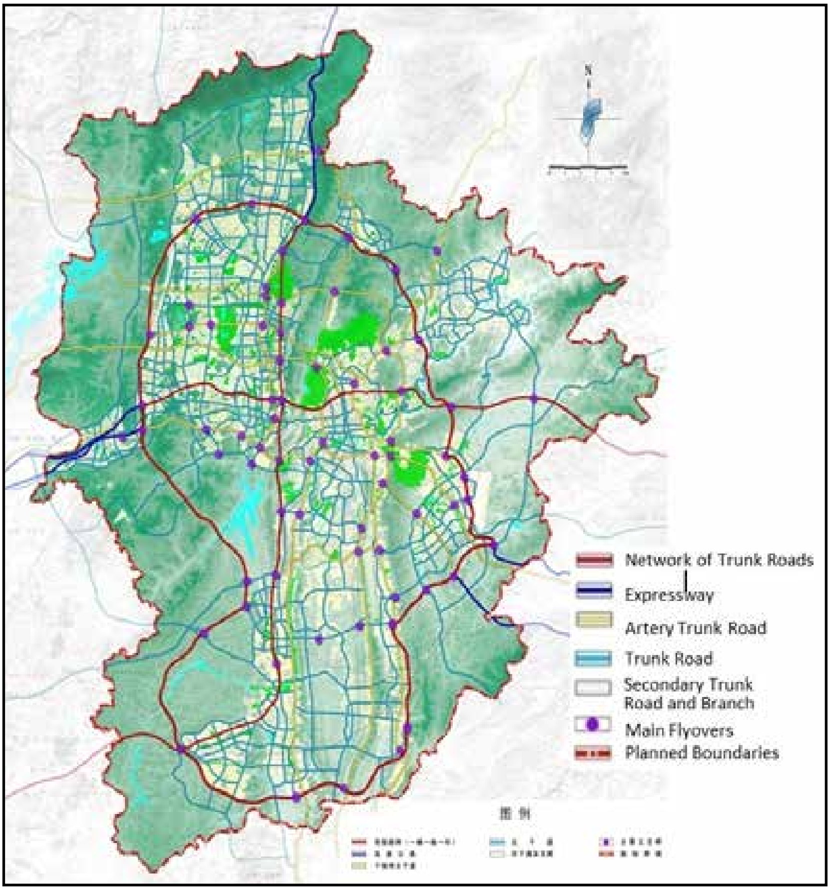

Figure 3.1 Study Region: Urban Area of Guiyang

3.2.7 Research Flowchart

For the research flowchart, please refer to Figure 3.2

3.3. Overview on Natural and Social Environments

3.3.1 Overview on Natural Environment

Extending from 106°07′ to 107°17′ east longitude and from 26°11′ to 27°22′ north latitude, Guiyang is located to the east of the Yunnan-Guizhou Plateau and the centre of the Guizhou Province. The highest and the lowest elevations of Guiyang are 1,762 metres and 506 metres respectively, and the average elevation of downtown Guiyang is 1,000 metres. It covers an area of about 113 kilometres from the east to the west and about 130 kilometres from the south to the north. As the capital of Guizhou Province, Guiyang is the political, economic, and

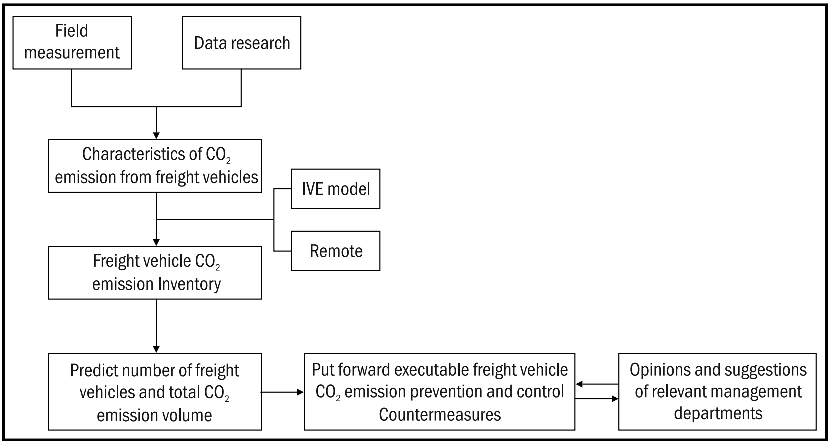

Figure 3.2 Research Flowchart

cultural centre of the whole province, and an important traffic hub in the southwest of China. Its total area is 8,034 sq. m, and the area of the urban section is 365.27 sq. m, accounting for 4.53 per cent of the total area of the whole municipality.

Guiyang is located in the middle of the hills of the Qianzhong Mountain Plateau and the watershed between the Yangtze River and the Pearl River. The terrain is high in the southwest and low in the northeast. Thus, with varied landforms, Guiyang sits in an area of hilly plains and basins with highlands and hillocks. It is under the influence of subtropical humid monsoon climate. The winter is warm and the summer cool. With mild seasons, ample rainfall and heat, a low sunshine rate, little wind and a warm and humid climate throughout the year, Guiyang is known as an 'ideal city to stay away from the summer heat'.

The average temperature of Guiyang is 13.5℃–16.1℃ (in urban area). Located in a humid region, Guiyang's mean annual precipitation is 1,197–1,284 mm, and the precipitation from April to September accounts for 75–80 per cent of the annual precipitation.

3.3.2 Overview of the Social Environment

Economic structure

In 2010, Guiyang's main economic indicators maintained a relatively fast growth. The GDP rose from RMB 52.562 billion in 2005 to RMB 112.182 billion in 2010, a rise of 110 per cent. The average annual growth rate was 14.2 per cent, 1 per cent higher than that during the Tenth Five-Year Plan period and also higher than the average growth rate of the whole country and the whole province. By doubling the GDP in five years, it is the fastest growth rate since the founding of the Republic of China. The primary, secondary and tertiary industries saw a rise of 7.9 per cent, 12.2 per cent, and 16.9 per cent, respectively, in the Tenth Five-Year Plan period. The proportions of the three industrial sectors were adjusted from 6.3:48.4:45.3 in 2006 to 5.1:40.7:54.2 in 2010. The GDP per capita exceeded USD 4,000.

Road traffic

Guiyang is an important traffic hub in the south-western region. With the Hunan–Yunnan, Guizhou–Kunming, Sichuan–Guizhou national railway trunk lines, national highways, provincial highways and other regional road arteries within the Guizhou Province passing through it, Guiyang enjoys major traffic corridors in four directions. Mainly composed of railroads, highways, and airways, the cross-shaped traffic and transportation corridors form a comprehensive external traffic and transportation network.

With the ring expressway at its core, Guiyang's regional backbone of highway traffic network radiates towards various regions, municipalities, and prefectures in Guizhou and other places such as Chongqing, Guangxi and the Pearl River Delta, Xi'an, Yunnan, Hunan and the Yangtze River Delta. Along with this highway network, a municipal highway traffic network featuring 8 provincial highways connects with 7,934.4 km of rural highways. According to the Urban Comprehensive Traffic Planning of Guiyang Municipality, the municipal backbone of trunk roads in Guiyang adopts a pattern of '1 ring road, 1 horizontal road, and 9 radial roads'.

In terms of the urban traffic of Guiyang, a backbone urban road traffic network characterized by '3 ring roads and 16 radial roads' has been largely built. The road–area ratio reaches 9.66 per cent, and the road–area per capita is 7.12 sq. m; in the old city, the sidewalk area per capita is 4.24 sq. m, and there are 257 pedestrian crossing facilities, including 25 overpasses, 185 crosswalks, and 47 underground passages; the construction of rail transit facilities has started, and phase one feasibility study on Line 1 and Line 2 has been accomplished. Currently, the routine bus system is the main form of urban public transport. In 2010, the bus companies in Guiyang operated 148 bus routes. Guiyang is now planning to become a demonstrative city of public transport according to the Twelfth Five-Year Plan in China.

3.4. Investigation of Freight Vehicles Transportation in Guiyang

3.4.1 Current Situation of the Freight Market in Guiyang

Currently, there are no standard freight stations in Guiyang. There are two main types of freight markets: roadside freight markets and centralized freight markets, and there are 392 less-than-truck-load (LTL) transport freight service providers. The roadside freight markets are located along the streets. Storefronts are used as storage and distribution venues for cargos, and freight vehicles stop and load/unload cargos on urban roads. Most of the roadside freight markets are located along five urban roads: Luoyanying, Touqiao Road, Haimachong and Qianchun Road in Yunyan District, and Jiarun Road in Nanming District. In these markets, there are 258 LTL freight service providers. Centralized freight markets are located along trunk roads. The operators of freight yards rent sites of a certain area (generally above 2,000 square metres), and build on these sites simple warehouses together with freight operating areas. Some of the freight yards have freight handling facilities which are leased to big freight shippers for cargo distribution. There are seven freight yards, with 134 LTL freight service providers operating in them (see Appendix A).

Most freight service providers have individual business licences granted by the Municipal Administration for Industry and Commerce and road transport operator's permits granted by the Municipal Transport Administration. A few of them are engaged in unlicensed business activities. The business scopes of LTL freight service providers as specified in their business licences are 'LTL freight stations'. They are also self-employed. Therefore, these LTL freight service providers are not logistics enterprises in a real sense. The centralized freight markets across the whole municipality are all just transfer stations and do not have the functions of modern logistics.

3.4.2 Investigation of the Number of Freight Vehicles in Guiyang

In recent years, about 222,800 tonnes of fresh agricultural products enter the circulation domain each year in Guiyang, and 60,100 tonnes of goods are transported through cold-chain logistics. There are now 14 cold storages with a total storage capacity of 74,600 cubic metres or around 27,300 tonnes. In 2011, the urban delivery quantity in Guiyang reached 3.75 million tonnes, and the daily delivery quantity within Guiyang was above 10,000 tonnes. The urban delivery in Guiyang involves more than 20,000 types of goods, 75,291 outlets, 1,300 urban logistics delivery starting points, 733 logistics enterprises, and over 40,000 delivery vehicles (Figure 3.3). According to the findings of a field investigation in Guiyang conducted in 2012, the no-load ratio of freight vehicles in Guiyang was 49.6 per cent. In addition, there are no optimized transportation routes—they are decided by the drivers according to their own habits.

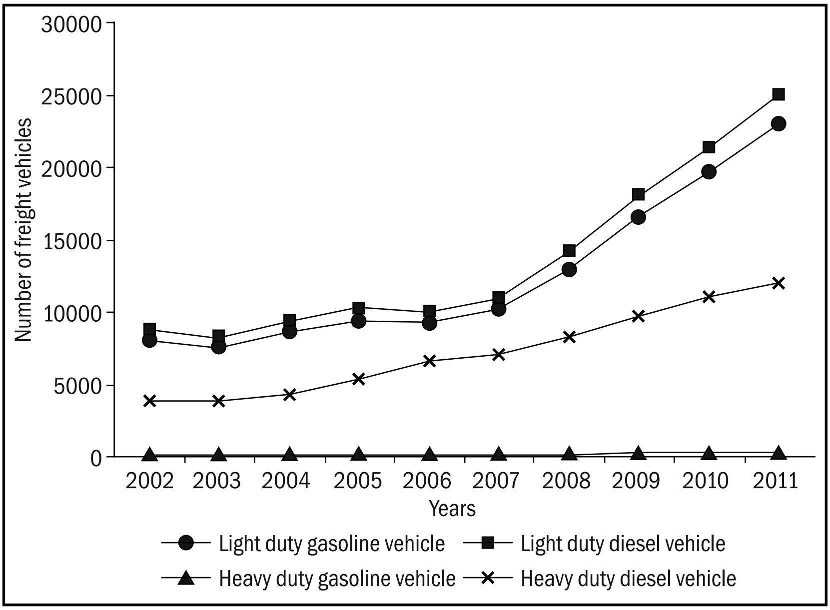

Figure 3.3 Freight Vehicles in Guiyang (2002–11)

3.5 Measuring CO_2 Emission Factors for Freight Vehicles Using on-Road Remote Sensing Devices

3.5.1 Experimental System and Test Method

Remote sensing devices

For the study, remote sensing measurement was carried out using the 4-gas INSPECTOR IV® from MD LaserTech Ltd. The INSPECTOR IV® is used to measure the exhaust emissions from gasoline vehicles. It uses tuneable laser diode (TDL) technology to measure carbon monoxide (CO) and carbon dioxide (CO_2), and ultraviolet differential optical absorption spectroscopy (UV-DOAS) to measure hydrocarbons (HC) and nitric oxide (NO). The components and working conditions of this instrument are described in Appendix B.

System Adjustment

Depending on the time and place, the environmental conditions (including the concentration of the exhaust in the air, wind speed, and wind direction) will change. The remote sensing system has to be adjusted every two hours before the start of the test to correct for the inevitable ground vibrations and in order to obtain a better test result. The CO and CO_2 data will be adjusted within the system.

Detection of the Conditions of the Road

Remote sensing monitoring of road traffic was done in five places in Guiyang. The monitoring sites were located in different parts of the city to cover as many road types (such as urban viaducts, main roads, secondary roads and urban tunnels) and ages of vehicles as possible. However, keeping the regulations in mind, the test could be performed only on single lanes, instead of the busy ones. Moreover, to ensure smooth traffic around the city, only those areas had to be selected which had more land, a moderate traffic volume, and smooth traffic. All testing sites were located in the middle of the road, in order to avoid the possible impact of cold starts of vehicles.

3.5.2 Data Analysis

In an ideal situation, the minimum value of motor vehicle exhaust emissions should be zero. However, due to the error of the measurement instrument itself, the measured values may be negative. For the study discussed in this chapter, the approach recommended by Burgard *et al*. (2003) was adopted to deal with negative values—the average emissions of a vehicle with minimum emissions in the year with the smallest amount of emissions as an adjusted value was used to offset the negative number from the measurement.

3.5.3 Results and Discussion

Based on the data from the five monitoring sites in Guiyang, there were 59,185 motor vehicles on the road; 46,753 of them produced valid CO and CO_2 emissions data. Around 69 per cent of the tested vehicles (32,260) can be matched with the data from the Inspection and Maintenance (I/M) database. The rest either did not have an easy-to-read licence plate or were non-local vehicles. Besides, there were also the ones that had been tested twice.

Figure 3.4 depicts the CO_2 emission factors for running freight vehicles. The CO_2 emission factor of running diesel vehicles was greater than that of gasoline vehicles. The CO_2 emission factor of running heavy-duty vehicles was also greater than that of light-duty vehicles.

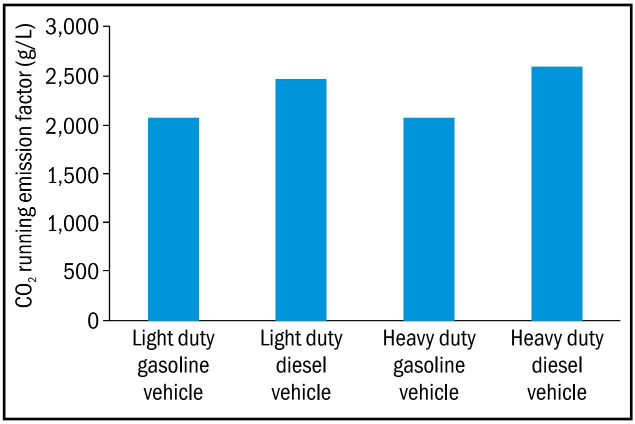

Figure 3.4 CO_2 Emission Factor Data for Freight Vehicles

Figure 3.5 shows the start emission factor for freight vehicles using different types of fuel. The vehicles are ranked from high to low as follows: heavy-duty diesel vehicle > heavy-duty gasoline vehicle > light-duty diesel vehicle > light-duty gasoline vehicle (unit: g/start and vehicle).

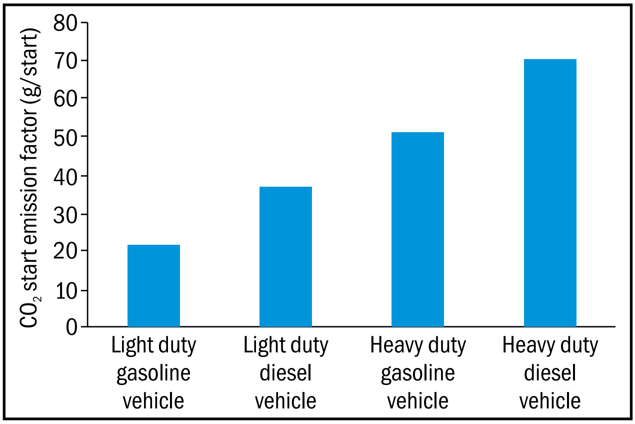

Figure 3.5 Start Emission Factor for Freight Vehicles using Different Types of Fuel in Guiyang

3.6 Research on the Inventory of CO_2 Emissions from Freight Vehicles

3.6.1 A Modified and Localized Version of the IVE Model

The international vehicle emission (IVE) model is supported by the United States Environmental Protection Agency (USEPA) and co-developed by the Center for Environmental Research and Technology, UC Riverside (CE-CERT), the Global Sustainable Systems Research (GSSR) and the International Sustainable Systems Research Center (ISSRC) to meet the needs of controlling pollution from motor vehicles and to facilitate the related research activities in developing countries. It provides an estimate of mobile source emissions. The model uses power-based driving factors, ensuring a higher recognition rate. Its classifications of vehicle types and levels of vehicle emission control technologies better suit the needs of developing countries, providing more transportability and accuracy than the widely used MOBILE model. At present, the IVE model has been applied in Brazil, Chile, Mexico, Kazakhstan, Peru, India, Kenya, and many other developing countries in the world. Researchers from Hangzhou, Beijing, and Shanghai have also conducted studies on the application of the IVE model.

2.3

However, the measurement of the IVE's basic motor vehicle emissions factors are actually based on the federal test procedure (FTP) bench test results of vehicles that use different levels of technology in the US. Studies show that there are some differences between the simulated results and the real assessment of pollutants from vehicles that use the corresponding level of technology in developing countries. Hence, based on local conditions, some modifications are needed for the basic motor vehicle emissions factors.

In China, based on the conditions and characteristics of the on-road vehicles in China and the actual remote sensing data, the basic parameters of the IVE were modified and the Honghuan vehicle exhaust pollutant analysis model was designed. The testing results of the model show that it can be well-applied. In addition, field tests have been conducted to verify the results obtained from the simulations of the model. As seen in Figure 3.6, which contains the measured values of carbon monoxide (CO), the oxides of nitrogen (NO_x) and their simulated values before and after the modification of the IVE model, the Honghuan model has obviously achieved a higher level of accuracy in the simulated values than the IVE.

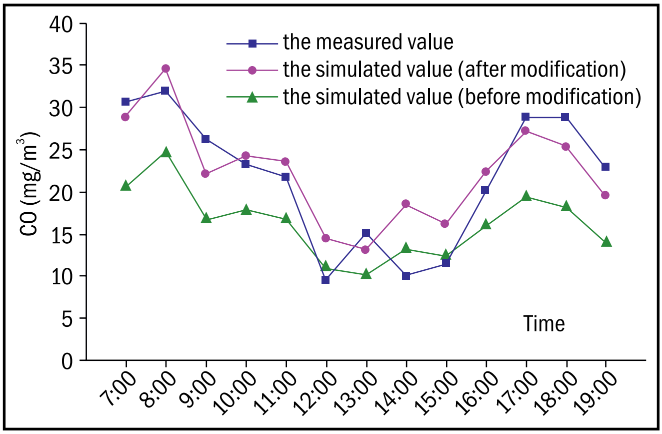

Figure 3.6 (a) Time-varying CO Concentration in Hangzhou (Observed on February 22, 2005)

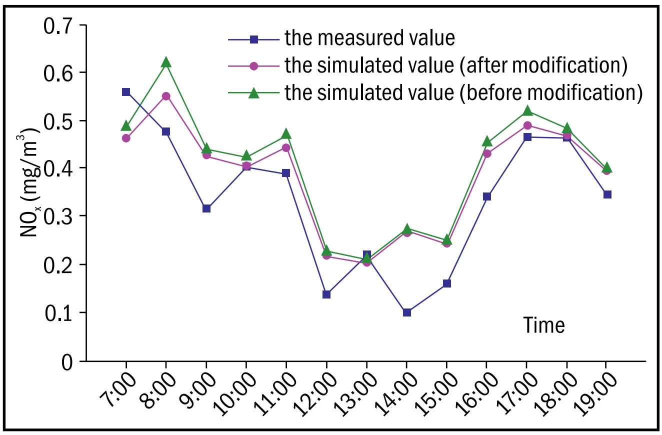

Figure 3.6 (b) Time-varying NO_x Concentration in Hangzhou (Observed on February 22, 2005)

3.6.2 Guiyang's Inventory of CO_2 Emissions from Freight Vehicles

In general, a motor vehicle emissions inventory can be developed in two ways: one is travel-based, and the other is fuel-based. For the study in this chapter, the travel-based approach which is widely used in China has been adopted. A travel-based motor vehicle emissions inventory includes both running and start emissions from traditional fuel cars. The equation is as follows:

$$Q = Q_{\mathrm{run}} + Q_{\mathrm{st}} = \mathrm{EF}_{\mathrm{run}} \times D \times L \times M + \mathrm{EF}_{\mathrm{st}} \times T \times M \quad (3.1)$$

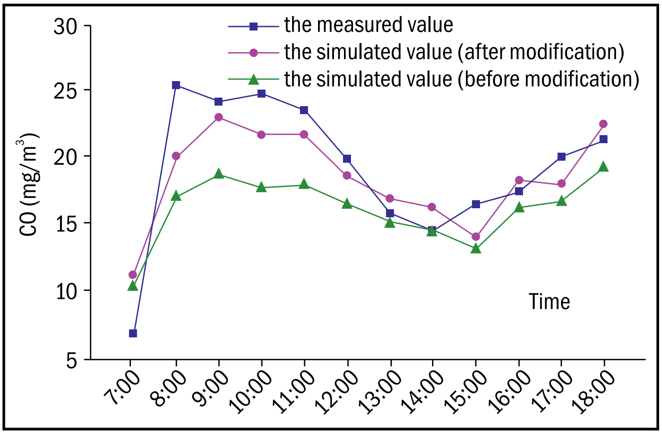

Figure 3.6 (c) Time-varying CO Concentration in Hangzhou (Observed on March 5, 2005)

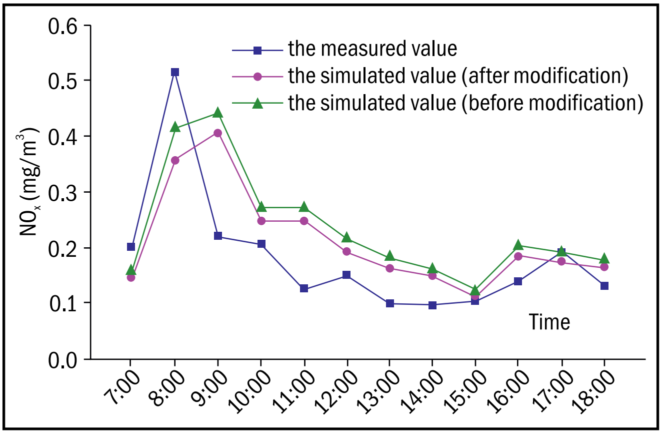

Figure 3.6 (d) Time-varying NO_x Concentration in Hangzhou (observed on March 5, 2005)

where,

Q = total annual emissions from motor vehicles (t/a)

Q_{run} = total annual running emissions from motor vehicles (t/a)

Q_{st} = total annual start emissions from motor vehicles (t/a)

EF_{run} = running emission factor for motor vehicles (g/L and vehicle)

EF_{st} = start emission factor for motor vehicles (g/start and vehicle)

L = average annual car mileage (km/a)

D = fuel economy (L/km)

T = total number of starts (start/a)

M = number of vehicles

The inventory of CO_2 emissions from freight vehicles in Guiyang was calculated. As shown in Table 3.1, the number of vehicles (only referring to freight vehicles) in Guiyang was 60,200, and their CO_2 emissions totalled 440,600 tonnes in 2011.

Table 3.1 Guiyang's Inventory of CO_2 Emissions from Freight Vehicles in 2011 (10,000 t/a)

Vehicle types	Fuel Types	Number	CO_2
Light-duty freight vehicle	Gasoline	22,982	20.81
	Diesel	24,897	24.11
Heavy-duty freight vehicle	Gasoline	316	0.87
	Diesel	12,014	23.80
Total (ten thousands)		**60,209**	**69.60**

From Table 3.1, it can be observed that the light-duty diesel vehicle is the largest source of CO_2 emissions (241,100 tonnes/year), followed by the heavy-duty diesel vehicles (238,000 tonnes/year), light-duty gasoline vehicles (208,100 tonnes/year), and heavy-duty gasoline vehicles (8,700 tonnes/year). The heavy-duty gasoline vehicles produced less CO_2 emissions because the number of this type of vehicle is the smallest, while the light-duty diesel vehicles is the largest in number. Its running emission factor is only second to the heavy-duty diesel vehicles.

3.7. Strategy Research on Reducing CO_2 Emission from Freight Vehicles in Guiyang

3.7.1 Quantitative Prediction of Freight Vehicles in Guiyang in 2015

The study discussed in this chapter predicts the quantity of freight vehicles in Guiyang in 2015 by applying the LEAP (long-range energy alternative planning) model, and calculates the elastic coefficient by applying the regression algorithm. The results of the forecast are shown in Figure 3.7.

3.7.2 Scenario Design of Emission Reduction for Motor Vehicles

In recent years, Guiyang has actively taken optimization measures for freight transport so as to control the CO_2 emission from freight vehicles, such as implementing the stricter vehicle emission standards of the state, eliminating aged motor vehicles, promoting clean fuel

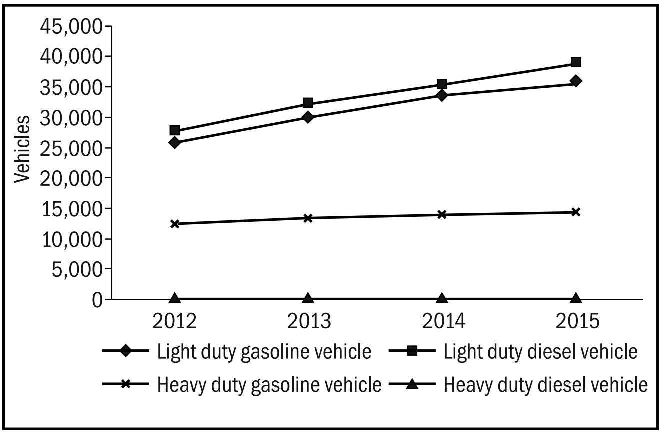

Figure 3.7 Results of the Quantitative Forecast of Freight Vehicles in Guiyang during 2012–15

2.3

vehicles, strengthening the administration of in-use vehicles, and traffic restrictions on motor vehicles according to their licence plate numbers in peak hours. Considering the status quo in the administration of freight vehicles in Guiyang, the study in this chapter used the LEAP system model to predict the number of vehicles that will be on the roads in the period from 2010 to 2015. Our previously developed methods of fuel economy calculation for different vehicle types and distance travelled (Zhang *et al*. 2007) are used to estimate fossil fuel consumption from 2010 to 2015. Finally, fuel consumption and the corresponding economic benefits were estimated for the four scenarios for the period between 2010 and 2015.

Business as Usual (BAU)

In the BAU (business as usual) scenario, it is assumed that Guiyang would take no other measures related to the administration of motor vehicles besides the current ones. During the period from now to 2015, the national IV (limits and measurement methods for emissions from light-duty vehicles; China IV) emission standards for motor vehicles shall be implemented in accordance with relevant requirements of the state. Considering the uncertainty in the implementation of the national V (limits and measurement methods for emissions from light-duty vehicles; China V) emission standards, all the motor vehicles registered during the Twelfth Five-Year Plan period must conform to the national IV emission standards.

Improved Load Capacity (ILC)

With BAU levels as the base, the no-load ratio of all vehicles is lowered from the present 50 per cent to 20 per cent in the ILC (improved load capacity) scenario. Thus, the use of freight vehicles may be reduced in order to reduce the CO_2 emissions from freight vehicles.

Alternative Energy Replacement (AER)

During the study on emission factors, it was discovered that the CO_2 emission factor of diesel vehicles is generally higher than that of gasoline vehicles. Therefore, an AER (alternative energy replacement) scenario can be designed, in which the newly increased light-duty freight vehicles are all gasoline vehicles.

Clean Energy Replacement (CER)

China has promulgated policies on promoting new energy vehicles, and encourages consumers to buy clean energy vehicles (such as electric vehicles [EVs] and hybrid electric vehicles [HEVs]) by means of tax exemption or government subsidies. Therefore, the cleaning energy replacement (CER) scenario assumes that the HEVs will account for 10 per cent of the total increased light-duty freight vehicles.

3.7.3 Scenario Analysis of Emission Reduction for Motor Vehicles

Quantitative Analysis of Motor Vehicles in Different Scenarios

In accordance with the scenario analysis, different quantities of freight vehicles were estimated for the different scenarios. Refer to Table 3.2 for details.

Table 3.2 Quantities of Freight Vehicles in Guiyang in 2015 in Different Scenarios

Parameters	2011	2015			
		BAU	ILC	AER	CER
Light-duty gasoline vehicles	22,982	35,948	25,163	27,527	27,072
Light-duty diesel vehicles	24,897	38,944	27,260	24,897	24,897
Heavy-duty gasoline vehicles	316	373	261	261	261
Heavy-duty diesel vehicles	12,014	14,187	9,931	9,931	9,931
Light-duty hybrid electric freight vehicles					454
Total	**60,209**	**89,451**	**62,616**	**62,616**	**62,616**

Pollutant Emission from Motor Vehicles in Different Scenarios

After setting the scenarios for emission reduction, the CO_2 emission volumes were calculated for the four scenarios by adopting the establishment method for the emissions inventory of motor vehicles (refer to Figure 3.8 for details). As shown in the figure, the CO_2 emission volume of freight vehicles will increase to 994,000 t/a in 2015 in the BAU scenario. In the ILC scenario, it will be the same as that in 2011, showing that improvement in the load capacity of freight vehicles can effectively solve the problem of CO_2 emission from freight vehicles. In the AER scenario, the CO_2 emission volume of freight vehicles will be less than that in 2011, with a total emission volume of 694,400 t/a. Finally, in the CER scenario, the CO_2 emission volume of freight vehicles will be further reduced to 693,700 t/a; though it is a minor reduction, the increase in the quantity of HEVs will lead to more significant emission reduction results.

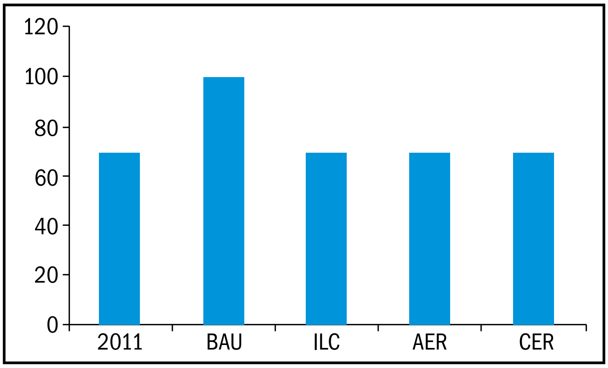

Figure 3.8 Analysis of the Reduction of CO_2 Emission from Freight Vehicles in Different Scenarios in Guiyang in 2015 (CO_2 emission in t/a)

3.8. Economic Benefit Analysis of CO_2 Emission Reduction

Based on the above analysis and study, this chapter will take the BAU scenario (with the supposition that Guiyang would take no other measures related to the administration of motor vehicles besides the current ones) as the benchmark and make the comparative analysis between it and the ILC, AER and CER scenarios in terms of economic benefit, in order to study the economic benefit of energy conservation and emission reduction for freight vehicles in multiple scenarios. We focus on three fields where we can save money—*(i)* cost for fuel consumption, *(ii)* cost for clean CO_2, and *(iii)* depreciation cost.

Notations

TM : Total mileage
L : Mileage per car (km/a), data obtained from online database
S : Quantity of cars
O : Total fuel consumption
Q : Fuel consumption per car, data obtained from online database
C^o : Cost for fuel consumption
P^o : Price for fuel consumption (yuan), value based on the China market situation
Z^{co_2} : Quantity of CO_2 emission
$Z^{\lg v}$: Quantity of CO_2 emission by light gasoline vehicles, the data obtained from Section 6.
Z^{ldv} : Quantity of CO_2 emission by light diesel vehicles, the data obtained from Section 6.
Z^{hgv} : Quantity of CO_2 emission by heavy gasoline vehicles, the data obtained from Section 6.
Z^{hdv} : Quantity of CO_2 emission by heavy diesel vehicles, the data obtained from Section 6.
C^{co_2} : Total cost for cleaning CO_2
P^{co_2} : Cost for clean CO_2 per tonne, the data obtained from online database in 2012
θ : Rate of depreciation
d : Total depreciation
$\mathrm{d}^{\lg v}$: Depreciation for light gasoline vehicles
d^{1dv} : Depreciation for light diesel vehicles
d^{hgv} : Depreciation for heavy gasoline vehicles
d^{hdv} : Depreciation for heavy diesel vehicles
$S^{\lg v}$: Quantity of light gasoline vehicles
S^{1dv} : Quantity of light diesel vehicles
S^{hgv} : Quantity of heavy gasoline vehicles
S^{hdv} : Quantity of heavy diesel vehicles
$P^{\lg v}$: Average price of light gasoline vehicles
P^{1dv} : Average price of light diesel vehicles
P^{hgv} : Average price of heavy gasoline vehicles
P^{hdv} : Average price of heavy diesel vehicles

3.8.1 Economic Benefit Analysis in the ILC Scenario

On the basis of BAU, we assume that the no-load ratio of all vehicles can be lowered from the present 50 per cent to 20 per cent in the ILC scenario. Thus, the total quantity of freight vehicles in 2015 will be 62,616 (refer to Table 3.2), which is 26,835 less than the 89,451 in the BAU scenario. Due to the lower increase of the quantity, the total fuel consumption of freight vehicles in the ILC scenario will be less than that in the BAU scenario, which will bring along substantial economic benefit to the freight transport system of Guiyang in 2015. The benefit can be calculated as follows:

$$\mathrm{TM} = \mathrm{S} \times L \quad (3.2)$$

$$O = (TM \times Q)/100 \quad (3.3)$$

$$C^{o} = O \times P^{o} \quad (3.4)$$

If we use Eqs (3.2)–(3.4) to calculate the cost for fuel consumption in the BAU scenario and the ILC scenario, the results are RMB 3,095 million and RMB 2,255 million. Finding the difference between these values, we get RMB 840 million which will be saved in the ILC scenario than in the BAU scenario in 2015. Refer to Appendix D, Table D.1 for details.

Furthermore, ILC will reduce the CO_2 emission from freight vehicles by reducing the use of freight vehicles. According to the current technologies for cleaning carbon, RMB 202 is needed to clean each tonne of CO_2 in China. Thus the costs for clean CO_2 in 2015 in the ILC and BAU scenarios can be calculated using Eq. (3.5) and Eq. (3.6) as follows:

$$\mathrm{Z}^{co_2} = \mathrm{Z}^{\lg v} + Z^{ldv} + Z^{hgv} + Z^{hdv} \quad (3.5)$$

$$C^{co_2} = Z^{co_2} \times P^{co_2} \quad (3.6)$$

The results are RMB 20,080 million and RMB 14,056 million, for BAU and ILC scenarios; the difference of which gives RMB 6,024 million which will be saved for the cost for clean CO_2 in the ILC scenario. Refer to Appendix D, Table D.2 for details.

Besides, freight vehicles will be more efficiently used in the ILC scenario. Thus, the depreciation cost in the ILC scenario will be less than that in the BAU scenario. According to the current market conditions for freight vehicles, we suppose that the average market price of a light-duty gasoline freight vehicle would be RMB 60,000 million, that of a light-duty diesel freight vehicle, RMB 70,000 million, that of a heavy-duty gasoline freight vehicle, RMB 100,000 million, and that of a heavy-duty diesel freight vehicle, RMB 120,000. Depreciation can be calculated using Eqs (3.7)–(3.11) as follows:

$$\mathrm{d}^{\lg v} = S^{\lg v} \times P^{\lg v} \times \theta \quad (3.7)$$

$$\mathrm{d}^{ldv} = S^{ldv} \times P^{ldv} \times \theta \quad (3.8)$$

$$\mathrm{d}^{hgv} = S^{hgv} \times P^{hgv} \times \theta \quad (3.9)$$

$$\mathrm{d}^{hdv} = S^{hdv} \times P^{hdv} \times \theta \quad (3.10)$$

$$d = \mathrm{d}^{\lg v} + d^{ldv} + d^{hgv} + d^{hdv} \quad (3.11)$$

Here, we assume that the depreciation change is in a straight line, with the rate of depreciation θ=1.98 per cent (the value used at present in China). Using the above equations, the depreciation in the BAU and ILC scenarios are RMB 331,135 million and RMB 231,790 million. RMB 993.45 million will be saved in the depreciation cost of freight vehicles in ILC scenario. Refer to Appendix D, Table D.3 for details of the depreciation costs in the BAU and ILC scenarios.

3.8.2 Economic Benefit Analysis in the AER Scenario

Similar to the ILC scenario, the total fuel consumption of freight vehicles under the AER scenario will be less than that in the BAU scenario due to the lower increase in the number of freight vehicles. Using Eqs. (3.2)–(3.4), the cost for fuel consumption in the BAU and AER scenario can be calculated as RMB 3.095 million and RMB 2.270 million, respectively. Compared with the BAU scenario, RMB 825 million will be saved in 2015 under the AER scenario. Appendix D, Table D.4 presents the summary of the analysis results.

Using Eqs. (3.5)–(3.6), the costs for clean CO_2 in the BAU and AER scenarios can be calculated as RMB 20,080 million and RMB 14,026 million respectively. RMB 6,054 million will be saved for the cost of clean CO_2 in the AER scenario.

Besides, as freight vehicles are more efficiently used under the AER scenario, there will be less depreciation cost than in the BAU scenario. Using Eqs. (3.7)–(3.11), the depreciation in the BAU and AER scenarios can be calculated as RMB 331,135 million and RMB 230,612 million, respectively. RMB 1005.23 million will be saved in the depreciation cost of freight vehicles in the AER scenario. Refer to Appendix D, Table D.5 for the summary of the comparative analysis results.

3.8.3 Economic Benefit Analysis in the CER Scenario

Using Eqs. (3.2)–(3.4), the cost for fuel consumption in BAU and CER scenarios can be calculated as RMB 3,095 million and RMB 2,234 million, respectively. Compared with the BAU scenario, about RMB 846 million will be saved in 2015 under the CER scenario. Refer to Appendix D, Table D.6 for the summary of the comparative analysis results.

Using Eqs (3.5)–(3.6), the costs for clean CO_2 in the BAU and CER scenarios can be calculated as RMB 20,080 million and RMB 14,012 million, respectively. RMB 6,068 million will be saved for the cost of clean CO_2 in the CER scenario. Refer to Appendix D, Table D.7 for the summary of comparison of the depreciation costs.

Using Eqs. (3.7)–(3.11), the depreciation in the BAU and CER scenarios can be calculated as RMB 331,135 million and RMB 229,274 million, respectively. RMB 1018.88 million will be saved in the depreciation cost of freight vehicles in the CER scenario.

3.9. Measures for Reducing CO_2 Emission from Freight Vehicles in Guiyang

3.9.1 Effectively Integrating Transport Resources

'Professional delivery motorcades' can be established, and the certificate of 'Professional urban delivery motorcades' issued to qualified enterprises after examination and verification. The competent authorities for different industries shall require the enterprises in their respective industries to preferentially use such professional urban delivery motorcades when organizing the bidding of freight transport and logistics projects. Professional delivery motorcades can organize meetings and build a platform for communication between supplying parties and demanding parties, according to the demands in different industries. The enterprises providing professional urban delivery services can engage in normalized operations and improve their transport efficiency, so as to provide safe, standardized, and quality transport services to society and lead the professionalized and socialized development of the urban delivery sector.

3.9.2 Strengthening Scientific Management of the Transport Market

A sound management system for the supply of goods can be established with the development of modern logistics industry as the driving force, logistics institutions as the basis, and by strengthening the scientific organization and management of the road transport market. Flexible

Table 3.3 Operation Conditions, CO_2 Emission and Reduction Costs from Freight Vehicles under Different Scenarios in 2015 in Guiyang

	BAU					ILC					AER				CER			
	TM	C^o	Z^{co_2}	C^{co_2}	d	TM	C^o	Z^{co_2}	C^{co_2}	d	TM	C^o	C^{co_2}	d	TM	C^o	C^{co_2}	d
Light-duty gasoline vehicles	158,484,307	12.09	32.55491	—	107,844	110,936,340	8.46	22.78844		75,489	121,358,560	9.26		82,581	119,352,597	9.11		81,216
Light-duty diesel vehicles	153,560,930	11.66	37.71618	—	136,304	107,489,497	8.16	26.40133		95,410	98,159,908	7.45		87,140	98,159,908	7.45		87,140
Heavy-duty gaseoline vehicles	4,984,026	0.38	1.032462	—	1,865	3,487,482	0.27	0.722724		1,305	3,487,482	0.27		1,305	3,487,482	0.27		1,305
Heavy-duty diesel vehicles	89,864,720	6.82	28.10418	—	85,122	74,621,534	5.66	19.67292		59,586	74,621,534	5.66		59,586	74,621,534	5.66		59,586
Total	—	**30.95**	**99.40773**	**20,080**	**331,135**	—	**22.55**	**69.58541**	**14,056**	**23,1790**	—	**22.7**	**14,026**	**230,612**	—	**22.49**	**14,012**	**229,247**

and diversified transport manners can be developed; service functions can be expanded; and the transport service market can be broadened. The logistics and transport activity can be innovated so as to guide the market demand and improve the utilization rate of vehicles. The return load can be improved so as to realize the round-trip load of vehicles. Route planning can be rationalized so as to ensure the complete round-trip load of vehicles.

3.9.3 Establishing Standardized and Scientific Logistics Network

With the aid of modern and computer software technologies, procurement services shall be equipped to offer transport operators with goods transport information and establish a trading platform for vehicles and goods; finding a more rational loading and running route for freight transport. This way also helps the realization of the ILC scenario.

3.9.4 Strengthening Organizational Leadership

A leading group for pilots of professional urban delivery motorcades in Guiyang (hereafter referred to as the Leading Group) with a leader of the Guiyang Municipal Government as the head can be set up, consisting of the Guiyang Bureau of Commerce, Guiyang Transport Bureau, Guiyang Traffic Management Bureau, Guiyang Finance Bureau, Guiyang Agricultural Commission, Guiyang Bureau of Commodity Prices, and Guiyang Tobacco Corporation. Such competent authorities from different industries as the Guiyang Bureau of Commerce and the Guiyang Agricultural Commission can encourage and guide relevant enterprises (units) to establish professional urban delivery motorcades satisfying the demands of the respective industries and special demands; Guiyang Traffic Management Bureau can be responsible for accepting applications for temporary parking points for urban delivery vehicles, issuing passes for delivery in downtown areas in daytime, and ensuring the passage of such vehicles so as to reduce their operation time; Guiyang Transport Bureau can be responsible for examining the applications of enterprises for freight transport qualifications and the road transport qualifications of vehicles and practitioners; Guiyang Bureau of Commodity Prices can be responsible for supervising the charging standards of delivery enterprises. The office of the Leading Group can be set up within the Guiyang Bureau of Commerce and can be responsible for the overall coordination and arrangement of relevant work.

3.9.5 Establishing a Reporting System for Urban Delivery Motorcades

The pilot enterprises for urban delivery can report relevant operation information (such as delivery and transport information), emergencies, and enterprise developments to the office of the Leading Group on time. The office can write a thematic report after summarizing and processing such information which can be submitted to the Guiyang Municipal Government. This would help to establish and modify the established logistics network

3.10 Conclusion

A CO_2 emission inventory of freight vehicles in Guiyang was drawn up, comprehensively showing the levels and features of CO_2 emission from motor vehicles in Guiyang; a forecast of the development level of freight vehicles and the total CO_2 emission in Guiyang in the future was made. Through the analysis of four scenarios, the volume and benefits of reducing CO_2 emission from freight vehicles in Guiyang was discussed, providing an effective basis for relevant government departments to manage and make decisions.

3.10.1 CO_2 Emission Factor

The actual measurement through remote sensing shows that the CO_2 emission factor of freight vehicles in Guiyang varies according to the composition of vehicles in different years. The CO_2 emission factor of diesel vehicles is greater than that of gasoline vehicles, while that of heavy-duty vehicles is greater than that of light-duty vehicles. Different freight vehicles in Guiyang can be listed according to their CO_2 emission factors in the order from big to small as follows: heavy-duty diesel vehicles, heavy-duty gasoline vehicles, light-duty diesel vehicles, and light-duty gasoline vehicles.

3.10.2 CO_2 Emissions Inventory

The total number of freight vehicles in Guiyang in 2011 was 60,200, and the annual CO_2 emission from freight vehicles was 440,600 tonnes. The annual CO_2 emission from light-duty diesel vehicles was the highest—241,100 t/a; that from heavy-duty diesel vehicles was 238,000 t/a; that from light-duty gasoline vehicles was 208,100 t/a; that from heavy-duty gasoline vehicles was the lowest—0.8700 t/a—mainly due to the fact that there were far fewer heavy-duty gasoline vehicles in the city than that of the other freight vehicle types. Since the population of light-duty diesel vehicles is the highest and such freight vehicle type has a CO_2 emission factor next only to heavy-duty diesel vehicles, these freight vehicles contribute most of the CO_2 emissions of the freight transport sub-sector. As a result, the numbers of light-duty diesel vehicles should be reduced or the quality of fuel for the light-duty diesel has to be improved.

3.10.3 Strategy Research on CO_2 Emission Reduction

Four scenarios were formulated to forecast the CO_2 emission from freight vehicles in Guiyang in 2015. The results were as follows: in the BAU scenario, the CO_2 emission from freight vehicles in 2015 will increase to 994,000 t/a; while under the ILC scenario, the CO_2 emission from freight vehicles in 2015 will remain the same as that in 2011, showing that the reduction of the no-load ratio of freight vehicles can effectively solve the problem of CO_2 emission from freight vehicles. Under the AER scenario, the CO_2 emission from freight vehicles will be less than that in 2011, at 694,400 t/a; while under the CER scenario, the CO_2 emission volume of freight vehicles will be further reduced to 693,700 t/a. Though it is a minor reduction, the increase in the quantity of HEVs will lead to more significant emission reduction results. Consequently, reduction of the no-load ratio and improvement of the fuel quality of vehicles would be preferable alternates for CO_2 reduction from freight vehicles.

3.10.4 Economic Benefit Analysis of CO_2 Emission Reduction

The economic benefits of reducing CO_2 emission from freight vehicles in Guiyang in four different scenarios were analysed. The results are as follows: in comparison with the BAU scenario, the ILC scenario can save RMB 6,024 million in the CO_2 treatment cost and RMB 993.45 million in the depreciation cost of freight vehicles; the AER scenario can save RMB 6,054 million in the CO_2 treatment cost and RMB 1,005.23 million in the depreciation cost of freight vehicles; the CER scenario can save RMB 6,068 million in the CO_2 treatment cost and RMB 1,018.88 million in the depreciation cost of freight vehicles. Consequently, all of these three scenarios efficiently save the depreciation cost of freight vehicles, other than the cost for CO_2 treatment.

3.10.5 Measures for Reducing CO_2 Emission from Freight Vehicles in Guiyang

Based on the above research results, the following assurance measures are recommended: effectively integrate transport resources; strengthen scientific management of the transport market; establish standardized and scientific logistics network; strengthen organizational leadership, and establish reporting forms for urban delivery motorcades.

Appendix A: Current Situation of the Freight Market in Guiyang

Table A.1 Basic Information About the Main Freight Markets in Guiyang

Type of Freight Yard	Name of Freight Yard	Location	Established in	Scale	Number of Freight Service Providers	Radiation Range of Freight Services
I. Roadside freight markets	Freight belt along Jiarun Road	Jiarun Road	1980s	2 km along the road	120	A goods distribution centre around Dongzhan Railway Station, radiation range covers entire province, focus on specific line transportation to counties.
	Freight belt along Luohanying Road	Luohanying	1990s	660 m along the road	49	Providing freight services for over 200 neighbouring wholesalers and retailers, radiation range covers entire province, especially counties.
	Freight belt along Touqiao Road and Haimachong	Touqiao Road and Haimachong	Late 1990s	600 m along the road	73	Formed on the basis of the retailing and wholesaling general markets of electric appliance, hardware, labour protection appliance, building material, clothing, etc., in the neighbourhood of the original passenger station. Radiation range covers counties in Zunyi, Bijie and Liupanshui, Kaiyang and Qingzhen, and freight lines between Guiyang and Chengdu, Chongqing, Guangzhou, and Guangxi.
	Freight belt along Qianchun Road	Qianchun Road	Around 2002	500 m along the road	16	Radiation range covers Zunyi, Bijie, Anshun, Dujun and other counties to the west of Guiyang; freight lines between Guiyang and Chengdu, Chongqing and Kunming, etc.
II. Centralized freight markets	Huashunda Logistics Market	Baihua Avenue (No. 143 Xinjie Street), Yunyan District	Prepared by Huashunda Logistics Company and put into use in 2000	10,000 sq. m	35	Radiation range covers Zunyi, Bijie, Anshun, Xingyi, Liupanshui and other main prefectures and municipalities, freight lines between Guiyang and Guangzhou, Shenzhen, Zhengzhou, Xi'an, Kunming, Chengdu, Beijing, etc. A distribution point in Guizhou for goods transported from other provinces.

contd...

2.3

Table A.1 Basic Information About the Main Freight Markets in Guiyang

Type of Freight Yard	Name of Freight Yard	Location	Established in	Scale	Number of Freight Service Providers	Radiation Range of Freight Services
	Donglian Logistics Market	Crossroads of Jiarun Road and Dongzhan Road	1990s	8,900 sq. m	20	Site rent from Guiyang Mechanical Handling and Transportation Company, radiation range covers Zunyi, Anshun, Bijie, Xingyi, Kaili, Dujun and other main prefectures and municipalities, and the special freight lines between Guiyang and Guangzhou, Zhengzhou, and Chengdu.
	LongdongbaoJingwei Drivers City	Longdongbao	2006	123 mu	20	Radiation range covers special freight lines between Guiyang and Shanghai, Guangzhou and Chengdu, etc.
	Kaifeng Logistics Market	Jinya Gas Station, Baihua Avenue	2009	2,000 sq. m	13	Radiation range covers the special freight lines between Guiyang and Anshun, Bijie, Zunyi, and other prefectures and counties.
	Jinya Logistics Market	Jinya Gas Station, Baihua Avenue	2009	2,500 sq. m	10	Radiation range covers the special freight lines between Guiyang and Anshun, Bijie, Zunyi, Tongren, and other prefectures and counties.
	Jiahua Logistics Market	Caijiaguan, Yunyan District	2010	3,000 sq. m	6	Radiation range covers the special freight lines between Guiyang and Shandong, Wenzhou, Chongqing, Chengdu and Xi'an, and the freight lines between Guiyang and Zunyi, Anshun, Bijie, Liupanshui, and other prefectures, municipalities and counties within Guizhou Province.

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Table A.1 Basic Information About the Main Freight Markets in Guiyang

Type of Freight Yard	Name of Freight Yard	Location	Established in	Scale	Number of Freight Service Providers	Radiation Range of Freight Services
	Bus Factory Sanqiao Freight Station	No. 18, Sanqiaoxin Street	2002	2,0000 sq. m	30	Radiation range covers the special freight lines between Guiyang and Guangzhou, Shenzhen, Changsha, Chongqing and Chengdu, and the freight lines between Guiyang and Zunyi, Anshun, BijieTongren and other prefectures, municipalities and counties within Guizhou Province.

Note Freight yard/freight market: A kind of market for the storage, delivery, and management of goods. Freight service provider: The enterprise who operate the freight yard.

Appendix B: Instrumental Setup for Measuring Emissions

A remote sensing device is used for measuring the exhaust emissions from gasoline vehicles. As shown in Figure B.1, the gas scope (GS) and the retro reflector (RR) are put on either side of the road and aligned with each other. The gas scope emits infrared and ultraviolet beams (IR/UV), which run horizontally across the road and are reflected by the RR back to the GS. When a vehicle passes by, the light beam goes through the exhaust gas plume coming out of the vehicle. Part of the light beam will be absorbed by the exhaust. When the beam is reflected back to the GS, both infrared and ultraviolet rays will have been reduced to some degree. After measuring the degree of weakening of the light intensity, the light intensity signal is then converted to an electric signal, which is converted by the sensor and data acquisition board to a digital signal. The digital signal is then sent to the central processor, and the data on the composition of the exhaust emissions from each passing vehicle is obtained.

During the testing process, the length and density of the exhaust plume changes greatly due to several factors, including the height of the exhaust pipe (relative to the road), the wind speed, and the turbulence at the rear of the vehicle. Hence, the remote sensing system cannot detect the concentration of the exhaust directly. The instrument measures the composition of the exhaust (e.g., CO, HC, and NO to CO_2 ratio ($CO/\ CO_2$, HC/CO_2, NO/CO_2)), which is constant for a given exhaust plume. The concentration of the exhaust is calculated and represented by volume: CO (per cent), HC (ppm), NO (ppm). For the INSPECTOR IV ® system, the range of accuracy of CO and CO_2 concentrations by volume is ±0.25 per cent. When the CO and CO_2 concentrations by volume are greater than 3 per cent, the error is 15 per cent of the measured value. The range of error of the HC and NO concentrations by volume is 250 ppm to –250 ppm or 15 per cent of the measured value (whichever is greater).

The system is equipped with a low-energy laser velocimeter, which can measure both the running speed and the acceleration of a vehicle simultaneously. A high-speed colour digital camera is also placed on one side of the road to take a shot of the vehicle's licence plate and acquire further information. The measured values of the running speed and acceleration as well as the image signal is sent to the central processor. The speed accuracy is ± 1km h^{-1}, and the accuracy of the acceleration is 0.5 km $h^{-1}s^{-1}$. During this process, the meteorological conditions such as temperature, humidity, wind speed and wind direction are also detected. It only takes 0.6 seconds to complete all these measurements. Figure B.2 shows the components of the INSPECTOR IV ® instrument.

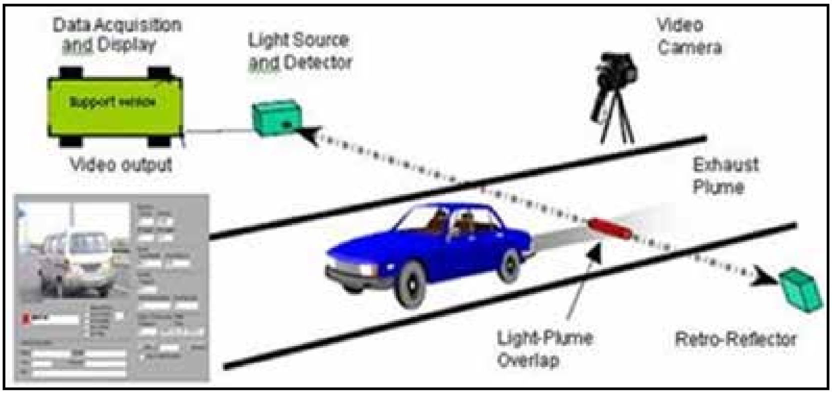

Figure B.1 Schematic Diagram Showing the Remote Sensing System in Operation

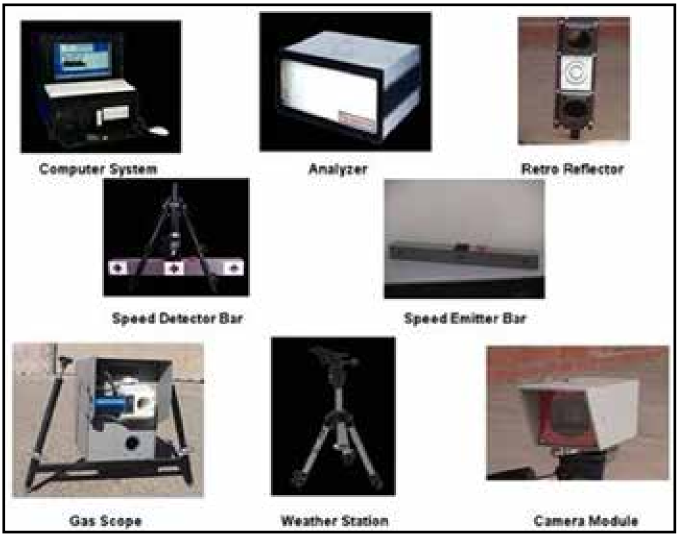

Figure B.2 INSPECTOR IV ® System Components

Appendix C: Model for Estimating the Population of Freight Vehicles

We used the elastic coefficient method to estimate the population of freight vehicles in Guiyang in 2015 under various scenarios. This method utilizes the history inventory of freight vehicles and elastic coefficient to estimate the vehicle inventory in the future. Simultaneously, the proportion of vehicle types can also be estimated. Finally, data of the future freight vehicles inventory can be obtained. Details for the model are depicted in Figure C.1.

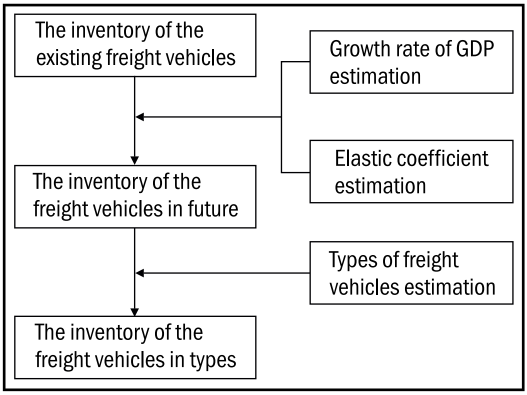

Figure C.1 The Procedure for Elastic Coefficient Method

Appendix D: Operational Conditions and Results of Scenarios

Table D.1 Operational Conditions of Freight Vehicles in BAU and ILC Scenarios

	BAU			ILC		
Type of Freight of Vehicles	**TM**	O	C^o	**TM**	O	C^o
Light-duty gasoline vehicles	801,640,400	158,484,307	12.09	561,134,900	110,936,340	8.46
Light-duty diesel vehicles	868,451,200	153,560,930	11.66	607,898,000	107,489,497	8.16
Heavy-duty gasoline vehicles	12,682,000	4,984,026	0.38	8,874,000	3,487,482	0.27
Heavy-duty diesel vehicles	408,476,000	89,864,720	6.82	337,654,000	74,621,534	5.66
Total			**30.95**			**22.55**

2.3

Table D.2 Analysis of CO_2 Emission from Freight Vehicles and Reduction Costs in BAU and ILC Scenarios

	Z^{lgv}	Z^{ldv}	Z^{hgv}	Z^{hdv}	Z^{co_2}	CO_2
BAU	32.55491	37.71618	1.032462	28.10418	99.40773	20,080
ILC	22.78844	26.40133	0.722724	19.67292	69.58541	14,056

Table D.3 Analysis of Depreciation Costs of Freight Vehicles in BAU and ILC Scenarios

	d^{lgv}	d^{ldv}	d^{hgv}	d^{hdv}	d
BAU	107,844	136,304	1,865	85,122	331,135
ILC	75,489	95,410	1,305	59,586	231,790

Table D.4 Operation Conditions of Freight Vehicles under the BAU and AER Scenarios

	BAU			AER		
	TM	O	C^o	TM	O	C^o
Light-duty gasoline vehicles	801,640,400	158,484,307	12.09	613,852,100	121,358,560	9.26
Light-duty diesel vehicles	868,451,200	153,560,930	11.66	555,203,100	98,159,908	7.45
Heavy-duty gasoline vehicles	12,682,000	4,984,026	0.38	8,874,000	3,487,482	0.27
Heavy-duty diesel vehicles	408,476,000	89,864,720	6.82	337,654,000	74,621,534	5.66
Total			**30.95**			**22.7**

Table D.5 Summary of Results of the Analysis of Depreciation Costs of Freight Vehicles under the BAU and AER Scenarios

	d^{lgv}	d^{ldv}	d^{hgv}	d^{hdv}	d
BAU	107,844	136,304	1,865	85,122	331,135
AER	82,581	87,140	1,305	59,586	230,612

Table D.6 Summary of Operation Conditions of Freight Vehicles under the BAU and CER Scenarios

	BAU			CER		
	TM	O	C^o	TM	O	C^o
Light-duty gasoline vehicles	801,640,400	158,484,307	12.09	603,705,600	119,352,597	9.11
Light-duty diesel vehicles	868,451,200	153,560,930	11.66	555,203,100	98,159,908	7.45
Heavy-duty gasoline vehicles	12,682,000	4,984,026	0.38	8,874,000	3,487,482	0.27
Heavy-duty diesel vehicles	408,476,000	89,864,720	6.82	337,654,000	74,621,534	5.66
Total			**30.95**			**22.49**

2.3

Table D.7 Summary of Results of the Analysis of Depreciation Costs of Freight Vehicles under the BAU and CER Scenarios

	d^{lgv}	d^{ldv}	d^{hgv}	d^{hdv}	d
BAU	107,844	136,304	1,865	85,122	331,135
CER	81,216	87,140	1,305	59,586	229,247

PART III

LOW CARBON DEVELOPMENT IN INDIA

CHAPTER 1

LOW CARBON TECHNOLOGY AND INNOVATION POLICY

1.1 Introduction

Innovation nowadays is understood as a broad and complex phenomenon involving many interactive dynamic processes occurring in a range of contexts and landscapes. The Oslo Manual defines innovation as encompassing either introduction of new or significantly improved goods and services (product innovation), or introduction of production or delivery method that is new or significantly improved (process innovation), implementation of a new marketing method (marketing innovation), and implementation of a new organizational method in business practices, workplace organization or external relations (organizational innovation) (OECD/Eurostat 2005). 3.1

A key feature of innovation that emerges from existing analysis is that it does not follow a linear path that begins with research, moves through the processes of development, design, engineering, production, and ends with the successful introduction of new products and processes into the market, rather, it is an interactive (and cumulative) process that involves continuous feedback loops between the different stages. A second feature is that innovation is essentially the result of an interactive process between many actors, including companies, universities, and research institutes.

It is now well-accepted that economic performance is not just a matter of access to natural resources and large markets, or even having a skilled (and much less cheap) labour force; innovation, knowledge creation, and the diffusion of new knowledge are today the key vehicles for enterprises, industries, regions, and countries for pursuing economic growth, and thus, essential components for achieving sustained competitive advantages in the economy. A country's performance is measured today by the degree of innovativeness of its enterprises as well as of its governmental, financial, and academic institutions. Innovation is the result of a process, influenced (and influencing) by the contextual conditions that favour development, thus, it is not only technology based. In fact, innovations in business models, organizational design, and functional strategies are also critical for success. Although technology and non-technology innovation have been normally differentiated for research, in practice they very often go hand-in-hand.

Recent times have seen several concerns about the future sustainability of economic growth, social upheavals, and environmental degradation patterns, underpinning the need for a greener model of growth. However, the existing production technology and consumer behaviour can produce positive outcomes only up to a point or a frontier; beyond which depleting natural capital has negative consequences for overall growth of the economy. According to OECD (2010), innovation can push the frontier outward and help to decouple growth from natural resource degradation. Innovation is the key to developing low carbon technologies that will underpin transition to a low carbon economy, and make it affordable and accessible.

Different external factors can influence innovation fostering low carbon development (LCD)—these may be barriers or incentives to the diffusion of the low carbon technology, products and outputs. If innovation does not contribute to a low carbon economic growth, the nature and level of innovation activity needs to be changed. These modifications could occur regarding all types of innovation, the quality of knowledge and technologies, and the institutional or organizational arrangements. As markets might not always be able to generate outcomes promoting low carbon development due to market failure, there is a need for policy intervention. These policy interventions can trigger innovation activity that may generate more 'greener' outcomes in the long run.

Various policy instruments could be used for supporting low carbon innovation such as, support for R&D, regulation, eco-labelling, technology procurement, technology legitimization and standards, voluntary agreements and self-regulation, etc. Although a larger role has been attributed to scientific research, however, regulatory, financial, cultural, institutional, and political instruments are equally important for understanding the problems of sustainability and designing efficient solutions. Law and regulation play a very important role in the context of innovation in general and innovation for low carbon development in particular, in terms of providing an enabling environment for incentivizing innovation, while ensuring that the innovations cater to the larger public good. The role of the intellectual property rights regime is particularly relevant in this context and has assumed a central role in the debate on technology transfer (of low carbon technologies) from developed countries to the developing countries. Developing countries particularly perceive it as a key barrier in indigenization of technologies. A case has also being made out that the formal intellectual property framework is not particularly amenable to grassroots level innovations and innovations of communities, owing to its exacting requirements, hence, necessitating the development of *sui generis* (uniquely designed for the context) legal mechanisms.

The nature and characteristics of innovation, across various sectors, in a national context might not be structured and addressed in the same way. Therefore, the different stages of development of low carbon technologies, from R&D through to commercial diffusion, introduce new and unique barriers, opportunities, and policy challenges that need to be understood and addressed sectorally.

The following sections provide insights on innovation and low carbon development in the Indian context. At first, an overview of the innovation ecosystem in India is provided, followed by a brief description of low carbon technology innovation initiatives in India and an analysis of the results of the stakeholder need assessment exercise undertaken as a part of the study. Thereafter, the next section will seek to highlight research and development initiatives and status for low carbon development for the selected sectors in India. Identification of various low carbon technologies and their innovation stage for the selected sectors and science, technology, and innovation policy related issues relevant to low carbon development in the sectors concerned is discussed.

1.2 Innovation ecosystem in India

The science and technology (S&T) infrastructure in India today encompasses S&T organizations under the Central government, State governments as well as public, private, and non-governmental organisations. The S&T departments under the Central government include: the Department of Science and Technology (DST), the Department of Scientific and Industrial Research (DSIR), the Department of Atomic Energy (DAE), the Department of Space (DoS), the Department of Biotechnology (DBT), and the Department of Ocean Development (DOD).

Besides the above, there are independent research institutes, private sector players, academic institutes, and other ancillary departments, such as IT, health, environment, and agriculture research, which carryout R&D in their respective areas.

The R&D and S&T related ecosystem in the country is elaborate and multi-layered, having evolved over several decades. Figure 1.1 gives

Government Departments	Industry Associations	Research	Supporting Infrastructure	Funding Institutions	Standards
• Department of Science and Technology • Department of Scientific and industrial Research • Department of Biotechnology • Department of Atomic Energy • Department of Space • Ministry of Earth Sciences • Ministry of New and Renewable Energy • Other Ancillary Research Departments	• Confederation of Indian Industries • Federation of Indian Chambers of Commerce and Industries • Associated Chambers of Commerce and Industry of India • National Association of Software and Services Companies • Federation of Asian Biotech Associations • Association of Biotechnology-led Enterprises	• Universities • Government R&D Organization • Non-for-profit Independent Research Institute • Government-funded Technical Institutes • Private Technical Institutes • Business Schools • Corporate	• Business Incubators • Technology/ Science Parks • Special Economic Zones	• Baking Institutions • Venture Capital Associations/ Angel Funding • Indian Angel Network	• University Grants Commission • All India Council for Technical Education • Bureau of Indian Standards

Figure 1.1 R&D Ecosystem in India
Source: Adapted from Evalueserve Business Research (2008)

an overview of the R&D ecosystem in India. The Council of Scientific and Industrial Research (CSIR) is the main body for research and development in India. Currently, there are 39 national laboratories and 80 field centres under CSIR which carry out fundamental and applied R&D in all areas of science and technology, barring atomic energy.

The Department of Science and Technology (DST) plays a lead role in identifying and promoting priority areas of R&D in various disciplines, and produces a working group report on R&D based on the Five-Year Plans. The Science and Engineering Research Council (SERC) acts as an advisory body, consisting of eminent scientists and technologists that contribute to DST's priority setting. The Science and Technology Advisory Committees formulate joint technology development programmes for the 24 socioeconomic ministries. DST has set up an autonomous body, the Technology Information, Forecasting and Assessment Council (TIFAC), to prepare technology forecasts, assessments, and market surveys. TIFAC previously carried out a programme known as 'Technology Vision for India up to 2020' to provide insights into setting national science and technology initiatives for the government. DST has also built other facilities to facilitate R&D such as the centres of excellence and the patent facilitating centres.

The total R&D spending in India is about 0.88 per cent of the national GDP of 1.21 billion USD (INR 72.62 billion) (DST, 2013).[1] Of this around 2/3rd of the funding was done through the public sector and the rest was from the private sector. Of the various sources of funding for R&D and S&T in India—Central government allocation made through the Planning Commission (now NITI Aayog), State governments, and the private and business sector—the major share is contributed by the Central government. Of the total R&D expenditure by major Indian scientific agencies, a sizeable chunk (~61 per cent) is cornered by strategic sectors, i.e., defence, atomic energy, and space, leaving a somewhat deficient share for the civilian S&T in which the ICAR and CSIR are the largest recipients. Figures 1.2 & 1.3 provide some key R&D related statistics of India vis-à-vis some other countries of the world. It is important to note that whereas R&D investment as percentage of GDP in India increased marginally from 0.3 per cent in 1980 to around 0.8 per cent in 2011 while for China the increase has been substantial, from 0.1 per cent in 1980 to around 1.84 per cent in 2011.

With regard to breakdown of government expenditure on R&D by type of research, the relative share of basic research and applied research to total R&D expenditure declined from around 28 per cent and 38 per cent, respectively, in 2003 to 26 per cent and 36 per cent, respectively, in 2010 whereas, the share of experimental development to total R&D expenditure witnessed an increase from 34 per cent in 2003 to 38 per cent in 2010 (DST 2013). There has been a gradual change in the R&D scenario with the focus of the government shifting towards commercially oriented R&D and private-public sector partnerships. A major perceptible change in government R&D is that the mission-oriented projects are replacing open-ended research programmes. The Twelfth Plan Approach Paper calls for launching mission mode projects, addressing national needs and priorities through extensive participation of stakeholders, in the areas of health, water, energy, food, and environment security with the objective to achieve the goals and targets in a defined time frame.

India's global share of scientific publication in the year 2008 is about 3.7 per cent with a global ranking of 9. In comparison, China has achieved spectacular success in increasing its publication standing at second position in the global ranking, with a global share of scientific publication of around 11 per cent (See Figure 1.4). Further, China

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[1] Research and Development Statistics 2011–12, Department of Science and Technology, Ministry of Science and Technology, Government of India, New Delhi, September 2013.

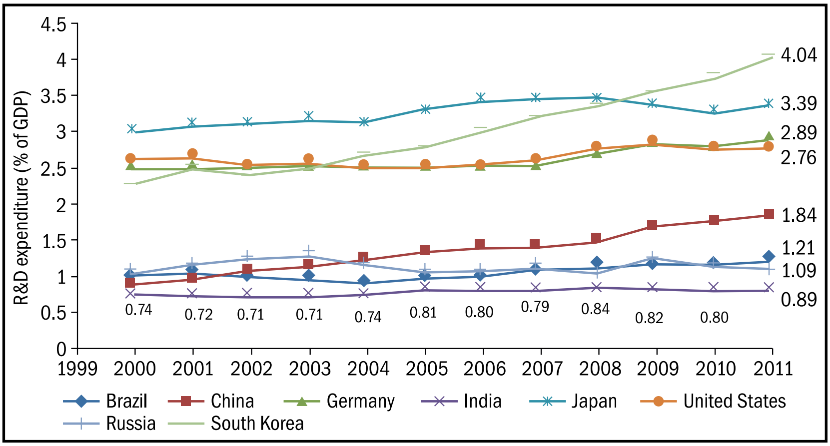

Figure 1.2 Percentage of GDP Spent on R&D in BRICK and other Countries, 2000–11
Source: World Development Indicators, World Bank

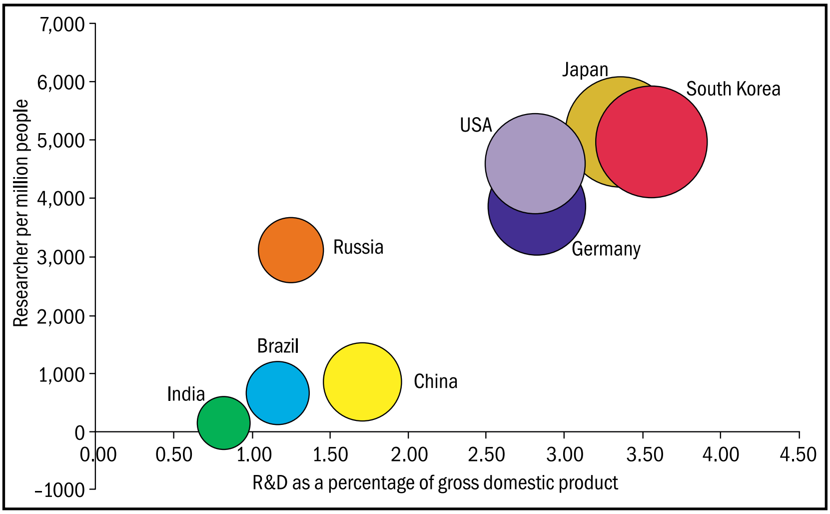

Figure 1.3 R&D Expenditure (percentage of GDP) and S&T Human Resources (per million people) of BRICK and other countries, 2009
Note: Size of circle reflects the relative amount of annual R&D spending by the country
Source: R&D expenditure data from World Development Indicators, World Bank; S&T human resources data from UNESCO

accounted for the largest number of patent applications received by any single IP office with fastest annual growth in filings received. India is also included in the top ten list in terms of patent applications filed in its patent office (See Figure 1.5). Looking at the number of patents granted in the USA, India has increased its number of patents from 8 in

1980 to 1,137 in 2010 whereas China witnessed a rapid increase in the number of patents from four in 1980 to 3,303 in 2010 (Ramani 2014).[2]

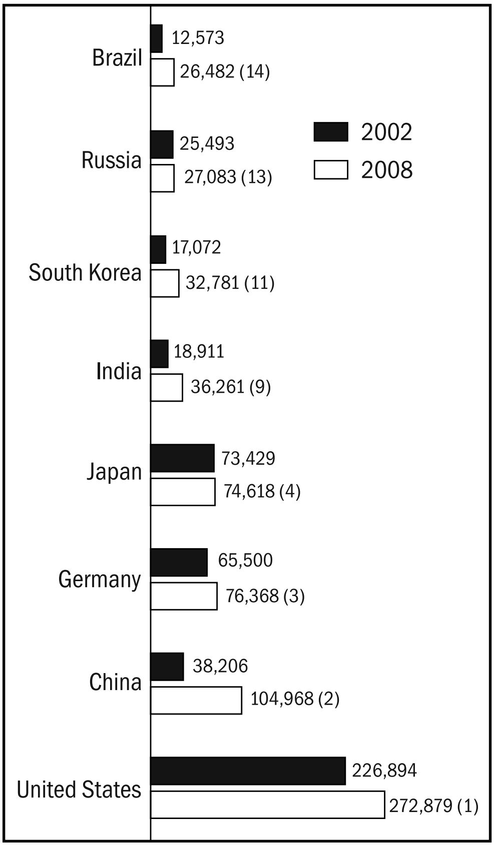

Figure 1.4 Publications by BRICK and other Countries, 2002 and 2008
Note: Figures in parenthesis indicate global ranking in publications of respective countries in 2008
Source: UNESCO Science Report, 2010

While discussing the innovation ecosystem, it would also be prudent to look at how science and technology is being perceived in contributing to the nation's growth in the various vision documents of the government.

Vision 2020 plan proposed by Late Dr APJ Abdul Kalam identifies five areas to make India a developed country by the year 2020, viz., agriculture and food processing, infrastructure with reliable electric

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[2] Ramani, S.V. (ed.) (2014). *Innovation in India: Combining Economic Growth with Inclusive Development*, New Delhi: Cambridge University Press.

3.1

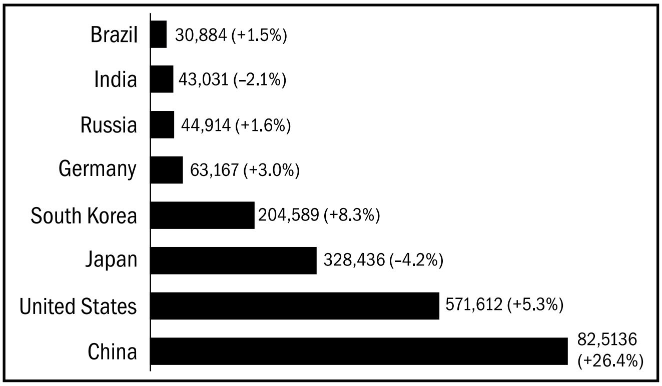

Figure 1.5 Patent Applications by BRICK and other Countries in their Respective IP Offices, 2013
Note: Figures in parenthesis indicate percentage increase or decrease over the previous year
Source: WIPO (2014)[3]

power, education and healthcare, information and communication technology, critical technologies and strategic industries.

The Indian National Science Academy (INSA), during the Platinum Jubilee Year in 2009, commissioned a group of comparatively young scientists to prepare a draft vision document for Indian science. 'A Vision Document for Indian Science', released in August 2010, supposed to serve as a guide for Indian science policy in the short and intermediate term, addresses the four key problems in Indian science: bureaucracy, hierarchy, lack of autonomy, and insufficient participation of scientists at different levels.

A vision document for Indian science, prepared by Indian Prime Minister's Science Advisory Council, and released in September 2010 has charted a roadmap for the growth of Indian science for the next 20 years. The 47-page report, 'India as a Global Leader in Science' has called for a hike in R&D expenditure to 2.5 per cent by 2020 (against 0.8 per cent at present) and creation of an environment for generating S&T human resources to the tune of at least 15 lakh graduate scientists, 3 lakh postgraduate scientists, and 30,000 PhDs every year by the year 2025. The report suggests the need to move from incremental innovations to radical innovations and proposes the creation of a public company for supporting start-up ventures up to INR 10 billion, besides tax incentives to innovative companies and extra-budgetary grants for new ideas and innovation in government-funded research organizations and encouraging their scientists to set up commercial

[3] World Intellectual Property Organization (2014) WIPO IP Facts and Figures. Available at <http://www.wipo.int/edocs/pubdocs/en/wipo_pub_943_2014.pdf>.

ventures. The document emphasizes the role of science in the next stage of national development and various socio-economic sectors; and also attempts to link basic science research programmes to development challenges related to food, energy, and water security.

The Twelfth Plan Approach Paper calls for a well-enunciated Science, Technology and Innovation policy, which is supported by an ecosystem that addresses the national priority for inclusive and accelerated growth. Towards this, a paradigmatic shift in the S&T system from the current input driven model to an output directed development strategy has been envisaged. For aligning S&T with developmental needs, the paper highlights the need for breakthrough innovations and areas like energy, water, health, and agriculture, requiring significant S&T input. For fostering innovation, the need for a framework that takes into account the entire life cycle of ideas would be required and a critical review of the relevance of the areas of S&T research would be needed to release the much needed resources, both financial and human, to the present priority areas. It also calls for transferring some of the research programmes to the university system from the national laboratories. Targeting an overall increase in R&D expenditure to 2 per cent of GDP by the end of the Twelfth Plan, the need for greater private sector R&D expenditure to at least 50 per cent in the Twelfth Plan from the present 25 per cent has been envisioned. The paper also proposes to further expand the Inter-University Centres and Inter-Institutional Centres to bring about functional connectivity across universities and domain institutions.

The Science, Technology and Innovation Policy of India, 2013 prepared by the Department of Science & Technology (DST), recognizes the role of the science, technology and innovation (STI) system in the National Action Plan on Climate Change (NAPCC). The document states that the STI system will 'serve as a source of strategic knowledge to cope with the challenges of climate variability and change as well as to meet equity-based differentiated and shared responsibilities of India'.

To foster a culture of innovation, R&D, and scientific research in India, the Government of India has announced to establish an ATAL Innovation Mission (AIM) in National Institution for Transforming India (NITI) Aayog. AIM will be an Innovation Promotion Platform involving academics, entrepreneurs, and researchers and will provide funds to a network of institutions to conduct research on innovations that can improve economic growth and job creation. The mission will also provide inputs to all central ministries on innovation and suggest a funding mechanism for result-oriented research. It would also promote a network of world-class innovation hubs in India. In the budget for 2014–15, INR 150 crore ($2.5 million) has been allotted for the innovation mission.

1.3 Low carbon technology innovation initiatives in India

India is ranked 21st among 40 countries in the Global Cleantech Innovation Index, 2014, brought out by WWF and the CleanTech group (Figure 1.6). The average score of India on the overall index

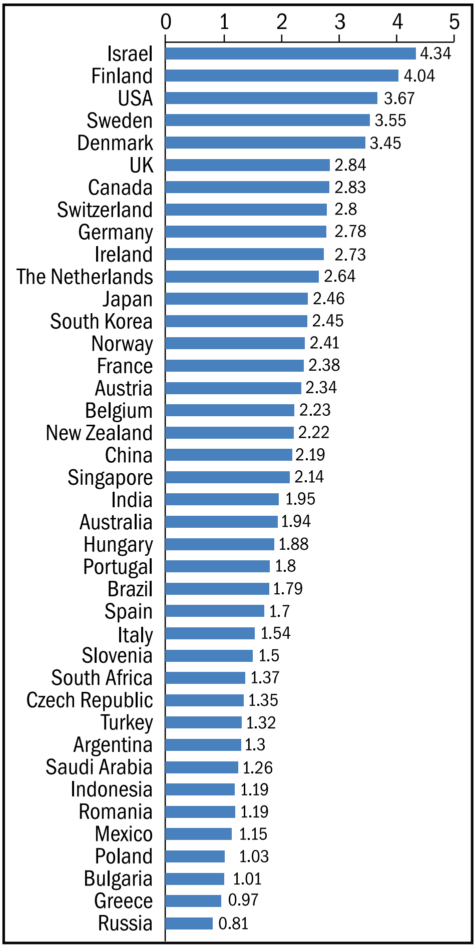

Figure 1.6 Cleantech Innovation Index for Different Countries, 2014
Source: Global Cleantech Innovation Index (2014). Available at http://www.cleantech.com/wp-content/uploads/2014/08/Global_Cleantech_Innov_Index_2014.pdf

is characterized by weak general innovation inputs, an average entrepreneurial culture, and an average clean technology innovation, although its performance in clean technology-specific innovation drivers, based on the country's public R&D spending and density of cleantech funds is higher (See Figure 1.7). On the commercialization of clean technologies front, India's performance is low because of low renewable energy consumption and few publicly traded cleantech companies. As per the report, India has a strong potential to rise through the ranks, as it possesses a strong climate for growth and development, high levels of pollution, or resource drivers to commercialize clean technology innovation.

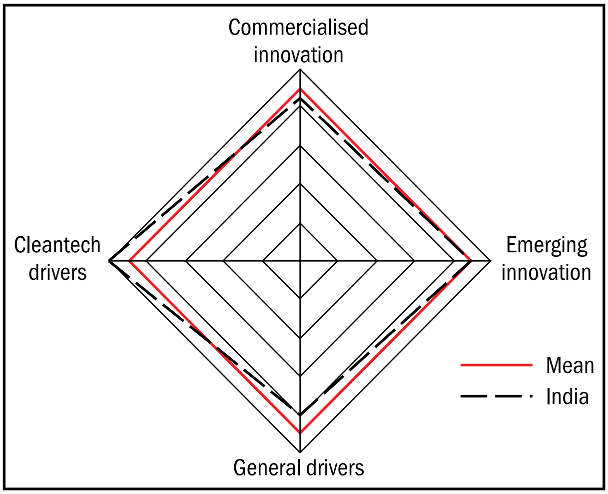

Figure 1.7 India's Performance Profile in Global Cleantech Innovation, 2014
Source: Global Cleantech Innovation Index (2014). Available at http://www.cleantech.com/wp-content/uploads/2014/08/Global_Cleantech_Innov_Index_2014.pdf

A range of initiatives have been initiated towards low carbon developmentin India. The Technology Development Board (TDB), Department of Science and Technology, Government of India, is responsible for aspects related to technological development in the country. With the support of the World Bank, TDB has initiated a project to create a Facility for Low Carbon Technology Deployment (FLCTD) with resources of approximately of USD 9.1 million. The project aims at promoting and adopting increasing use of new technologies in crucial energy-consuming applications in the country, so that the new appliances and machines installed over the next decades consume less energy to deliver the required performance. To begin with, the project focuses on three areas: *(i)* industrial low-grade waste heat recovery; *(ii)* pumping; and *(iii)* heat transfer in HVAC (heating, ventilation, and air conditioning), cold storage, etc. The main activity of the projects will be innovation challenges that will award teams who develop prototypes that meet performance-based technical specifications and also provide support for deployment of the selected prototypes by industrial and other users.

The National Clean Energy Fund has been created by the government in 2010 to fund research, innovative projects in clean energy technologies, and environmental remedial programmes. Any project/scheme relating to innovative methods to adopt clean energy technology and research & development are eligible for funding under the NCEF. However, no projects relating to basic/fundamental research are supported through NCEF. An indicative list of projects supported under NCEF includes: projects supporting the development and demonstration of integrated community energy solutions, smart grid technology renewable applications with solar, wind, tidal, and geothermal energy; projects in critical renewable energy infrastructure areas such as silicon manufacturing; projects, which result in replacing existing technology in energy generation with a more environmentally sustainable approach; Projects related to environment management, particularly in the geographical areas surrounding the energy sector projects; renewable/alternate energy and clean fossil energy related projects; Mission projects identified in the National Action Plan on Climate Change (NAPCC) and projects relating to R&D to replace existing technologies with more environment friendly ones under National Mission on Strategic Knowledge for Climate Change (NMSKCC). As of September 2014, NCEF has recommended projects worth INR 18,577 crore (USD ~3,096 million)

WWF-India launched the cleantech innovation platform called as Climate Solver platform in 2012 to provide an interface between low carbon technology innovators and industry associations, investors, government, incubation centres, and the media. Climate Solver aims to showcase the potential of innovative clean technologies developed by small and medium enterprises, expand their outreach, and generate awareness about them along with the overall value of innovation, as an immediate and practical solution to climate change. The objective of this platform is to promote the use of innovative clean technologies and thereby contribute to reducing emissions and enhancing energy access. Towards this endeavour, Climate Solver is partnering in India with the Confederation of Indian Industry (CII), New Ventures

India, Centre for Innovation Incubation and Entrepreneurship (IIM Ahmedabad), Skyquest Technology Consulting Pvt Ltd, and Technology Development Board (Department of Science and Technology, Government of India). For financing clean technology innovation, the Government of India is also obtaining financing from the Clean Technology Fund (CTF) to support a set of projects and initiatives that have been identified for their critical impact on social and economic development with significant co-benefits for climate change. To support low carbon growth objectives in the country, an allocation of USD 775 million has been made in 2011 under the CTF which would finance eight projects combined with additional resources from Multilateral Development Banks (MDBs), Government of India, private sector, and other sources. As of October 2014, four projects viz., Himachal Pradesh Environmentally Sustainable Development Policy Loan, Super-Efficient Equipment Program (SEEP), Partial Risk Sharing Facility for Energy Efficiency (PRSF) and Solar Park: Rajasthan, amounting to USD 375 million have already been approved from CTF and the remaining USD 400 million is yet to be sanctioned for the following projects—Solar Park: Gujarat, Solar Park: Maharashtra, Integrated Solar Hybrid Project, and National Mission on Enhanced Energy Efficiency—Perform, Achieve, Trade (PAT)—Phase 1.

1.4 Understanding Science, Technology and Innovation for Sectors

This section describes the current activities related to R&D and policy initiatives in India relevant for low carbon development in the identified sectors.

1.4.1 Renewable Energy

Innovation and R&D

The continuous need to innovate and to pursue R&D vigorously in direct and translational research has been emphasized upon for promotion of renewable energy in India. The revised target of the Government of India of adding 175,000 MW of renewable energy capacity by 2022 enhances the imperative for R&D in the sector. Government support for R&D in the sector is directed towards cost reduction, improvement of efficiency, reliability, long-life, and manufacture of complete systems. Efforts are directed towards building the indigenous capacity in renewable energy, by making it more competitive and self-sustainable. Strategic drivers behind R&D in renewable energy relates to: diversification of the energy base to improve energy security; augmentation of energy supply in rural areas in a cost-effective manner to improve the quality of life; and reducing the GHG emission impact from the energy conversion process.

India's advantages in terms of endowment of natural resources and the availability of scientific and industrial infrastructure has led to engagement in leading-edge R&D in several key areas such as rural energy, solar energy, energy from urban and industrial wastes, wind, bio-mass and small hydro, ocean and geothermal energy, and new technologies—fuel cells and hydrogen. Synergies are also being sought with Indian Space Research Organization (ISRO) for a more scientific resource assessment and data validation of both wind and solar energy potential. As part of the renewable energy programme in India, solar, wind, biomass energy, and small hydropower is being considered as important resources and have been a research focus for a number of institutions within the country. The Solar Energy Centre is now the autonomous National Institute of Solar Energy (NISE) that acts as the nodal agency for R&D. The Centre for Wind Energy Technology (C-WET), Chennai, is now the autonomous National Institute of Wind Energy (NIWE). The National Institute of Renewable Energy (NIRE) will focus on research on bio-energy. The Alternate Hydro Energy Centre (AHEC) established in Indian Institute of Technology, Roorkee, focuses on power generation through the development of Small Hydropower projects. Efforts towards skill development are also being promoted with the recently launched programme, Suryamitra (Friends of the Sun) for Solar Energy and solar and biomass technician courses under the vocational training programmes.

R&D for the renewable energy sector has witnessed growth in the recent years. Outlay for R&D activities in the Ministry of New and Renewable Energy (MNRE), Government of India, is presently around INR 910 crore (approx. USD 152 million) in the Twelfth Five-Year Plan, up from 525 crore (approx. USD 88 million) in the Eleventh Five-Year Plan which funded 169 projects.

Table 1.1 provides an overview of the R&D projects supported by the MNRE for various years.

Table 1.1 R&D Projects Supported by MNRE

Year(s)	Total no. of projects sanctioned	Amount (INR crore)	Amount (USD million)	Areas
2014–15	22	N.A	N.A	Solar thermal, solar photovoltaic, biogas, hydrogen and wind hybrid systems

2013–14	17	N.A	N.A	Higher efficiency solar cells, Solar thermal, Hydrogen energy storage, Fuel cells, bio-fuel, bio-gas and waste to energy
2012–13	4	3.43	1	Hydrogen, Solar Energy, Biomass cook stoves programme continued
2011–12	29	118.60	20	Solar thermal power, solar PVs, hydrogen and fuel cell, biofuel, and biomass cook stoves
2009–10	21	N.A.	N.A.	Solar energy, bio-energy and new technologies
2006–07, 2007–08, and 2008–09	71	71.0	12	Fuel cells, hydrogen, concentrator-photovoltaic system, biogas and solar thermal refrigeration

Source: MNRE (2015)

In addition to government investment, there has been considerable interest and investment in R&D by the industry. The RE-Invest 2015 mobilized 200 global investors and financers that made commitments of close to 273,000 MW for the renewable energy sector.

Policies Promoting Renewable Energy Innovation

The Ministry of New and Renewable Energy (MNRE) support for renewable energy R&D activities comprises areas including grid interactive renewable energy, rural and urban energy needs, waste to energy, alternate fuels, and emerging technologies. Recognizing the market led nature of the renewable energy sector and to make the sector a net foreign exchange earner, the Ministry primarily aims to support industrial R&D to make the industry competitive.

A comprehensive policy on research, design, development and demonstration (RDD&D) is in place to support R&D in the new and renewable energy sector, including associating and supporting RDD&D by industry for market development. In this regard, a scheme has been evolved that provides guidelines for project identification, formulation appraisal, approval, and financial support.

Various policy instruments for promoting R&D in the renewable sector are broadly categorized as market-based policy instruments and command and control policy instruments (Box 1.1).

Box 1.1: Policy Instruments

Market-based policy instruments

Feed-in-tariffs (FITs): FITs are minimum prices at which renewable energy power (REP) must be purchased from the generating companies or private producers through contracts (power purchase agreements) with transmission or distribution utilities or with trading licensees.

Renewable Energy Certificate (REC) mechanism pooled with an Average Power Purchase agreement (APP) is also available. Developers can opt for it if they are not interested in the feed-in-tariff (or preferential tariff) scheme.

Policy and fiscal incentives: Incentives to attract private sector investment in REP development include, among others tax holiday for REP generation; other financial incentives like accelerated depreciation for wind energy and capital subsidies for devices with high initial cost. In addition, administrative procedures are facilitated for projects promoting REP.

Command and control policy instruments

Renewable purchase obligations (RPOs): The RPO makes it necessary for each distribution licensee to include REP as a certain percentage in its resource portfolio. Percentages and timetables of implementation vary across states, across renewable energy sources and across distributors. Distribution licensees can satisfy this obligation by either owning a renewable energy facility and producing their own power, or purchasing it from other utilities producing it more cheaply.

Renewable Generation Obligations (RGOs): The RGO is an obligation on a conventional power producer to produce a certain proportion of power through renewable resources.(Currently under consideration)

Source: Adapted from Schmid (2012)

1.4.2 Non-renewables

Innovation and R&D

The technical challenges of the electricity sector in India include low efficiencies of thermal power plants, continued reliance on coal plants, and inadequate transmission and distribution networks. The Ministry of Power (MoP), Government of India, has set up ambitious plans for the power sector during the Twelfth Five Year Plan to ensure sustainable development of the power sector. It has estimated a capacity addition of about 88,537 MW during the Twelfth Five-Year Plan (MoP 2015).TEDDY 2014–15 informs that reliance on coal will be as high as 50 per cent in 2031 therefore, improving the efficiency of electricity generation from coal is needed to exploit the extensive domestic coal resources and reduce air pollution. Integrated gasification combined-cycle (IGCC) technology could achieve this. However, it has to be adapted to India's coal quality or India has to rely on imported coal. The Indian high-ash coal requires the use of fluidized-bed gasifiers, which is different from the well-established entrained-flow gasifier used for low-ash coals (Remme *et al*. 2011).

The integrated gasification combined cycle (IGCC) is an advanced coal combustion technology which improves the overall cycle efficiency of the system, for generation of electricity. It is a process in which the fuel is gasified in an oxygen or air-blown gasifier operating at high pressure. The raw gas, thus produced is cleaned of most pollutants (almost 99 per cent of its sulphur and 90 per cent of nitrogen pollutants). It is then burned in the combustion chamber of the gas turbine generator to generate power. The heat from the raw gas and hot exhaust gas from the turbine is used to generate steam which is fed into the steam turbine for power generation. A 6.4 MW IGCC pilot unit set up by Bharat Heavy Electricals Limited (BHEL) has been operating since 1989. It is based on Siemens and Alstom technology. Construction of the 200 MW IGCC demonstration plant in Vijayawada, Andhra Pradesh, began in 2010 by a consortium of BHEL, Andhra Pradesh Power Generation Corporation Limited (APGENCO), and the Department of Science and Technology. 3.1

Coal plants are concentrated in regions close to the coal mines (such as in Uttar Pradesh and West Bengal), and in more distant regions with high electricity demand (such as in Maharashtra and Andhra Pradesh). India is working on supercritical coal-fired power plants (660 MW/800 MW units); 37 units at eleven power plant sites were under construction, corresponding to a capacity of around 26 GW (Platts 2010).

Supercritical technology is mandatory for the ultra-mega power projects (UMPP), five of which will add 20,000 MW capacity (MoP 2015). The minimum capacity for a UMPP is 4,000 MW. The projects are awarded to developers through competitive bidding and operated through plug and play mode, thereby reducing investment bottlenecks. In the Twelfth Plan, a capacity addition of 78 GW of coal-based power is planned along with 100 GW in the Thirteenth Plan based on supercritical and ultra-supercritical technology (Goel *et al*. 2015). Supercritical plants operate at increasingly higher temperatures and pressures (538°C, 246–250 kg/cm^2) and, therefore, achieve higher efficiencies than conventional subcritical units and significant carbon dioxide reductions. This is currently being enhanced to a heat level of 565°C, 246–250kg/cm^2 (CEA 2013). As mentioned earlier, a large number of supercritical units are under construction, using either indigenous or outsourced technologies (TEDDY 2012–13).

Research on Advanced Ultra-Supercritical Thermal Plants (AUSCTP) is ongoing (DST 2014). In September 2010, the Indira Gandhi Centre for Atomic Research (IGCAR) announced the development of an advanced ultra-supercritical boiler with a steam capacity of 350 bar and 700°C for an 800 MW coal power plant. This will be undertaken in cooperation with BHEL and the National Thermal Power Corporation (NTPC), the largest and state-owned power utility in India. Construction of the plant should start by 2018 (Jagannathan 2010). The Cabinet Committee on Economic Affairs (CCEA) is in the process of approving INR 1100 crore (USD 183 million) to develop AUSCTP technology.

There is also emphasis on the development of a smart grid with a smart grid research laboratory comprising of a Smart Grid Technology Centre. A total sum of INR 11.05 crore (USD 2 million) has been sanctioned for its development under the National Smart Grid Mission. In addition, the capacity of smart metering and tamper proof meters under the Integrated Power Development Scheme is also being enhanced through the use of Information and Communication Technology (ICT) (MoP 2015).

Policies Promoting Non-Renewable Energy Innovation

The Ministry of Science and Technology is the central government ministry that formulates and administers the rules and regulations related to science and technology development in the country. From a Carbon Capture and Storage (CCS) standpoint, the Climate Change Programme of the Department of Science and Technology (DST), which is one of the three departments under the ministry, is of particular importance. In 2007, DST set up the National Programme on Carbon Sequestration (NPCS) with the sole aim of emerging as a leader in pure/applied research and its industrial applications in important sectors of the economy. In addition, the Indian Carbon Dioxide Sequestration Applied Research (ICOSAR) was set up to facilitate information sharing (Goel *et al*. 2015). The focus areas of its research includes carbon dioxide sequestration through micro algae bio-fixation techniques, carbon capture process development, policy development studies, and network terrestrial agro-forestry sequestration modelling. In addition, state-owned entities such as Oil and Natural Gas Corporation (ONGC), National Aluminium Company (NALCO), NTPC, along with research organizations like Indian Institute of technology (IIT) and Indian Institute of Petroleum (IIP), Dehradun and working on research in CCS. At the international-cooperation level, India has also engaged in USA's FutureGen project; Big Sky Carbon Sequestration partnership, and the Asia Pacific Partnership for Clean Development and Climate. India has also engaged in laboratory collaborations with National Energy Technology Laboratory, USA; Pacific Northwest National Laboratory, USA, and SINTEF, Norway (Goel *et al*. 2015). Currently issues of commercial deployment, high investment costs, and associated risks with underground storage must be addressed by R&D. Only one project by the Indian Farmers Fertilizer Limited is in operation using amine technology for CO_2 capture (ibid.). An integrated approach to R&D has to be adopted that informs on carbon capture and sequestration, pre-combustion, combustion and post-combustion options, bio-sequestration, terrestrial sequestration, earth process utilization, and storage in the oceans (ibid).

According to the Working Group on Power for the Twelfth Plan, R&D programmes can be facilitated through various schemes such as the National Perspective Plan (NPP) and the Research Scheme on Power (RSoP) (MoP 2012). Some of them can be in collaborative mode with participation from Central Public Sector Undertakings (CPSUs), industry and academic institutes, and utilities. The Central Power Research Institute (CPRI), the National Thermal Power Corporation (NTPC), the National Hydro Power Corporation (NHPC), Satluj Jal Vidyut Nigam Limited (SJVNL), Power Grid, DISCOMs, Bharat Heavy Electronics Limited (BHEL), the Council for Scientific and Industrial Research (CSIR), Crompton Greaves, Indian Institute of Technology (IITs), and National Institute of Technology (NITs) will execute the projects identified. The projects will be coordinated and managed by the Central Electricity Authority (CEA) and CPRI, on behalf of MoP. The Standing Committee on Research and Development (SCRD), which is presently managing NPP R&D, can also be strengthened to make policy documents on R&D in the power sector and prioritize problems of national importance having short-, medium-, and long-term impacts (ibid). The R&D schemes sanctioned by CPRI under the Twelfth Plan (2012–17) is provided in Table 1.2.

Table 1.2: Research Related Schemes Sanctioned by CPRI under the Twelfth Plan (2012–17)

Scheme	Amount (INR crore)	Amount (USD million)	Areas
In-house research scheme of CPRI	15	3	Focus on improving and expanding Research and testing facilities. Finding new techniques for product and process improvements also ensuring product standardization

Research scheme on power	20	3	Focus on decentralized generation, power electronics application to power system, improvements in power generation, transmission and distribution systems, Advanced Remaining Life Assessment (RLA) methodologies, Information & Communication technology applications to Power Sector and Insulation Engineering and Technology for High temperature superconducting (HTS) based Power Apparatus
R&D under National Perspective Plan	45	8	New Product and Process development leading to field implementation

Source: CPRI (2015)

In order to initiate the smart grids the Government of India has set up the India Smart Grid Task Force along with the Indian Smart Grid Forum that would ensure the development and demonstration of smart grids in a cost effective, innovative, and scalable manner, by bringing in together all the key stakeholders and enabling technologies in a public-private partnership framework (Goel *et al*. 2015).

MoP (2012) also recommends that SCRD serve as an apex committee for R&D in the power sector and look into the following issues:

- Utilities should have collaboration with research institutes so that the problems faced by them can be taken up as research work which will have immediate application.
- Manufacturers should also participate and sponsor the research programmes relevant to the power sector.
- Successful R&D projects should be given wide publicity within the power sector
- The power sector should have joint collaboration with similar research institutes abroad to engage in exchange of know-how and the latest methods.

The Power Grid Corporation of India Ltd (PGCIL) is facilitating the development of a transmission system for granting long-term access to private producers. Nine high-capacity power transmission corridors (HCPTCs) have been finalized to meet the evacuation requirement of independent power producers (IPPs) coming up in Andhra Pradesh, Chhattisgarh, Jharkhand, Odisha, Madhya Pradesh, Sikkim, and Tamil Nadu at an estimated cost of INR 580,000 million (USD 11.6 billion approx.)—the Central Electricity Regulatory Commission (CERC) has already given regulatory approval to two new and two existing

HCPTCs in Chhattisgarh, Maharashtra, and Madhya Pradesh (TEDDY 2012–13). PGCIL has taken up the implementation of these corridors in a phased manner, matching the progress of the power projects.

In order to build capacity of the power sector and to make the power sector competitive, the National Power Training Institute has been set up as the apex institution with state of the art training infrastructure and expert faculties. As the power sector is highly technology intensive, there is a need to promote extensive research and development in the country, especially while considering introduction of new and advanced technologies. Collaborative research, in a phased manner, is needed to bridge knowledge and technology gaps, build expertise, and to find solutions for the problems existing in the system and for the problems that may arise in the future.

1.4.3 Transport

Innovation and R&D

Of late, transitioning to a green transportation pathway has been emphasized upon in India. Green technologies would have a key role to play in terms of helping achieve this goal. Some of the transport technologies that can help achieve green transport goals are listed in Table 1.3. Research efforts in transport technologies in India have largely been directed towards improving the fuel efficiency of conventional engines, development of alternative technologies, such as electric vehicles, and the like.

Table 1.3: Low Carbon Technologies in Transport and Associated Co-benefits

Technology	Promotes energy efficiency	Reduces local pollutants and GHG emissions	Increases use of renewable resources	Reduces use of non-renewable resources	Minimizes waste and land pollution	Reduces noise pollution	Promotes safety
Hybrid electric vehicles	X	X		X		X	
Battery electric vehicles		X		X		X	
Solar electric vehicles		X	X	X		X	
Fuel cell vehicles		X	X	X		X	
Improved diesel vehicles	X	X		X			
Flex-fuel vehicles		X		X			

contd...

Table 1.3: Low Carbon Technologies in Transport and Associated Co-benefits

Technology	Promotes energy efficiency	Reduces local pollutants and GHG emissions	Increases use of renewable resources	Reduces use of non-renewable resources	Minimizes waste and land pollution	Reduces noise pollution	Promotes safety
Energy efficient technologies to enhance fuel savings (vehicle add-on technologies)	X	X		X			
Vehicle technology improvements (e.g., aerodynamics)	X	X		X			
Retrofitting technologies	X	X		X			
Alternative fuel technologies–Biofuels, CNG, LNG and LPG		X					
Material substitution technologies focussing on life cycle CO_2 emissions savings		X			X		
Non-motorized transport vehicles		X		X		X	
Public transport systems		X		X			
Smart traffic infrastructure/intelligent transport systems/use of information technologies for traffic management		X		X			X
e/tele-technologies for travel demand reduction		X		X		X	
Material substitution, use of composite materials					X		
Recycling technologies					X		
Silencers						X	
Tyre-pressure monitoring, adaptive cruise control/collision mitigation, emergency brake assist/collision mitigation, etc.	X	X		X			X

Source: 'Green transport technologies', TRL and TERI Joint Background Paper for UNEP Green Economy Report

R&D efforts in the automotive sector in India are primarily supported by the Department of Heavy Industry (DHI) through the automotive cess funds allocated to the Development Council for Automobile and Allied Industries (DCAAI). Till date, DCAAI has approved 209 projects related to R&D in the automotive sector since 1983–84 with total project cost of INR 543.55 crore (USD 91 million). The Technology Development Board (TDB) of the Department of Science and Technology (DST) which aims at accelerating the development and commercialization of indigenous technologies or adapting imported technologies to wider domestic application also provides financial assistance in the form of equity, soft loans, or grants.

Presently, most policies for promoting R&D in the country are focused on encouraging 'in-house R&D', conducted in CSIR approved in-house R&D units of companies. The Technology Information Forecasting Assessment Council (TIFAC) of DST in association with the Department of Heavy Industry (DHI) has initiated the CAR (Collaborative Automotive R&D) Programme in 2005, for undertaking consortia based pre-competitive automotive R&D projects. This programme has seen 11 academia–industry consortia research projects, involving 14 national laboratories/institutes, 15 companies, and 10 technology-intensive SMEs. The total amount of funds deployed for the CAR activity was INR 35 crores (USD 7 million approx.) over the past eight years.

3.1

The Department of Heavy Industry has also proposed a budget of INR 175 crores per year (USD 35 million approx.), increasing by INR 25 crores (USD 5 million approx.) yearly. It will be made available from the automotive cess for the next five years (2012–17) for automotive R&D purposes. The majority of this will be used to fund R&D activities related to electric vehicles and the required testing infrastructure. Further, the Automotive Mission Plan 2006–16 (AMP 06–16) and the National Electric Mobility Mission Plan 2020 (NEMMP 2020) provide a roadmap for affordable and environmentally friendly transportation and give direction for the R&D in the sector. Manufacturing and faster adoption of hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and extended-range electric vehicles collectively referred to as xEVs is the key focus in NEMMP 2020. The Government has also launched Faster Adoption and Manufacturing of Electric Vehicles (FAME) aims to introduce 6–7 million xEV's on the road by 2020. It will serve a twin goal of reducing GHGs with estimated savings of 9,500 million litre equivalent of INR 62,000 crore (USD 10,333 million), along with employment generation with the 'Make in India' mandate. A subsidy incentive of INR 738 crore (USD 123 million) is being allocated.

To develop domestic xEV manufacturing capacity and cost reduction, the need for R&D aimed at greater localization and responsive to the needs of the country has been emphasized upon in NEMMP 2020. Towards this, there is a need for R&D investments both from the government and the private sector, adopting either a consortium building approach or direct grant models. Table 1.4 depicts the government R&D investments in the transport sector as envisaged in the report of the Working Group on Automotive Sector for the Twelfth Five-Year Plan (2012–17).

Table 1.4: R&D Focus and Proposed Investment in Transportation Technologies for 2012–22

Transportation technologies	R&D focus	R&D investments in INR crores (USD million)					
		Component research		Component development		Component and vehicle testing infrastructure	
Battery cell	Cell materials and electronics	4-wheeler	200 (40)	2-wheeler Bus		4-wheeler	50 (10)
		2-wheeler	200 (40)			50 (10)	
		Bus	200 (40)			80 (16)	
Electric motor		4-wheeler	125 (25)	4-wheeler	125 (25)		
		2-wheeler	125 (25)	2-wheeler	125 (25)		
		Bus	125 (25)	Bus	125 (25)		

Note: Numbers in parantheses indicate approximate values in USD million
Source: Report of the Working Group on Automotive Sector for the Twelfth Five-Year Plan (2012–17), Department of Heavy Industry, Ministry of Heavy Industries and Public Enterprises

Policies to Promote Innovation in the Transportation Sector

In India, laws and regulatory framework in the transport sector, particularly the road sector, have tried to attenuate to some extent, the problems of GHG emissions and pollution, attributable to this sector. The primary legislations governing road transport are the Motor Vehicles Act, 1988, and the Central Motor Vehicles Rules, 1989. The former is the result of a series of amendments brought to the Motor Vehicles Act, 1938. The objectives of some of these amendments have been to encourage adoption of higher technology in the automotive sector, and pollution-control measures among others (recommendations of the Working Group set up in 1984 to review the provisions of the Act). Some of the important provisions of the 1988 legislation provide for standards for anti-pollution measures, provision for issuing fitness certificates of vehicles by authorized testing stations with the requirement that vehicles obtain regular 'Pollution Under Control' certification to monitor levels of suspended particulate matter and noxious gas emissions. A number of initiatives and policies have been adopted in India aimed at improving vehicle emission norms, as well as improving fuel quality. The Auto Fuel Vision Committee has recommended universal adoption of Bharat Standards BS IV, BS V, and BS VI emission norms across the country by 2017, 2020, and 2024, respectively. In order to encourage alternate fuels, the Government has come up with the National Policy for Biofuels, under which a blending target of 20 per cent has been aimed at by 2017. There have also been a number of judicial interventions, particularly in New Delhi, which have ensured conversion of all Government of India vehicles into CNG, restrictions on the plying of old commercial vehicles and replacement with new vehicles on CNG or other clean fuels, transformation of the city bus fleet into a single mode on CNG, augmentation of public transport, etc.

Innovations in last mile connectivity of e-cart or e-rickshaw which are special purpose battery operated vehicles less than 4,000 watts, having three wheels for carrying goods and passengers have been given legal status under the Central Motor Vehicles (Amendment) Bill, 2015.

A key issue is that the research in the transport sector is primarily being undertaken by the industry. The government needs to provide support by collaborating with ongoing programmes in research institutes and industries to encourage R&D and promote innovation.

1.4.4 Buildings

Innovation and R&D

Smart cities are the emerging model for urban development in India. Smarter Buildings that are designed in energy efficient ways will be an integral part of these smart cities. According to Indian Green Building Council, currently India has a 2.2 billion sq. ft of green buildings footprint, making it the second largest in the world and the target is to construct 10 billion sq. ft by 2022. The construction sector, of which buildings is a subsector, is the second largest employer after the agriculture sector. The sector is highly diverse, covering a spectrum of activities carried out by a group of linked organizations providing design and engineering, supplying materials and equipment, carrying out construction work, and providing operation and maintenance services.

The report of the Planning Commission's Working Group on Construction for the Twelfth Five-Year Plan (2012–17) points out three thrust areas:

- Focus on innovation
- Strengthening the R&D institution and facilitating establishment of new institutes (given the huge lack of R&D in the academia, research institutes, and industry)
- Incentivizing the R&D and innovating initiatives

It further emphasizes making 'green construction' (including green buildings) a major thrust area and adherence to the environmental protection laws by the sector in a manner that does not retard progress.

Energy efficiency is one of the sub-tasks of demand side management, energy efficiency, and energy conservation where buildings also play a certain role.

In 2001, the Government of India created the Bureau of Energy Efficiency (BEE) to institutionalize the promotion of energy efficiency and building energy efficiency. BEE focusses on deployment which can help commercialization. R&D in the building sector in India is undertaken by a number of research institutions as listed in Table 1.5. The Table is only an indicative list.

Table 1.5: Building-related Research and Deployment Institutions in India

Name	Areas
Central Building Research Institute (CBRI)	Building materials; development of new technologies for the promotion of building materials and systems; transfer of developed technologies to industry for further commercialization. R&D in the field of efficiency of buildings have led to climatic zoning of the country for building design, formulation of standards for thermal and visual comfort, wind speed, and lighting levels indoors and evolution of guidelines and methods for designing energy-efficient buildings. Development of devices for solar energy utilization has resulted in commercial exploitation of various types of solar water heaters. An autonomous hybrid PV-thermal system has also been developed for electrical and thermal use in buildings
Indian Green Buildings Council (IGBC)	Has a rating system for green buildings in collaboration with the UK government
Indian Institute of Technology (IITs)	Solar, zero-energy buildings, heat transfer
Bureau of Energy Efficiency (BEE)	Building codes and labels
International Council for Local Environmental Initiatives (ICLEI)	Sustainability and energy-efficiency projects deployed by local governments; a variety of energy-efficiency deployment programmes in urban and rural areas
Centre for Environmental Planning and Technology (CEPT)	Openings and fenestration in buildings

contd...

Name	Areas
Glazing Council of India (GCI)	Certification and labelling of envelopes and windows
Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE)	Development and promotion of heating, ventilation, and air conditioning (HVAC) standards and test procedures
National Institute on Solar Energy (NISE), MNRE	Solar resource assessment, solar thermal, solar buildings, solar photovoltaics, solar energy materials, solar thermal power generation, interactive R&D, technology evaluation, testing and standardization
The Energy and Resources Institute (TERI)	Energy efficiency research and deployment; green building demonstrations; building energy efficiency, building codes, solar energy, lighting, various deployment programmes
India Institute of Science (IISc)	Alternative building technologies and materials, energy-efficient and environmentally sound technologies; functional efficiency of buildings including climatic performance, energy, solar architecture; renewable energy; solar, biomass combustion and gasification, biomethanation, biofuels, etc.; renewable energy; energy planning, demand-side management, energy efficiency
Bharat Heavy Electricals Corporate R&D Centre	Solar lanterns, solar photovoltaics, solar water heating systems, surface coatings, building energy management

Source: Compiled from various sources

With considerable boost from BEE's initiatives, the energy efficient products market has grown considerably. The star labelling programme along with proactive information dissemination through TVC's and an attractive advertising campaign can lead to an increase in the sales. With the rising demand for insulation materials, high performance glass, heat reflective paints, energy-efficient masonry units and the like, the number of manufacturers and suppliers of these materials is also increasing. However, there is still a huge market potential for energy-efficient products, equipment, and technologies, in India. A few energy-efficient products available in India are given in Table 1.6.

There is also a potential and necessity for promoting alternate materials and construction technologies which are more environment-friendly, less resource-intensive, and respond to the diverse demands of the huge construction sector. Some of these include filler slabs, pre-cast lintels and *chajjas*, HI-SEB, pre-fabricated panes, pre-cast door/window frames/sunshades/staircases, bamboo mat corrugated sheet, bamboo particle board, sakura roof, etc. These materials and technologies are

Table 1.6: Energy-efficient Technologies in Buildings

Technology category	Products
Energy-efficient envelope	Roof and wall insulation High performance glazing Energy efficient masonry Heat reflective paints Heat reflective tiles
Efficient lighting system and controls	Energy-efficient lamps and luminaires Lighting controls: Timers, occupancy sensors, photo sensors
Efficient HVAC system and controls	High COP chillers Air handling units with variable air volume units Variable speed drives in motors Economizers Heat recovery wheels
BEE star rated appliances	Air conditioners (standards and labelling programme mandatory) Ceiling fans Direct cool refrigerators Frost free refrigerators (standards and labelling programme mandatory) Fluorescent tube lights (standards and labelling programme mandatory) Storage water heaters Distribution transformers (standards and labelling programme mandatory) Colour televisions Induction motors Pump sets LPG stoves Washing machines

Source: Compiled from various sources

made from locally available materials, are less resource-intensive and also give better thermo-physical properties, compared to conventional materials. There is also impetus to developing AAC bricks and RC bricks through Fly Ash technology. The private sector has also been playing an active role in developing indigenous technologies. A few emerging technologies recommended by the Building Materials and Technology Promotion Council (BMTPC) for further exploration to ensure better quality products are listed below:

- Fly ash-based bricks, RCC blocks, cellular light weight concrete, bamboo-based materials, bagasse boards
- Partial pre-fabrication technology along with easy to operate machines for deployment
- Monolithic concrete technology using plastic/aluminium composite formwork
- Rapidwall construction system

Research has gone into the brick making industry by the government, bilateral and multilateral agencies. The details are stated below in Table 1.7.

Table 1.7: Key Interventions from the Government for the Bricks Making Industry

Agency/Programme	Type of Intervention
Central Building Research Institute (CBRI), Government of India	Introduction of zig-zag firing technology and semi-mechanization process (1970s)
Central Pollution Control Board/Ministry of Environment and Forests	Air emission regulation for brick kilns (1990s)
Swiss Agency for Development and Cooperation	Introduction of Vertical Shaft Brick Kiln (VSBK) Technology (1995–2004)
United Nations Development Programme-Global Environment Facility (UNDP-GEF)	Introduction of hollow bricks and other resource efficient bricks (2009-ongoing)

Source: KPMG analysis, Greentech Knowledge Solutions Analysis

Apart from the above, there is a huge capacity building requirement for the sector. GoI has set up a Ministry of Skill Development and Entrepreneurship. Under the National Skill Certification and Monetary Reward Scheme branded as STAR (Standard Training Assessment and Reward), formal training programmes and systems related to skill assessment and certification of construction workmen is being undertaken.

Policies to Promote Innovation in the Buildings Sector

India has a comprehensive regulatory framework aimed at mainstreaming energy efficiency and green buildings through the use of both incentives as well as deterrents. The Environmental Impact Assessment (EIA) is an important management and regulatory tool which makes environmental clearance mandatory for building and construction projects with a built up area ≥ 20,000 sqm and ≤ 150,000 sqm; and for townships and large area development projects with a built up area ≥ 150,000 sqm. The Ministry of Environment, Forest and Cimate Change (MoEFCC) has also initiated a procedure to enable fast track environmental clearance for buildings and construction sector projects having green rating (Pre-Certification or Provisional Certification) under the rating programmes of GRIHA (Green Rating for Integrated Habitat Assessment) and IGBC (Indian Green Building Council). A list of policy initiative for the sector under the central government is provided in Table 1.8.

Table 1.8: Central Level Policy Initiatives on Green Buildings

Policy Action	Purpose
Sustainable Habitat Mission under the NAPCC	Mission calls for energy savings in buildings by calling for energy saving building codes mandatory for new commercial buildings
Energy Conservation Building Code (ECBC)	Ensures construction of energy efficient building with a concomitant reduction in energy demand
Green Rating systems for buildings (GRIHA: Green Rating for Integrated Habitat Assessment)	Aims to strike a balance between environment and development

Source: KPMG analysis, Greentech Knowledge Solutions Analysis

An important legislation in this context is the Energy Conservation Act, 2001, which has important provisions related to designated consumers, standards and labelling of appliances, energy conservation building codes (ECBC), creation of institutional set up (Bureau of Energy Efficiency), and establishment of the Energy Conservation Fund. The Act was amended in 2010 to also include commercial buildings having a connected load of 100 kW or a contract demand of 120 kVA and above under the purview of the ECBC under the EC Act. The scope of the Energy Conservation Building Code is to provide minimum energy standards for buildings having a connected load of 100 kW or a contract demand of 120 kVA. It aims to reduce baseline energy consumption by setting minimum energy performance standards for new commercial buildings, including building envelopes; mechanical systems and equipment, including heating, ventilation and air conditioning (HVAC) systems; interior and exterior lighting system; service hot water, electrical power and motors.

The Ministry of New and Renewable Energy (MNRE), Government of India, has also launched a scheme on 'energy efficient solar/green buildings'—modification of the building component of the ongoing scheme on 'promotion of solar thermal systems for air heating/steam generating applications, solar buildings and Akshay Urja sops'. The intent of the scheme is to promote widespread construction of green buildings in the country through a combination of financial and promotional incentives. According to an official circular released by the Ministry of New and Renewable Energy on September 17, 2009, all new buildings of the central government/public sector undertakings shall comply with the mandatory guidelines and benchmarks of at least a GRIHA (national rating system endorsed by the Ministry of New and Renewable Energy) 3 star rating. The Central Public Works Department (CPWD) has also issued an official circular on

March 16, 2009, which states that all constructions undertaken by CPWD shall be green. In view of this, all projects undertaken by CPWD shall comply with GRIHA guidelines and benchmarks and shall be at least internally certified as green by CPWD officers. To facilitate the process, CPWD has introduced the approved guidelines regarding green buildings in the *CPWD Works Manual* 2007, under Chapter 1, Section 6, 'Green Building Norms'. The Energy and Resources Institute (TERI), along with CPWD, has recently completed the revision of key CPWD documents (including plinth area rates) to incorporate mandatory and prescriptive requirements of GRIHA and ECBC. This is likely to bring key changes in the construction field primarily in the public domain as the document is followed by most of the state PWDs as well. In the context of green buildings, it is also important to refer to the National Building Code of India (NBC) which is a national instrument, providing guidelines for regulating the building construction activities across the country. It serves as a model code for adoption by all agencies involved in building construction works such as the Public Works Department, other government construction departments, local bodies or private construction agencies. The code mainly contains administrative regulations, development control rules and general building requirements; fire safety requirements; stipulations regarding materials, structural design and construction (including safety); and building and plumbing services. It was first published in 1970 at the instance of the Planning Commission and then revised in 1983. Thereafter, three major amendments were issued, two in 1987 and the third in 1997. Recently, harmonization of ECBC with the National Building Code (NBC) 2005 has been finalized by including a chapter, 'Approach to Sustainability' which would be adopted in all future constructions in the country.

Technology interventions must also be made to make the cement production more environmentally sustainable. The permissible limit for stack dust emissions from new cement plants in the country is 50mg/Nm^3 (for existing plants, this is 150 mg/Nm^3 and 100 mg/Nm^3 for critically polluted areas. The Cabinet Committee on Economic Affairs has recently approved Housing for All by 2022 with a focus on economically weaker sections (EWS) and Low Income Groups (LIG). This will bring greater opportunity to focus on green buildings and use of local resources for a sustainable habitat. It would need greater capacity building of urban local bodies (ULBs) and parastatals, currently responsible for construction of such housing along with innovative investment models such as public private partnership (PPP), foreign direct investment (FDI), among others.

1.4.5 Demand Side Management (DSM)

Innovation and R&D

The Bureau of Energy Efficiency (BEE) under the Ministry of Power (MoP), Government of India, has launched the National Mission on Enhanced Energy Efficiency (NMEEE). It aims to accelerate market-based approaches to unlock energy efficiency opportunities, estimated to be about INR 74,000 crores (USD 14.8 billion approx.). It would achieve annual fuel savings in excess of 23 MTOE, and carbon dioxide emission mitigation of 98 million tonnes per year by 2014–15 (BEE).

India has made considerable progress in achieving energy savings through the different programmes launched by the BEE. In the Twelfth Plan (2012–17), the BEE schemes will see continuity due to their regulatory, financial, and facilitative activities under these schemes in achieving energy efficiency. There are proposals to introduce new schemes that will expedite the use of super-efficient equipment through incentives. There would be accelerated deployment of energy efficient appliances through electricity distribution company-led demand side management (DSM) programmes. Through these activities, an avoided peak capacity of 7,489 MW can be achieved. At the end of the Twelfth Plan, the avoided peak capacity is estimated to be 12,350 MW.

The allocations to BEE for the years 2012–14 have increased (Table 1.9); however, in the current budget year these have been scaled down. This is largely because not many new schemes have been launched and efforts are being focussed on consolidating existing schemes.

Table 1.9: Union Budget Allocation to the Bureau of Energy Efficiency (BEE)

Year	INR (crore)	USD (million)
2007–08	45.0	9.0
2008–09	70.0	14.0
2009–10	57.8	11.6
2010–11	66.9	13.4
2011–12	65.0	13.0
2012–13	58.8	11.8
2013-14	193.4	32
2014-15	139.5	23
2015-16	50	8

Source: Compiled from Union Budget (various issues), Ministry of Power; Available at http://indiabudget.nic.in.

India has developed the National Energy Efficiency R&D Plan and an associated National Energy Fund (NEF) under the Eleventh Five Year Plan with a focus on building energy efficiency, solar energy, and solid state lighting (SSL). The national R&D programme includes work on commercialization and market transformation mechanisms. The Twelfth Plan Working Group on Power emphasizes on developing State Designated Agencies (SDAs) so that efforts of energy efficiency can be decentralized. The State Energy Conservation Fund (SECF) would be set up in order to implement these energy conservation measures.

In order to encourage Demand Side Management (DSM), the Working Group on Power of the Twelfth Plan informs on setting up 10 research centres in collaboration with Department of Science and Technology (DST). The financial budget requirement of INR 200 crores (USD 33 million) has been stated in order to engage academic institutions, manufacturing associations, and Energy Service Companies (ESCOs). It will offer funding for initial setting up, partial running and maintenance cost for the first five year period. The Twelfth Plan also articulates the need for a demonstration centre on lighting technologies.

Policies Promoting Innovation in Energy-Efficient Appliances

The Energy Conservation Act, 2001, is a multi-sectoral legislation aimed at ensuring energy efficiency in India. It elaborates energy consumption standards for appliances, designated consumers, prescribes energy conservation codes, and establishes a compliance mechanism. The schemes under BEE include Standards and Labelling (S&L), Energy Conservation Building Code (ECBC), Bachat Lamp Yojana (promoting CFL and LED lighting through fiscal incentives), Energy efficiency in Small and Medium Enterprises (SMEs), agriculture and municipal demand-side management and contribution to the State Energy Conservation Fund (SECF).

The market for BEE's star-labelled (energy-efficient) appliances is rapidly expanding and there is a move towards making appliances super-efficient. Super-efficient appliances save as much as 30–50 per cent energy than the most energy-efficient appliance available in the market. The Super-Energy Efficient Programme (SEEP) seeks to promote domestic manufacturing of energy-efficient appliances by reducing their cost through market incentives. One of the first appliances to benefit under the Super-Energy Efficient

Programme (SEEP) was the ceiling fan. The current technology is reaching limits of efficiency and alternative technological platforms are being explored. Efficiency in fans can be increased by using energy-efficient motors or brushless direct current motors. BEE has completed consultations with major fan manufactures, R&D bodies, technology developers, and policy institutions and is in the process of finalizing specification, incentive structure and a measurement and verification (M&V) strategy. Manufacturers who produce and sell SEEP fans with set specifications/standards will be paid an incentive. Around 26.86 million SEA fans are expected to be sold during the Twelfth plan period which will result in savings of 2.2 billion units in 2016–17. SEEP would be extended to LED tube lights and LED bulbs as well at a later stage.

To accelerate the shift to super-efficient appliances in different sectors and to encourage innovation among manufacturers in India, BEE launched the Market Transformation for Energy Efficiency (MTEE) initiatives under NMEEE. The MTEE initiative encourages the development of new products that are super-efficient and promotes their market introduction. This has to be complemented by R&D in the early stages and loans and rebates and targeted outreach to purchasers who would buy in bulk (example, power utility companies who are interested in DSM measures) so that market penetration of the super-efficient products can be increased. Consumer education about such products is also essential in expanding the market share. Mandatory performance standards could be introduced at a later stage to complete the market transformation.

Manufacturers are often reluctant to make the initial investment to change production lines for super-efficient appliances because of high upfront cost, coupled with uncertainty about market demand. The MTEE initiative offers manufacturers incentives to produce super-efficient appliances that are 30–50 per cent more efficient than the most efficient appliance available in the market.

Other programmes under NMEEE are Perform Achieve Trade (PAT), which is a market mechanism to bring efficient energy use in Industries, Energy Efficiency Financing Platform (EEFP), and Framework for Energy Efficiency Economic Development (FEEED). Under PAT, resources are being mobilized by the National Clean Energy Fund whereby a 3 per cent interest subsidy is given on procurement of energy efficient technologies by designated consumers in seven sectors. This needs investment into newer technologies, renovation, and modernization.

Other DSM strategies include technical capacity building of distribution companies (Discoms) for them to execute load surveys to develop load profiles, initiate a demand response by augmenting peak demands, and ensuring better management in off-peak load. Interventions such as dynamic pricing based on demand and supply in real time, smart metering and leveraging ICT to inform consumers about prices and usage are being mooted. With technologies, such as advanced metering, it is possible for Discoms to implement DSM through demand response. To build DSM cells in Discoms, an amount of INR 300 crore (USD 50 million) has been estimated for the Twelfth Plan.

Agriculture DSM is another strategy that will operate through a public private partnership (PPP) mobilizing resources through financial mechanisms like Venture Capital Fund (VCF) and Partial Risk Guarantee Fund (PRGF). During the Eleventh Five Year Plan, agriculture DSM resulted in 97 MU of annual energy saving potential assessed across eight different states, covering about 20,885 pump sets.

1.4.6 Agriculture

Innovation and R&D

India's agricultural sector, once in a state of food crises in the 1960s was able to move towards a state of food surplus by the 1990s. The underlying factors for this development have been massive public investments in irrigation, rural infrastructure, and most importantly, agricultural research. R&D in the agricultural sector is capable of increasing farm production, providing greater employment opportunities, lowering food prices, and reducing the vulnerability to climate change threats (Hazell & Haddad 2001).

In India, the Ministry of Agriculture (MoA) and the Department of Agricultural Research and Education (DARE) has set up the Indian Council of Agricultural Research (ICAR), which coordinates, guides, and manages research and education in the agriculture sector for various themes including horticulture, fisheries, animal sciences, and natural resource management. The council has about 100 institutes, 71 agricultural universities, and 642 Krishi Vigyan Kendras (KVKs) spread across the country. The major thrust areas of agricultural research in the country as articulated in the Twelfth Plan (2012–17) is for ICAR to focus on challenges of rain-fed areas and State Agricultural Universities to build technical human resources and to adopt applied research to solve local problems. There is also a shift of approach from commodities-based research to agro-climatic zone-based research which is informed by stakeholder priorities (CBGA 2015).

Table 1.10 below highlights the institutions established to promote science and technology in agriculture:

Table 1.10: S&T Infrastructure in Agriculture

	Institutions	No	Activities undertaken
A	**Research and Development**		
1	State Agricultural Universities	63	All
2	Deemed-to-be Universities	5	All
3	Central Universities with Agriculture Faculty	4	All
4	Research Institutes	61	Region specific (crop, animal, fish, water, soil)
5	National Research Centres (NRC)	14	Various crops, horticulture, fish, poultry, water, soil, etc.
6	National Bureau	6	Plant, animal, fish, insect, soil and micro-organism
7	Project Directorates	15	Crops, water, animal, poultry, etc.
8	International Linkages	several	CGIAR, FAO, WTO, etc.
B	**Transfer agencies**		
1	Agricultural Technology Management Agency (ATMA)	-	
2	Agriculture Extension - KVKs	642	
3	State Agriculture Department	29	-
4	Seed Companies	>400	Large, medium, small and others
C	**Seed Production/Distribution/Marketing**		
1	National Seed Corporation	1	Apex central agencies
2	State Seed Corporation	28	Region specific
D	**Regulatory agencies**		
1	Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA)	1	At national level
2	Plant Quarantine	1	With regional office

Source: Various sources

The Twelfth Plan emphasizes the need to increase spending on National Agricultural Research Systems (NARS) to 1 per cent of the Agri-GDP by the end of the Plan period (ibid). Since 2007–08, the share of allocation to the Department of Agricultural Research (DARE) by the Ministry of Agriculture has been in the range of 18–22 per cent. However, in the current budget, there is a boost to Agricultural Research and Education. This can be seen in Table 1.11.

Table 1.11: Allocation to the Department of Agricultural Research and Education (DARE)			
Year	**Allocation to the Department of Agricultural Research and Education (DARE)**		**Share of allocation to DARE in the total allocation to MoA (%)**
	(INR crore)	**(USD million)**	
2007–08	2337	390	21.21
2009–10	2960	493	20.69
2009–10	3210	535	20.24
2010–11	5386	898	22.61
2011–12	4929	788	20.76
2012-13	4510	752	18.59
2013-14	4731	789	18.57
2014-15	4884	814	18.35
2015-16	6320	1053	25.37
Source: CBGA (2011, 2015)			

The ICAR articulates its success over the year with several developments. There has been a significant impetus given to expanding and strengthening research institutions. Table 1.12 highlights the current initiatives and resources allocated for S&T institutions in the agriculture sector. 3.1

Table 1.12: Current Initiatives on Expanding and Strengthening Agricultural Research Institutions		
Institutions established	**Amount allocated INR (crore)**	**USD million**
Two new Indian Agricultural Research Institutes (IARI) in Assam and Jharkhand	100	17
Four new agricultural universities	200	33
Indian Institute of Agricultural Biotechnology, Ranchi	238	40
Agri education in the North East	738	123
Consortia Research Platform on aspects of productivity: Seed, water, health foods, precision farming, and nanotechnology	1,600	267
Source: www.icar.org.in		

A lot of the research projects have been focussed with a lab to land approach. Drought mitigation through late varieties, alternate crops, moisture conservation practices, and seed provision. The following crop varieties have been developed for better productivity and greater resistance to pests and abiotic constraints (soil and water salinity, soil acidity, drought, floods, etc) (Table 1.13).

Table 1.13: Resilient Crop Varieties Developed

Crop	Number
Rice	21
Wheat	11
Cereals	17
Oilseeds	16
Pulses	8
Forage Crops	4
Fibre Crops	3
Sugarcane	1
Tomato	4
Chilli	1
Cauliflower	2
Ash gourd	1
Brinjal	1
Okra	2

Source: www.icar.org.in

In addition, scientists at ICAR in collaboration with other institutions have succeeded in slicing the wheat genome. The decoded draft sequence of bread wheat genome has revealed more than 125,000 genes assigned to individual wheat chromosomes. This path breaking research will assist in DNA finger printing, diversity analysis, and marker assisted breeding. High protein rice variety 'Heera', which is a short duration early maturing variety useful for both rainfed and irrigated areas has also been discovered. It has 11.5 per cent protein and is used to address malnutrition in Odisha.

Cloning of high ranking progeny tested bull, 'Rajat', has been successful. It is cloned from the frozen semen of elite Marah bull (MU4393). Also successful cloning of the wild buffalo 'Deepasha' found in Chattisgarh, which has been declared endangered under the Wildlife Conservation Act, 1972, has been accomplished. Additionally, two indigenous variety of buffalos have been cloned. To sustain local livelihoods, Kamrupa, a multi-coloured poultry bird, a hybrid of the Assamese local ecotype, coloured broiler, and Dalhem red population was released for backyard poultry in the North-Eastern region.

The Government of India has also introduced 'Mridaparikshak' (related to the Soil Health Card Scheme), a soil-based testing intervention at the farmer's doorstep. Through an SMS, the farmer will be informed about a balanced use of fertilizers in accordance with the soil type. It will determine parameters, such as pH, electrical conductivity, organic carbon, available nitrogen, phosphorus, potassium, sulphur, and micronutrients such as zinc, boron, and iron. Improved Light trap for trapping beneficial insects, as part of Integrated Pest management is also a result of R&D efforts. To prevent diseases like Brucellosis in calves, the Lateral Flow Assay technology has been introduced.

The Indian Meteorological Department has set up the National Monsoon Mission with an allocation of INR 400 crore (USD 67 million) under the Twelfth Plan. Its objective is to set up a state-of-the-art dynamic model framework for improving prediction skill of both seasonal and extended range prediction as well as short- and medium-term predictions. The Indian Institute of Tropical Meteorology (IITM) has the supercomputer Aditya, operating at 790+ TeraFlops. The Government of India has recently sanctioned INR 4500 crore (USD 750 million) towards a National Supercomputing Mission in building the capabilities in India (The Economic Times 2015). Use of geoinformatics for planning agro practices is being encouraged through the CHAMAN (Coordinated Horticulture Assessment and Management using Geoinformatics) Project (MoA 2015). The Government has launched 'Nowcast', an early warning SMS service to farmers who live in 200 km radius of IMD monitoring stations. This is under the National e-Governance Plan.

Livestock is seen as one of the largest contributors to greenhousegas (GHG) emissions and hence, technology interventions such as Coding formethanogenic archea and amelioration using vaccines, finding alternate pathways as H sink propionate enhancers), and entrapping methane using nano adsorbents (NIANP 2013). There is also an emphasis on post-harvest technologies and management. Between 2011–12 and 2012–13, 7947 and 4808 technology demonstrations had been made for PHT&M, 1221 and 1128 units have been established, and 1,770 and 3,450 trainees have been trained. Women-friendly technologies have also been developed, close to 30 are in demonstration phase in the States. The States also have to earmark 10 per cent of their funds for training women. The MoA has reformed the National Mission on Agricultural Extension which includes four sub-missions:

- Sub-Mission on Agricultural Extension
- Sub-Mission on Seed and Planting Material
- Sub-Mission on Agricultural Mechanisation
- Sub-Mission on Plant Protection and Plant Quarantine

The Sub-Mission on farmer mechanization focusses on small and marginal farmers and how to enhance their productivity.

These interventions have significantly contributed in addressing agricultural and animal husbandry productivity. Studies conducted for China and India point out that in addition to its large impact on rural poverty reduction, agricultural research has also contributed towards reduction of urban poverty (Fan 2002). Agricultural research investments are expected to increase agricultural output, which in turn lowers food prices. Increased agricultural research is considered to be an important government policy instrument to achieve the objectives of poverty reduction.

Policies and Programmes Promoting Agricultural Innovation

The Twelfth Plan states strategic areas for research as conservation agriculture and climate change, addressing biotic stresses, improving water quality and productivity, alternate energy for agriculture, micro-nutrients and their use efficiency, precision and controlled environment agriculture, use of nanotechnology for agriculture and safety concerns, RNAi gene silencing technology, minimizing agricultural waste, mechanisation of horticulture, research in agricultural extension system, and the development of pod borer resistance in pulses. These areas are priorities under the National Agriculture Science Fund. To implement R&D in agricultural technology, ICAR coordinates the National Agriculture Innovation Project (NAIP). Key achievements made under this project are listed in Table 1.14.

Table 1.14: Major Agricultural Research Projects in India

Name	Implemented by	Key achievements
National Agriculture Innovation Project (NAIP)	ICAR with support from The World Bank	• Advanced Super-Computing Hub for OMICS Knowledge in Agriculture (ASHOKA) at the Indian Agriculture Statistical Research Institute • Create an analytical online database of bioinformatics for biotechnology-based research • Successful Business Planning and Development (BPD) efforts which supported 91 incubatees; commercialized 331 technologies, facilitated filing of 186 patent applications, mobilized fund of 1,937 lakh and trained 3,743 entrepreneurs across the country

Source: MoA (2015)

Furthermore, in order to promote organic farming in the country, the current Budget has allocated an amount of INR 300 crore (50 million USD) for Parampargat Krishi Vikas Yojana (Organic Farming Programme). The States are also going to mobilize funds to give organic agriculture greater impetus. The Indian Institute of Farming Systems Research (IIFSR), Modipuram also hosts a Network Project on Organic Farming (NPOF) since 2004–05. The objective is to develop package of practices of different crops and cropping systems under organic farming in different agro-ecological regions of the country. The project is running at 13 cooperating centres. NPOF has the objective to address issues of comparing inorganic and organic agriculture, integrated nutrient management practices, methods and source of nutrient application, management of pests, diseases, and weeds in the crops.

Since the agriculture sector accounts for approximately 83 per cent of all water uses in the country, there is an urgent need to promote technologies and innovation capable of increasing the water use efficiency. Water use efficiency would help in sustaining the underground water table and also contribute towards energy savings in the agriculture sector. One such water saving technology, that is now been used in India, is the drip irrigation technology. Box 1.2 highlights this technology as an innovation in the agriculture sector. The current Government has launched Per Drop More Crop Scheme along with the Pradhan Mantri Krishi Sinchayee Yojana (Irrigation Programme) for which an amount of INR 5,300 crore (USD 833 million) has been sanctioned under the current budget.

Box 1.2: Drip irrigation technology in India

Among all the irrigation methods, drip irrigation is considered to be the most efficient and can be practiced for a large variety of crops, especially for vegetables, orchard and plantation crops. Drip irrigation results in a high water application efficiency of about 90–95 per cent. The technology contributes towards low carbon development indirectly by promoting water use efficiency. The Ministry of Agriculture and Farmer Welfare (MoA), Government of India, estimates that a total of 27 million hectares area in the country has the potential of drip irrigation application (IARI 2008).

In the states of Maharashtra and Tamil Nadu, drip irrigation technologies for sugarcane crop have been gaining popularity and are being increasingly adopted with necessary financial support from the state agricultural departments (MINT 2013).

MoA has also started the National Innovations for Climate Resilient Agriculture (NICRA) in 2011. Its objective is to mainstream climate-resilient agricultural practices into development planning. In order to bring the knowledge till the farmer a dedicated channel for farmers, 'DD Kisan' has been recently launched. It will serve as a key instrument in information dissemination. Further, the scheme of Mera Gaon Mera Gaurav (My Village, My Pride) has been launched to encourage practicing scientists to adopt a village and to take responsibility to disseminate cutting-edge knowledge to the farmers, in the region, in order to enhance productivity (MoA 2015). Extension reforms, such as use of unstructured supplementary services data (USSD) for accessing e-kisan portals, have helped disseminate information. In addition, pico projectors and hand-held devices have helped to inform the farmers. Another intervention for adoption of high yielding variety seeds is through the national postal system under KrishiDak (Farmer's Post). Such interventions will help mainstream the knowledge gathered through research into agricultural practices.

1.4.7 Industry

Innovation and R&D

Given that the industrial sector has high potential for energy saving, technological innovation is considered to be an important element to improve the overall sustainability of the sector. Energy innovations in industrial technology would primarily include tapping of unconventional sources of energy and application of cleaner fuel technologies.

The Department of Industrial Policy and Promotion (DIPP) under the Ministry of Commerce and Industry[4] is responsible for encouraging acquisition of technological capability in various sectors of the industry. Since 2008–09, a provision of budgetary allocation for project-based support to autonomous institutions has been made under the Union Budget. The autonomous institutions, thus aided, include the Quality Council of India, the National Institute of Design, Central Pulp and

[4] The DIPP also hosts the Office of the Controller General of Patents, Designs and Trade Marks (CGPDTM) which is responsible for intellectual property rights. Besides this, DIPP also promotes awareness regarding protection of the intellectual property rights inherent in industrial property in conjunction with the World Intellectual Property Organization (WIPO) and apex industry organizations apart from similar initiatives involving regional industry associations. It also provides inputs on various issues relating to the Agreement on Trade Related Aspects of Intellectual Properties (TRIPS) related to the World Trade Organization (WTO) in these fields.

Paper Research Institute (CPPRI), the National Council for Cement and Building Materials (NCCBM), Central Manufacturing Technology Institute, Indian Rubber Manufacturers Research Association, and the National Productivity Council. Table 1.15 shows that the budgetary provision under project-based support to autonomous institutions has increased by almost double. However, it is important to note that many technological innovations in India take place in private or non-governmental organizations. Moreover, technologies developed for industries in other countries may have to be adapted to Indian conditions.

Table 1.15: Union Budget Allocation Under Project Based Support to Autonomous Institutions

Year	INR (crore)	USD (million)
2008–09	45.0	9.0
2009–10	90.0	18.0
2010–11	88.2	17.6
2011–12	83.5	16.7
2012–13*	72.1	14.4
2013–14*	78.9	13
2014-15**	105	18

Note: * Revised **Allocated

Source: Compiled from the Union Budget (various issues); Available at http://indiabudget.nic.in.

3.1

Policies Promoting Industrial Innovation

There have been several initiatives taken up by the Government of India, under various ministries, to promote R&D activities in the industrial sector. Some of the major initiatives for energy-intensive industrial sub-sectors have been listed in Table 1.16.

Table 1.16: Major R&D Initiatives for Energy-Intensive Industrial Sub-sectors

Industrial sub-sectors	Key R&D initiatives and innovative technologies
Aluminium	*Jawaharlal Nehru Aluminium Research Development and Design Centre (JNARDDC):* • Implemented by the Ministry of Mines (MoM), in collaboration with UNDP • Performs the task of assimilating technologies within India and abroad; and, develops new technologies for the production of alumina and aluminium. • Research on rare earth elements (REE) and energy critical elements (ECE) and other issues related to exhaustion and fast decline of mineral deposits. Source: MoM (undated)

Iron and steel	*R&D with Steel Development Fund (SDF):* • Cabinet Committee of Economic Affairs (CCEA) with support from the Ministry of Steel had set up an SDF which comprises investments upto INR 150 crore (USD 30 million approx.) per annum made to promote R&D in the steel sector. • SDF supports and implements research projects for the iron and steel industry on issues related to productivity of the industry, reduction in energy consumption and pollution Source: Department of Mines (undated)
	Scheme for Promotion of R&D in Iron and Steel under Plan Fund: • In the Eleventh Five-Year Plan, the government started a new scheme namely 'Sector' • The scheme aims to develop technologies for utilization of iron ore fines and non-coking coal • It supports research on subjects of beneficiation of raw materials like iron ore and coal and how to improve quality of steel produced through the induction furnace • In the Twelfth Plan the scheme objectives have been expanded for development of technology for Cold Rolled Grain Oriented (CRGO) electrical steel sheets and other value added steel products Source: MoS (undated)
Cement	• The NCCBM is responsible for R&D activities in the sector. Current research include initiatives, such as: ◆ Adaptation of technology to reduce No_x and So_x and formulation of emission norms ◆ Productivity improvement in kiln through optimization of precalciner operation and thermal loading of kiln as well as computer based simulation techniques ◆ Development and adaptation of technologies for utilization of wastes in cement manufacture ◆ Studies to reduce CO_2 emissions from cement plants through absorption of CO_2 by algal farms ◆ Enhancing the use of fly ash in cement and concrete ◆ Use of nanotechnology in the cement and concrete industry to promote the development of eco-friendly, high-performance cements or binders and concrete with improved durability characteristics. Source: DIPP (2015) and NCCBM (2015)
Chlor-Alkali	• Indian government has a mandate to shift from mercury cell process (MRCP) technology to membrane cell process (MCBP) technology in order to avoid mercury pollution and minimize energy requirements • New technologies to minimize the waste from the sector are emerging to promote complete recycling of mercury effluent Source: IL&FS (2010)

Fertilizers	• Motivation to use technology of underground coal gasification (UCG) as the future coal utilizing technique due to environmental benefits such as no surface disposal of ash and coal tailings, reduced water consumption, reduced methane emission and other benefits. UCG technology is well developed and is being used in countries including China, Russia, and Spain. • Exploring the use of cleaner technology of using coalbed methane (CBM) which can be used as a feedback in the manufacture of urea Source: DoF (undated)
Pulp and paper	• CPPRI is a dedicated Institution to undertake R&D in Paper and pulp. It undertakes research in identification and quality upgradation of alternate raw materials, identification and development of technologies suitable to indigenous raw materials, resource conservation, quality standardization and environment protection
	• Research in paper making, stock preparation and coating, chemical recovery and energy management and application of biotechnology in paper management Source: CPPRI (2015)
Textiles	*Revised Restructures Technology Upgradation Fund Scheme(RR-TUFS):* • This is a scheme by the Ministry of Textiles, Government of India (GoI) for modernization and upgradation of technology for existing units and to set up new units in the textile industry of India. • The scheme extends investment support for energy-saving devices, effluent treatment plants, and other environment friendly technologies. • A Comprehensive Integrated Software Development has been launched to consolidate the existing TUFS (iTUFS). *Technology Mission on Technical Textiles (TMTT):* • The four centres of excellence (CoE) established within the mission (namely, Geotech, Protech, Meditech, and Agrotech) have elements that promote energy audits and hazardous waste management. Four additional CoE will be established Nonwovens, Composites, Indutech and Sportech. • Supporting research projects involved in studying environmental aspects of textile industry during the period between 2010–15 with a total outlay of INR 100 crore (USD 17 million) Source: MoT (2011, 2015) *Special Initiatives in the North East* • A centre established for apparel and garment making • Special schemes for promotion of geo-textiles • Promotion of handloom, handicrafts, and sericulture • Scheme for Integrated Textile Parks and Integrated Skill Development Scheme have also been initiated Source: MoT (2015)

Significant energy-efficiency gains have been identified in the micro, small and medium enterprises (MSMEs) industrial sector (TERI 2009). For the MSME sector in particular, the following government programmes and schemes have been implemented to promote R&D activities and to help these small industries acquire newer, cleaner, and better technologies:

- **BEE-SME program in 35 clusters:** BEE (Bureau of Energy Efficiency) has formulated the BEE–SME programme that aims to accelerate the adoption of energy-efficient technologies and practices, in a few chosen industry clusters, through focussed studies, knowledge sharing, preparation of detailed project reports, and facilitating the process of developing innovative financing mechanisms.
- **TEQUP scheme for MSMEs:** Technology and Quality Upgradation (TEQUP) support scheme aims at encouraging and supporting energy efficiency for MSMEs. TEQUP addresses the various facets of quality and technology upgradation with a current focus on energy efficiency and product quality certification, besides focusing on additional spin-offs for the MSME sector through clean development mechanisms (CDM). It is also based on an innovative concept of cluster-based carbon credit aggregation centres (CCAs) to enable MSMEs avail benefits from the CDM mechanism.
- **TERI–SDC partnership:** TERI initiated a partnership with the Swiss Development Corporation (2009–11) with a goal to obtain energy savings of 20–30 per cent in micro, small and medium enterprises. Replicable, efficient, and biomass-based energy technologies have been developed for MSMEs and replicated in several Indian states.

The Global Innovation and Technology alliance (GITA), in collaboration with DIPP, has introduced the Technology Acquisition and Development Fund (TADF) under the National Manufacturing Policy. This fund will be used to support MSMEs for "Green Manufacturing" by acquiring technology, indirect funding support through patent pools, subsidy for manufacturing Electrical equipment, water conservation, and pollution control equipment. There will be incentives for energy, environment, and water audits, incentives to construct green buildings and subsidies to implement waste water treatment facilities. A discussion paper released by DIPP highlights the need to incentivize Utility Models for indigenous technology, thereby providing a legal framework to promote frugal innovation.

Special emphasis has been put on food processing with grant in aid to develop cold chains/mega foodpark and modernization of abbatoirs, scheme on quality assurance, CODEX, R&D, and other promotional activities is also being undertaken. The 'Make in India' programme aims to give an impetus to industrial growth for which dedicated industrial corridors are being developed.

DIPP's discussion paper highlights that India share of global trade in high technology products is only 8 per cent and the aim is to double it through greater technology inputs into R&D. It also highlights the need to commercialize intellectual properties resulting from public funded R&D. Entrepreneurship Development and Incubation centres like the one in Indian Institute of Technology (IIT), Delhi (FITT-Foundation for Innovation and Technology Transfer), and National Institute of Technology in Tiruchirapalli (CEDI–Centre for Entrepreneurship Development and Incubation) would create the larger ecosystem to foster innovation.

1.4.8 Forestry

Innovation and R&D

Innovation and development of eco-friendly technologies not only benefits the commercialization of forest produce; but also enhances the welfare of forest communities at large.

The task of promoting environmental and forestry research in the country is being pursued by the Ministry of Environment, Forest and Climate Change (MOEFCC), Government of India. Several autonomous institutions have been set up by MOEFCC in order to promote R&D in the forestry sector. These institutions provide expert and specialist advice in respective areas and cater to the forestry research needs of the nation.

Table 1.17 gives an indicative list of some institutions which have actively taken up forestry research in the country.

Table 1.17: Institutions Engaged in Forestry Research in India

Forestry research institutes	Areas of research
Indian Council of Forestry Research and Education (ICFRE)	Planning, promoting, conducting, and coordinating research on all aspects of forestry
Indian Institute of Forest Management (IIFM)	Sustainable forest management and forest certification; community forestry including joint forest management; valuation of forests and natural resource accounting; remote sensing and GIS applications in forestry, etc.
Indian Plywood Industries Research and Training Institute (IPIRTI)	Efficient utilization of fast growing timber plantation species for production of sawn timber, plywood, and other composites of wood

Forest Survey of India (FSI)	Collection, storage and retrieval of necessary forestry and forestry related data for national and state level planning; creation of a computer-based National Basic Forestry Inventory System (NBFIS)
Wildlife Institute of India (WII)	Matters related to wildlife to provide consultancy and advisory services to Central and State governments
Other forestry research institutions under the aegis of the Indian Council of Agricultural Research (ICAR)	Agro-forestry related research; silvi-pastoral research (considering degraded forests and other wastelands); grassland management and ecology

Source: GoI (2010)

Increasing the productivity of wood and other forest produce per unit of area per unit time by the application of modem scientific and technological methods, re-vegetation of barren/marginal/ waste/mined lands and watershed areas, effective conservation and management of existing forest resources (mainly natural forest ecosystems), research related to social forestry for rural/tribal development, development of substitutes to replace wood and wood products and research related to wildlife and management of national parks and sanctuariesare some of the clear national research priorities in the forestry sector (Forestry Policy 1988).

Table 1.18 shows the budget allocation made for forestry research in the Union Budget of India. In 2014–15, the amount allocated to research increased by INR 22.55 crore (USD 4 million)

Table 1.18: Budget Allocation for Forestry Research in the Union Budget

Year	Amount (INR crore)	Amount (USD million)	Percentage share of research in the total budget allocation to MOEFCC
2011–12	118.80	20	5.16%
2012–13	143.17	24	8.81%
2013–14	144.13	24	7.79%
2014–15	166.68	28	8.15%

Note: The allocation primarily includes that made to the Indian Council of Forestry Research and Education and the Indian Plywood Industries Research Institute
Source: www.indiainfoline.com

ICFRE has also been undertaking research in technologies in order to support economic development. The vacuum oven technology developed by ICFRE is to be commercialized. It is also called a Thermal Chamber that will help process low quality wood varieties into high quality woods. A lot of emphasis is being given to agroforestry with demonstration activities being undertaken by the Forest Research Institute (FRI). In 2014, the Government has also initiated a national Agroforestry Policy. It articulates the need for research on agroforestry models suitable in the different climatic zones in the country. Currently, over 30 Institutions under Indian Council for Agriculture Research (ICAR) work on research on Agroforestry and they are co-ordinated under Central Agroforestry Research Institute (CAFRI). Such institutions must make the knowledge in the domain more robust and should disseminate it through adequate extension services. Current research includes agri-silviculture, silvipasture, silvi horticulture, social sciences, watershed development, and human resource development (CAFRI 2015). In addition, to promoting research in the forestry sector, the use of Geographical Information Systems (GIS) to enable a decision support system (DSS) has been initiated. Bhuvan, the geospatial portal of the Indian Government enables sub-national governments to design interventions and governance tools based on remote sensing. E-Green Watch as an e-governance initiative has also enabled streamlining and management of forestry works (SFR 2013). An Environmental Information System (ENVIS) has also helped in creating the ecosystem for policymakers, scientist and academicians to undertake research which is multi-disciplinary and engages relevant stakeholders.

There have also been significant advancements in the remote sensing technology to map forest cover. Table 1.19 below highlights the advancements in these technologies.

3.1

Table 1.19: Development of Remote Sensing Technology to Map Forest Cover in India over the Years

Cycle of assessment	Year	Sensor	Spatial resolution (meters)	Scale	Minimum mapping unit (ha)	Mode of interpretation
I	1987	LANDSAT-MSS	80	1:1 million	400	Visual
II	1989	LANDSAT-TM	30	1: 250,000	25	Visual
III	1991	LANDSAT-TM	30	1: 250,000	25	Visual
IV	1993	LANDSAT-TM	30	1: 250,000	25	Visual
V	1995	IRS-1B LISSII	36.25	1: 250,000	25	Visual & Digital
VI	1997	IRS-1B LISSII	36.25	1: 250,000	25	Visual & Digital
VII	1999	IRS-1C/1D LISSIII	23.5	1: 250,000	25	Visual & Digital
VIII	2001	IRS-1C/1D LISSIII	23.5	1: 50,000	1	Digital

contd...

Cycle of assessment	Year	Sensor	Spatial resolution (meters)	Scale	Minimum mapping unit (ha)	Mode of interpretation
IX	2003	IRS-1D LISSIII	23.5	1: 50,000	1	Digital
X	2005	IRS-1D LISSIII	23.5	1: 50,000	1	Digital
XI	2009	IRS-P6 LISSIII	23.5	1: 50,000	1	Digital
XII	2011	IRS-P6 LISSIII & IRS-P6 AWiFS	23.5 56	1: 50,000	1	Digital
XIII	2013	IRS-P6 LISSIII IRS Resourcesat 2 LISS III	23.5	1: 50,000	1	Digital

Source: State of the Forest Report, 2013

These advancements allow a more detailed analysis of the forests with three layers of forest density—very dense forests, moderately dense forests, and open forests, than the dual classification used until 2001. The LISS III sensors along with Resourcesat have increased the resolution uptill 23.5 m. the scale is now at 1:50,000, the minimum mapping unit at 1 ha and all information is recorded in digital mode.

Documentation of traditional knowledge is also an effort to bring innovation to the forestry sector. The Traditional Knowledge Digital Library (TKDL) has documented the indigenous varieties found in India such as Neem. The Kerela Agricultural University has also applied for a Geographical iIndicator (GI) for Nilambur Teak (ToI 2015). People's Biodiversity registers (PBR) to be maintained by Biodiversity Management Committee's (BMC) in local bodies under the Biological Diversity Act, 2002, is an intervention to encourage conservation and better utilization of local resources. Private sector intervention of Himalaya company in herbal medicines has also given a boost to research and development and brought robust validation processes in place. A dedicated Ministry of Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homeopathy (AYUSH) has been established in November, 2014, which has also given impetus to research and development in the forestry sector.

The improved cook stoves intervention by MNRE and civil society organizations like TERI have reduced the dependence on fuelwood and brought in energy efficiency. An amount of INR 294 crore (USD 49 million) has been dedicated for the Unnat Chulha Abhiyan (Biomass cookstove initiative) (MNRE 2014).

Policies Promoting Forestry Innovation

The National Mission for a Green India is one of the sub-missions under the NAPCC. It aims at increasing the forest cover by 5 million hectares (mha) and improve the quality of forest cover on another 5 mha over a period of 10 years and ensuring livelihoods to the forest dwelling communities. In order to leverage funds for the same, policy convergence between Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) has been affected. Further, any diversion of forests for non-forest purposes by industry will require a payment by the industry, based on the Net Present Value (NPV) and will be put in Compensatory Afforestation Fund. The Indian Government is looking at creating a statutory authority to utilize these funds.

Research has been an important component of the National Forest Policy. Several programmes under the Ministry of Environment and Forests (MOEF) have been initiated in order to undertake research. Ecosystems Research programme and the Research Programme of Socio-Economic Issues of Environment (RPSE) are some of the progammes. Research has also gone into identifying Ecologically Sensitive Zones (ESZ). A National Natural Resources Management System (NNRMS) has been set up under which remote sensing technologies are being used for inventorization, assessment, and monitoring of natural resources.

The National Forest Policy advocates the use of research and development for the conservation and sustainable development of forests. The MOEFCC has prepared the National Working Plan Code-2014 (For Sustainable Management of Forests and Biodiversity in India). The Working Plan articulates the need to document the carbon stock of the Forests, an exercise undertaken by the Forest Survey of India (FSI).

The Fourteenth Finance Commission recommendation to give 7.5 per cent of the weightage to forest cover in the distribution of the tax pool among states will also serve as an incentive to maintain forest cover. It helps to meet the opportunity cost of diverting those forests for other economic activities and will give an impetus in finding new ways of ensuring the minimum forest cover.

The Government has also initiated a mechanism for marketing minor forest produce (MFP) through minimum support price for 12 MFP's namely—bamboo, tendu, mahua seed, sal leaf, sal seed, lac, chironjee, wild honey, myrobalan, tamarind, gum karaya, and karanj. Such a policy will serve as an incentive in increasing productivity. The Tribal Cooperative Marketing Development Federation of India

Ltd (TRIFED) is acting as the nodal agency to commercialize MFPs. It also sponsors research and development in order to improve the technologies and processes used in MFP collection, post-harvest processing, value addition, while reducing the drudgery of the collectors. It aims to increase the benefits to the collectors while ensuring sustainability of the forests. The larger framework of the Van Bandhu Kalyan Yojana (Forest dwellers Benefit Scheme) will bring greater development for forest dwellers. State level interventions such as Madhya Pradesh's Vindhya Herbals is also seen as a good initiative in ensuring market access for forest produce.

Joint Forest Management and the Forest Rights Act are other policy interventions that provide a framework to promote social forestry whereby communities are engaged as owners of the forests and are responsible for management and sustainable utilization of the forests. Field interventions in Medha Lekha village of Gadchiroli where a bamboo plantation was leveraged for gaining revenue is a successful case in example.

The government has been undertaking several other initiatives to promote innovation in the forestry sector. These include forest biotechnology to improve forest plantations; and the National Mission on Bamboo Applications (NMBA) to improve forested area and also to provide village energy security. In addition, the mission ensures wood substitutes and composites has construction and structural applications, develops processing technologies suitable to Indian bamboo, undertakes propagation and cultivation practices, develops industrial products, knowledge management, and extends support to SMEs in the sector.

Other initiatives of the MoEFCC include all-India coordinated projects on taxonomy, ethno-botany, botanical, and zoological surveys which are important from the perspective of institutional capacity building. The major change of integrating the climate change aspects into the MoEFCC from 2014 has brought to the forefront, the integral relationship between strong forestry practices and corresponding mitigation and adaptation to climate change impacts. Hence, further research in the context of low carbon development need to be directed to understand linkages with existing as well as new initiatives.

1.4.9 Waste Management

Innovation and R&D

Greening of the waste sector requires innovation and technology. Technologies have to be developed for segregation, collection, reprocessing and recycling waste, extracting thermal and biochemical energy from organic waste, and efficient gas capture from potential landfills. Mechanical biological treatment (MBT) is the most widely employed technology to handle MSW in India. Thermal energy extraction, with the help of waste to energy plants, are gaining importance nowadays, due to their capacity to reduce waste volumes by more than 90 per cent. Refuse derived fuel (RDF) plants have also been setup in many cities and are gaining importance to replace coal at many locations. However, air pollutants through incineration plants and calorific values of refuse derived fuels are barriers which require innovation and R&D.

UNEP recommends "SLF [sanitary landfilling] is well-suited to developing countries (like India) as a means of managing the disposal of wastes because of the flexibility and relative simplicity of the technology". The number of SLFs is gradually increasing. The use of geographical information systems (GIS) and ICT is being promoted in order to identify adequate sites, to estimate quantum of waste and adequate means of its disposal.

The Ministry of New and Renewable Energy (MNRE), Government of India, is actively promoting all technology options available for energy recovery from urban and industrial wastes. The MNRE is also promoting research on waste to energy by providing financial support for R&D projects on a cost-sharing basis in accordance with the R&D policy of the MNRE. In addition to that, MNRE also provides financial support for projects involving applied R&D and studies on resource assessment, technology upgradation, and performance evaluation. Approximately, 33 projects have been sanctioned under Programme on Energy from urban, industrial, and agri-waste.

The Department of Science and Technology, under the Technology System Programme on Waste Management, focusses on electronic waste, biomedical waste, and plastic waste. DST has started new programmes on waste recycling and rehabilitation of scavengers and rag pickers, both in urban and semi-urban areas for management of garbage. These programmes aim at recycling of waste and conversion of biodegradable organic waste into compost through vermicomposting. R&D projects have been initiated in order to initiate decentralized waste management in urban areas (DST 2014). Table 1.20 gives an overview of the status, issues, and technology interventions relevant to waste management in India.

Table 1.20: Waste Management: Status, Issues and Technology Interventions

Category of waste management	Status	Issue	Technology intervention
Municipal solid waste (MSW) management	144,165 TPD MSW is generated out of which about 80.28% is reported to be collected and only 32,871 TPD (22.80%) is being treated	Contains 51% organic waste, 17% recyclables, 11% hazardous and 21% inert	535 waste processing plants (compost / vermin-compost), 172 bio-methanation plants, 76 Waste to Energy Plants, (refuse derived fuel (22 RDF/pellet+-, 41 Biogas plants-+, 13 power plants-) (out of these 30 plants are set up and 46 under construction/planned, 94 sanitary landfill facilities (SLF) have been constructed in the country for disposal of MSW
Plastic waste management	CPCB estimated about 5.7 MT of plastics waste annually in year 2008 i.e., 15,722 tonnes of plastic waste is generated per day.	60% of the total plastic waste generated is recycled and 40% is littered and remains uncollected. Therefore, approximately, 6,289 tonnes per day (TPD), i.e., 40% of plastics are neither collected, nor recycled and find their way into drains, open lands, rivers, railway tracks and coasts	Plastic recycling in India is carried out by 3,500 organized and 4,000 unorganized sector organizations Plastic to oil technology (Indian Institute of Petroleum (IIP), Dehradun) Rudra Environmental Solutions with Pune Municipal Corporation Plastic-aggregate Bitumen Technology for building roads
Packaging waste management	Food and beverages packaging are high volume but may have low weights, making up only 15–20% of all packaging. The non-food packaging make up almost 80–90% of the packaging by weight		Coir composite packaging, cushioning media, nature-based packaging (fibre from banana, jute, coir) Low temperature pyrolysis

contd...

Category of waste management	Status	Issue	Technology intervention
Construction and demolition waste management	The construction industry in India generates about 50 million tonnes of waste annually (WMW) in year 2013 (CSE 2014)	While some of the items like bricks, tiles, wood, metal, etc., are re-used and recycled, concrete and masonry, constituting about 50% of the C&D waste is not currently recycled in India	Alternate Building material Sanitary landfilling- Site in Narela 50/150 acres for C&D waste
Biomedical waste management	According to the available information from the State Pollution Control Boards (2007–08) 52,001 (53.25%), health care establishments (HCEs) are in operation without obtaining authorization from their respective SPCB/PCC.	Approximately 288.20 tonnes per day (56.87%) out of 506.74 tonnes per day wastes generated is being treated either through common bio-medical waste treatment facilities (159 in number), or captive treatment facilities.	There are 602 bio-medical waste incinerators (which include both common and captive incinerators), 2218 autoclaves, 192 microwaves, 151 hydroclaves, and 8,038 shredders in the country. About 424 (70.4%) of the 602 incinerators are provided with air pollution control devices and 178 (29.6%) incinerators are in operation without air pollution control devices.
Electronic Waste	1.7MT of e-waste annually (2014)	In India about 95 percent of the e-waste is being recycled through unauthorised recyclers.	Metals like copper, aluminium, gold, brass, are recovered and processors interaction with heavy metals like lead, mercury, cadmium and arcenic are causing harm to the people involved in recovery of e-waste.

Source: Authors compilation from various government documents

The recently launched Swachh Bharat programme of the Government of India has emphasized solid waste management and has the Following technological interventions to be scaled up (See Table 1.21).

3.1

Table 1.21: Technological Interventions in Solid Waste Management Under the Swachh Bharat Programme			
Organization	**Sector**	**Intervention**	**Use**
Ecoman Enviro Solutions Ltd	Private	FOODIE	Processes organic waste and converts into compost within 24 hours
		Esweeper	Battery operated road sweeping machines
Muskaan Jyoti Samiti	NGO	Drum technique Organic Manure Production	Converts organic waste into compost
NoKooda Solution Systems Pvt. Ltd	Private	Green Waste Reprocessor	Multi capacity decentralized machines for MSW and plastic wastes
The Energy and Resources Institute (TERI)	NGO	TEAM	Converts biodegradable organic waste to manure and leachate is fed for anaerobic digestion thus releasing methane gas with potential as an energy source

Source: Various sources

The Planning Commission report has estimated that an amount of INR 600 crores (~0.1 billion USD) must be allocated towards R&D in waste management. At least four centres of excellence must be established in order to give an impetus to research in the sector. This would encourage indigenous technologies and be aligned with the Make in India initiative. The institutions currently looking at issues of waste management are listed in Table 1.22.

Table 1.22: Waste Management Related Research Institutes in India	
Waste Type	**Institute**
Solid and Hazardous Waste Management	National Environmental Engineering Research Institute (NEERI)
Plastic	Indian Center for Plastics in the Environment (ICPE)
Packaging	Indian Institute of Packaging (IIPa)
Construction and Demolition Waste	Central Building Research Institute (CBRI)

Policies promoting innovation in waste management

Systematic collection of waste, its recycling, composting or waste-to-energy options have large potential for reducing emissions from this sector. The most common types of regulatory measures to obtain this objective include regulated targets for minimization, reuse, recycling;

regulation relevant to the waste management 'market', i.e., permitting/licensing requirements for waste handling, storage, treatment and final disposal; and recycled materials standards; facilities standards, including pollution control technologies.

The regulatory framework in this sector encompasses the Municipal Solid Wastes (Management and Handling) Rules, 2000; the Bio-Medical Waste (Management and Handling) Rules, 1998; the Plastic Waste (Management and Handling) Rules, 2011; E-waste (Management and Handling) Rules 2011, etc. The Government has recently circulated the draft for Solid Waste Management Rules, 2015, Bio-medical Waste (Management and Handling) Rules, 2015, E-Waste (management) Rules 2015, and Plastic Waste Management Rules, 2015, and is currently gathering comments from the different stakeholders. The Municipal Solid Wastes Rules puts the onus on municipal authorities to manage and develop any infrastructure for collection, storage, segregation, transportation, processing, and disposal of municipal solid wastes. It lays stress on the adoption of suitable technology or a combination of such technologies to make use of wastes so as to minimize burden on landfill, with also has an emphasis on recycling with respect to mixed waste, containing recoverable resources and incineration with or without energy recovery including pelletization for processing wastes in specific cases. The municipal authority or the operator of a facility, wishing to use other state-of-the-art technologies, has to approach the Central Pollution Control Board (CPCB) to get the standards laid down before applying for grant of authorization. The Plastic Waste Rules, on the other hand, places an emphasis on recycling and composting with adherence to certain standards as well as the adoption of suitable technology in fields, such as road construction, co-incineration, etc., which encourages the use of plastic waste and adheres to prescribed standards, including pollution norms. An important aspect of the Bio-Medical Waste Rules is the laying down of standards for incinerators, including operating standards (for enhanced combustion efficiency), and emission standards with a focus on suitably designed pollution control devices to achieve the prescribed emission limits.

The Government has also launched the ambitious Swachh Bharat Programme at multiple levels in order to address the issue of sanitation and solid waste management. The prohibition of employment as manual scavengers also creates an enabling framework to deploy suitable technologies in order to prevent human interventions.

1.5 Discussion and the Way Forward

Focussing on low carbon technology development and innovation across sectors would have certain co-benefits in terms of growth, inclusion, local environment, and carbon mitigation (Planning Commission, Twelfth Plan, Vol. 1). A brief qualitative assessment of co-benefit potential would be an important dimension of technology

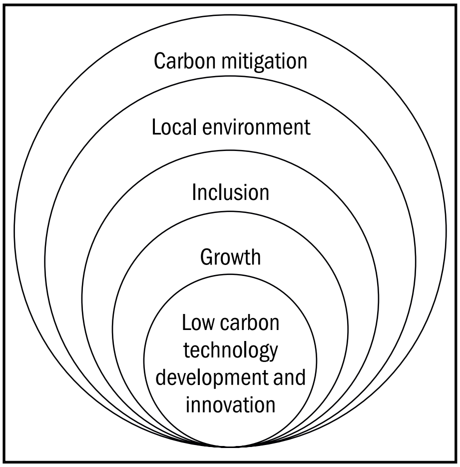

Figure 1.8 Co-benefits framework for technology innovation
Source: Author's compilation

development and innovation in the developing country context (see Figure 1.8).

India needs to adopt low carbon strategies in order to improve the sustainability of its growth process, while carbon mitigation will be an important co-benefit. Low carbon technology development and innovation in India would also need to factor in the social pillar of sustainable development as evident in the concept of 'inclusive growth' elucidated in the definition of 'green growth' of the Thirteenth Finance Commission of India. At the same time, since 'economic growth' would remain a priority of developing countries, competitiveness of domestic industries would continue to be relevant.

Figure 1.9 plots the data on patent applications to the EPO in environment-related technologies, collected for six Organisation for Economic Co-operation and Development (OECD) countries and five non-OECD countries for the year 2008. It can be observed, very clearly, that for developing countries including India and China, the percentage share of patents of the country in categories of general environmental management (air, water, waste) and energy generation from renewable and non-fossil sources is more. This could also

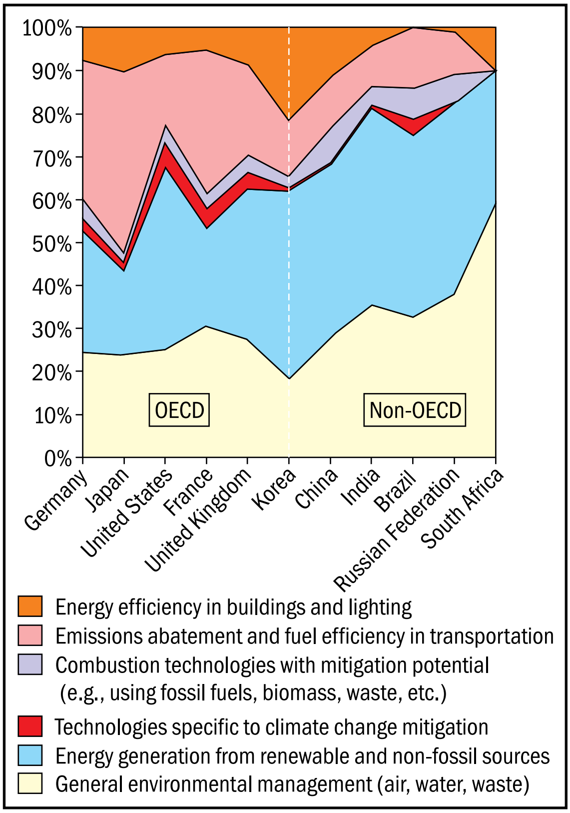

Figure 1.9 Trends for patents in OECD and Non-OECD countries (2008)
Source: Author's compilation

be attributed to other factors. One factor for more innovations in developing countries could be due to policies and institutions for local environment in countries—say for countries like India and China. The other factor is that renewable energy policies have been encouraged to promote energy security, along with them being a cleaner source of energy.

Transitioning to a low carbon development pathway would require a wide diversity of technologies and innovation activities across various sectors. As discussed in the chapter, there is an enormous diversity of low carbon technologies across sectors, at many different scales of development and diffusion. The relative maturity of various technologies in the sectors is shown in Figure 1.10. The bars in the figure indicate the areas where majority of activities are currently focused upon, while R&D and early stage activities are ongoing in all of these technology areas.

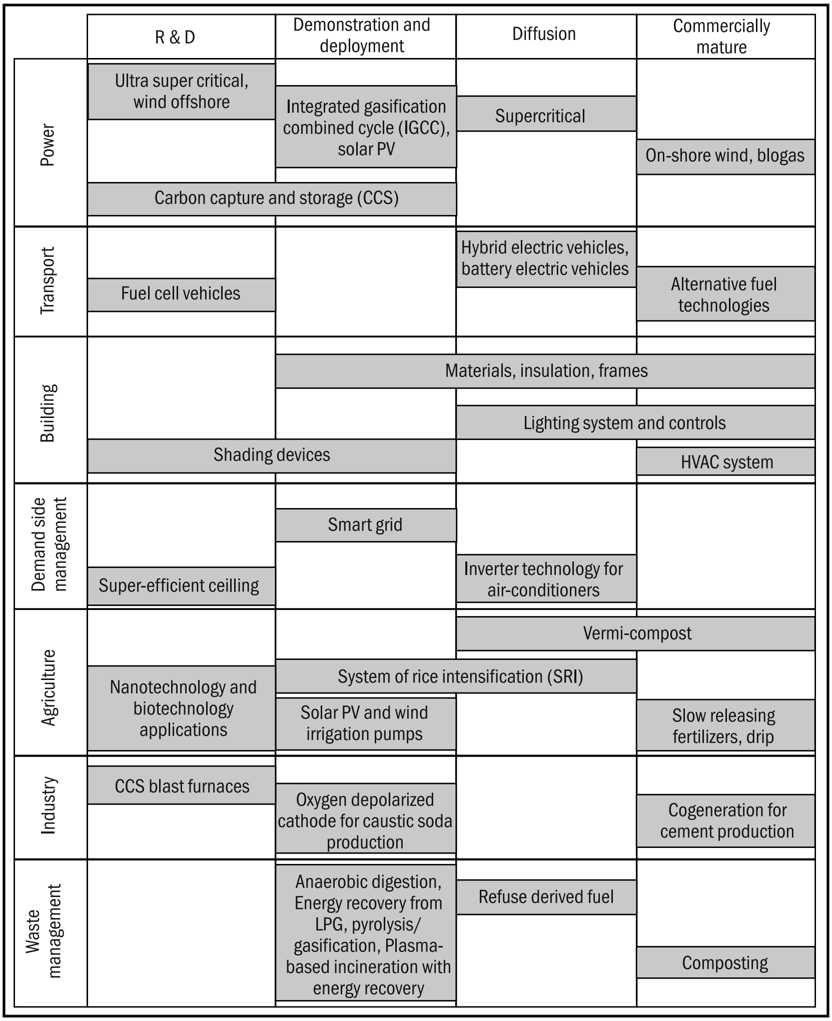

Figure 1.10 Status of Maturity of Different Low Carbon Technologies in Key Sectors
Source: Author's compilation

In summary, R&D and innovation activities in low carbon technologies are characterized by low investment and slow diffusion. Incentives for low carbon innovation are further weakened by real and perceived uncertainties about lack of clear direction and policy instruments. A matrix of this sort, enlisting various ongoing technological activities and their respective maturity stages would be the first step in understanding the opportunities and challenges for catapulting to a low carbon path of development. In the recent past, the dynamics of the innovation process have changed tremendously with increasing fragmentation in the production process and increasing diversity of business models, involving a multitude of players who are distributed worldwide. Differences between the developed and emerging world markets are leading to reinvention of products and reduction of costs and have fostered innovation in distribution, commercialization, and marketing chains in countries like India and China. Both India and China are making efforts to set foot on a trajectory of low carbon development with varying degrees of success. Although technology development and diffusion would assume different routes, the emerging experience of the national efforts of China, in the overall process of low carbon technology innovation and diffusion, might be extended to India and vice versa.

Innovation also benefits from the development of a sound policy and regulatory environment that contributes to incentives as well as protection of intellectual property. In this regard, transition to a low carbon pathway could be accelerated by incentives through a national directive for R&D in low carbon development, setting up of low carbon technology incubation centres with strong industry–academia–government linkages, facilitation of technology transfer through existing and new technology transfer offices (TTOs), a focus on low carbon innovations in the informal sector, among others. India can also learn from the innovations taking place in China such as the standards system and also the science and technology framework in China which is playing a major role in promoting R&D in low carbon development.

A wide range of low carbon technologies need to be developed and deployed across various sectors as indicated in the study. For this, R&D and deployment efforts in both the public and the private sectors, combined with targeted policies, need to be encouraged. The following measures could be considered and adopted for promoting and strengthening innovation for low carbon development:

- A clear vision and prioritization for R&D for development of low carbon technology needs to be determined through structured analysis. This could be facilitated by using the tools of technology foresight, technology road-mapping, technology assessment, and evaluation
- Allocation of appropriate level of funding by the government after finalization of priorities and strategies
- Identification of the weaker links and constraints in the innovation chain of a particular low carbon technology and taking a holistic approach to address those challenges
- Measures supporting R&D in micro, small and medium enterprises

need to be introduced to advance innovation in low carbon technology

- An integrated systems approach towards low carbon technology development and deployment needs to be adopted, involving various agencies, both at the national and local levels as well as across thematic areas of energy and environment. Such a coherent approach would also help avoid a wasteful proliferation and duplication of initiatives across the various sub-sectors and enable greater industry involvement
- Generic emerging technologies, such as nanotechnology, materials technology, life sciences, etc., holding potential for low carbon technology development and having cross-sectoral application potential need to be promoted.

Appendix A: Technologies and innovation stages for sectors

Table A.1: Technologies and Innovation Stage for Power

Sector	Technologies	R&D	Demonstration and deployment	Diffusion	Commercially mature
Power	IGCC		X		
	Supercritical			X	
	Ultrasupercritical	X			
	CCS/CCUS	X	X		
	Wind (on-shore)				X
	Wind (off-shore)	X			
	Biogas				X
	PV		X		

Table A.2: Technologies and Innovation Stage for Transport

Sector	Technologies	R&D	Demonstration and deployment	Diffusion	Commercially mature
Transport	Hybrid electric vehicles			X	
	Battery electric vehicles			X	
	Alternative fuel technologies — Biofuels, CNG, LNG, and LPG				X
	Fuel cell vehicles	X			

Table A.3: Technologies and Innovation Stage for Buildings

Sector	Technologies	R&D	Demonstration and deployment	Diffusion	Commercially mature
Buildings	Materials				
	Use of waste in construction materials such as fly ash, gypsum	X		Partly diffused	X
	Bamboo and its variants	X	X		X
	HI-SEB		X		X
	Filler slab		X		X
	Heat reflective coatings/paints		X		X
	Heat reflective tiles		X		X
	Green concrete	X			

3.1

Insulation				
Spray insulation		X		X
Sandwiched insulation		X		X
Building block integrated	X	X		
High performance glazing	X	X	Partly for some types	X
Frames				
UPV		X		X
Al with brakes/without brakes		X		X
UPV		X		X
Al with brakes/without brakes		X		X
Lighting system and controls				
Luminaries			X	X
Controls		X		X
HVAC system				
High COP Chillers			X	X
Heat Pumps	X	X		X
Economizers				X
VRV-inverter type		X		X
VRV-digital scroll			X	X
Split with inverter			X	X
Shading devices				
External blinds				X
Internal blinds			X	X
Louvers-Fixed				
Louvers-perforated	X	X		
Louvers-Operable	X	X		
Ventilated cavity walls	X	X		
Green façade	X	X		
Green roof		X		X

Table A.4: Technologies and Innovation Stage for Demand-side Management

Sector	Technologies	R&D	Demonstration and deployment	Diffusion	Commercially mature
Demand Side Management	Smart grid		X		
	Inverter technology for air-conditioners			X	
	Super-efficient ceiling fans	X			

Table A.5: Technologies and Innovation Stage for Agriculture

Sector	Technologies	R&D	Demonstration and deployment	Diffusion	Commercially mature
Agriculture	Vermicompost			X (in some states)	X
	Slow releasing fertilisers				X
	Drip technology				X
	System of Rice Intensification (SRI)		X	X	
	CO_2 tapping using Azolla to convert to O_2		X		
	Soil health card/ Leaf colour chart				X
	Machinery identified for conservation of crop residues to avoid burning	X			
	Reclamation of soil			X	
	Construction of check dams			X	
	Establishment of solar voltic irrigation pumps		X		
	Nano technology and biotechnology in enhancing quality of agri produce/varietal improvement	X			
	R&D—Cropping pattern customised as per climate change	X			
	Machinery identified for conservation of crop residues to avoid burning	X			
	Reclamation of soil			X	

Table A.6: Technologies and Innovation Stage for Industry					
Sector	**Technologies**	**R&D**	**Demonstration and deployment**	**Diffusion**	**Commercially mature**
Industry	CCS for blast furnaces	X			
	Oxygen Depolarized Cathode for caustic soda production		X		
	Cogeneration for cement production				X

Table A.7: Technologies and Innovation Stage for Waste Management					
Sector	**Technologies**	**R&D**	**Demonstration and deployment**	**Diffusion**	**Commercially mature**
Waste management	Composting				X
	Anaerobic digestion*				X
	Refuse Derived Fuel (RDF)				X
	Energy recovery from LFG		X		
	Pyrolysis/gasification*			X	
	Plasma based incineration with energy recovery		X		

* for MSW the technology not yet commercially successful

CHAPTER 2

INNOVATIVE FINANCING FOR LOW CARBON DEVELOPMENT

2.1 Introduction

Financing sustainability (including low carbon development) is arguably the most critical challenge of this century. The difficulty of this challenge has been greatly augmented in the wake of serious global macro-economic imbalances. While macro-economic decisions (including banking) come from the policy side, the finance decisions come from the investment side. When it comes to sustainability issues, synchronization of macro-economic and finance decisions have become fairly arduous. Macro-economic and banking regulations are moving towards safety; ironically, these regulations are impeding investments in sustainability. For instance, the forthcoming Basel III rules (for banking) may significantly limit the ability of financial institutions to provide long-term, non-recourse project finance which is considered unsafe in banking parlance but are quite important for renewable energy projects to begin. Tax regimes in various countries are also not helpful for financing sustainability. 3.2

Typically, sustainability projects (say, developing sustainable habitats or green buildings) are attributed with high initial capital costs which are usually offset by lower operations and maintenance (O&M) costs; however, in various economies, tax rebates are available for O&M costs but not for the initial capital costs. All these issues make financing sustainability extremely challenging. It can also be understood that making money available for sustainability in an effective and efficient method is not only a decision in finance but also of macro-economics.

Following the global economic crisis in 2008, many governments announced stimulus measures for their countries. These included sets of policies to stimulate the private sector, boost consumer demand for goods and services, and provide greater public investment in various sectors. Sizeable portions of these stimulus packages were directed at environmental goals, particularly the reduction of GHG emissions. China's National Development and Reform Commission announced a variety of green stimulus measures. Over one-third of the massive Chinese stimulus package and nearly 27 per cent of the 2009 budget was allocated to green themes, mostly rail, grids, and water infrastructure, along with spending on environmental improvement. Table 2.1 depicts the stimulus packages by various countries and the climate change investment in the economic stimulus plans.

Table 2.1: Stimulus Packages and Green Investment (USD Billion)

Countries	Stimulus package	Low carbon	Other	Total
Australia	43.8	9.3		9.3
Canada	31.8	2.5	0.3	2.8
China	**647.5**	**175.1**	**41.3**	**216.4**
France	33.7	7.1		7.1
Germany	104.8	13.8		13.8
India	**13.7**			
Japan	639.9	36		36
Mexico	7.7	0.8		0.8
South Africa	7.5	0.7	0.1	0.8
Korea	38.1	14.7	21.6	36.3
Britain	34.9	3.7	0.1	3.7
USA	787	78.5	15.6	94.1
EU	38.8	22.8		22.8

Source: Barbier (2010)

Figure 2.1 shows different actors in the global financial architecture. It is important that the multilateral financial regime recognizes the need for engaging with global financial regulatory frameworks such as the Bank for International Settlements, International Monetary Fund, and International Accounting Standards Board.

It is the policy side which takes a pre-eminent position on such matters which are considered as provisioning of public goods. However, the scale required in terms of public goods for climate action may show various attributes which will not be completely sufficient under a public finance outlay format. The question is whether the private sector would be interested in such implementation frameworks and what would incentivize them to work towards operationalizing the same?

According to a survey of the World Economic Forum in 2015 (WEF 2015), major investment side players, across the world, are increasingly worried about extreme weather events and recognize climate change

National policy

- Ministry of Finance
- Sectoral ministries (e.g., Ministry of Environment, Forest and Climate Change)
- Reserve Bank of India
- State finance, planning and sectoral departments
- Municipal corporations
- Special institutions (e.g., IREDA)

Investment

- Commercial banks (public and private)
- Industry
- Financial institutions (e.g., equity, NBFI)

Norms and rating agencies

- Banking norms (e.g., Basel III)
- International financial reporting systems
- Rating agencies

Global governance

- International Monetary Fund (IMF)
- World Trade Organization (WTO)
- The World Bank, UN bodies, and international agencies

Figure 2.1 Actors in the Global Financial Architecture
Source: Author's compilation

related risks (Table 2.2). It may be reasonable to say that there is no way to measure actions in sustainability or climate actions through a method, including financial accounting, most understandable to the investment side players. 3.2

There have been attempts to measure sustainability for investors, such as the Equator Principles and the Triple Bottom Line, but both these practices are for measuring environmental and social risks; they do not affect the actual bottom line (net profits) at all. Only if there is a liability which is real and present, will it get reported in the balance sheet as a liability. Environmental and social liability should have a 'valuation' with a timeline attached and clarity in terms of causality. When these criteria are met, the environmental and social liabilities will start affecting the net profits of a firm.

Investment related decision-making is also made on financial ratios, which thus play an important role in this kind of decision-making. There is a need for a method—similar to financial ratio analysis—to obtain the efficiencies of private finance without getting into the grey area of actual financial impact reporting of environmental and social factors.

Table 2.2: Top Five Global Risks in Terms of Likelihoods

	2007	2008	2009	2010	2011	2012	2013	2014	2015
1st	Breakdown of critical information infrastructure	Asset price collapse	Asset price collapse	Asset price collapse	Meteorological catastrophes	Severe income disparity	Severe income disparity	Income disparity	Interstate conflicts with regional consequences
2nd	Chronic disease in developed countries	Middle East instability	Slowing Chinese economy (<6%)	Slowing Chinese economy (<6%)	Hydrological catastrophes	Chronic fiscal imbalances	Chronic fiscal imbalances	Extreme weather events	Extreme weather events
3rd	Oil price shock	Failed and failing states	Chronic disease	Chronic disease	Corruption	Rising greenhouse gas emissions	Rising greenhouse gas emissions	Unemployment and underemployment	Failure of national governance
4th	China economic hard landing	Oil and gas price spike	Global governance gaps	Fiscal crises	Biodiversity loss	Cyber attacks	Water supply crises	Climate change	State collapse or crisis
5th	Asset price collapse	Chronic disease in the developed world	Retrenchment from globalization (emerging)	Global governance gaps	Climatological catastrophes	Water supply crises	Mismanagement of population ageing	Cyber attacks	High structural unemployment or underemployment

Note: Boxes in green represent risks related to the environment as classified in WEF (2015)
Source: WEF (2015)

Thus, another fundamental issue relevant to financing strategies in the low carbon development field is the absence of financial indicators.

2.2 Financial Mechanisms in India for Low Carbon Development

The chapter will now look into the various aspects of financial mechanisms for low carbon development in India. Seven types of financial mechanisms will be covered as depicted in Figure 2.2. These include public finance, traditional finance, risk management instruments, market-based tradable instruments, international climate finance, public-private partnerships, and philanthropy.

1) Public Finance Initiatives

- Special national funds
- Fiscally supported guarantee schemes
- Special funds at the sub-national level

2) Traditional Finance

- Banking
- Innovation in financial products
- Green Bonds

3) Risk Management Instruments

4) Climate Change and Market-Based Instruments

- International carbon markets
- Domestic carbon market
- Other market-based innovations

5) International Climate Finance

6) Public–Private Partnerships

7) Philanthropy

Figure 2.2 Financial Mechanisms for Low Carbon Development in India

2.2.1 Public Finance Initiatives

Special National Funds

The National Clean Energy Fund (NCEF), announced in the Union Budget 2010–11, is seen as a major step in India's quest for energy security and reducing carbon intensity of energy. Funding research and innovative projects in clean energy technologies and harnessing renewable energy sources to reduce dependence on fossil fuels constitutes the objectives of the NCEF. The NCEF is being built up using the cess imposed on both the domestically produced and imported coal. This cess, which was earlier INR 50 per tonne of coal, was increased to INR 100 per tonne in July 2014. At this price the cess would have fetched INR 6,000 crore ever year.[5] The cess has now been doubled again to INR 200 per tonne on all forms of coal in the Union Budget of 2015–16—this would add an approximate amount of INR 12,000 crore (approx. USD 2 billion) annually for clean energy initiatives. Box 2.1 presents projects that are eligible to be financed through the NCEF.

Box 2.1: Projects eligible to be financed through the NCEF

According to the guidelines issued by the Ministry of Finance, the following initiatives are eligible for financing under the National Clean Energy Fund.

- Development and demonstration of integrated community energy solutions, smart grid technology, renewable applications with solar, wind, tidal, and geothermal energy;
- Critical renewable energy infrastructure in areas such as silicon manufacturing;
- Replacing existing technology in energy generation with more environmentally sustainable approaches;
- Environment management projects particularly in the geographical areas surrounding energy sector projects;
- Renewable/alternate energy including advanced solar technologies, geothermal energy, bio-fuels from cellulosic bio-mass/algae/any waste, offshore marine technologies (wind, wave and tidal), onshore wind energy technologies, hydrogen, and fuel cells;
- Clean fossil energy including power, oil, gas and coal technologies including coal gasification, shale oil/ gas, lignite/coal bed methane, and advanced turbine and technology for integrated gasification combined cycle power (IGCC) plants, methane hydrates, enhanced recovery from unconventional resources and fossil energy advanced research, carbon capture and sequestration, and carbon capture and reformation;
- Basic energy sciences including energy storage for hybrid and plug-in electric vehicles, solid state lighting, catalysis, biological and environmental research, advanced computing, high energy and nuclear physics;
- Pilot and demonstration projects for commercialization of clean energy technologies;
- Projects identified under the eight missions of the National Action Plan on Climate Change (NAPCC) and projects relating to R&D to replace existing technologies

[5] http://www.livemint.com/Politics/7008Rw5aY79CmN9MEzqpcO/Govt-uses-green-energy-fund-for-fiscal-balancing.html, last accessed on May 6, 2015.

with more environment friendly ones under the National Mission on Strategic Knowledge for Climate Change (NMSKCC).
- Projects relating to creation of power evacuation infrastructure for renewables.

Source: Compiled from MoF (2011)

The coal cess goes to the National Clean Energy Fund, which has a fund amounting to INR 17,000 crore (approx. USD 2.833 billion) in its kitty. By September 2014, 46 clean energy projects worth INR 16,511.43 crore (approx. USD 2.752 billion) were recommended for funding out of the NCEF (MoF 2015). Also, so far, the projects that have been approved or are under consideration to be funded under the NCEF are routine in nature, and should have been funded by the ministries through their regular schemes. While the objectives of NCEF seem to be in line with the critical needs of the clean energy sector in India, there is no guidance for the overall vision and the strategy that should be employed to realize these (NIPFP 2013). There is also a need to both substantially augment the resources made available for energy related R&D and allocate these strategically, according to its needs and priorities.

Fiscally Supported Guarantee Schemes

The Government of India adopted the National Action Plan on Climate Change in 2008 that consisted of several targets on climate change issues and addressed the urgent and critical concerns of the country through a directional shift in development patterns. The Partial Risk Guarantee Fund (PRGF) has been proposed under the National Mission on Enhanced Energy Efficiency (NMEEE) to cover specified technology and the associated commercial risks for new technologies in energy efficiency and renewable energy that are not usually priced by commercial banks. To help extend the reach of private financing by mitigating perceived risk and encourage private sector involvement in these sectors, this facility will act as a risk-sharing mechanism that will provide commercial banks with partial coverage of their risk exposure, thereby helping investors get lower cost debt. The Government of India has approved around INR 312 crore (approx. USD 52 million) for PRGF for Energy Efficiency (PRGFEE).

The fund would be available only in case of default, that is, it will be paid out to participating banks in the event of a loss or default, as specified in the structure of the PRGF mechanism. The mechanism is intended to address the key barriers of *(i)* availability of long-term finance at reasonable rates of interest to solar and energy-efficient applications, and *(ii)* build capacity within financial institutions to assess commercial risks in these businesses.

Similar to PRGF, the World Bank is facilitating efforts from Clean Technology Fund (CTF) and Global Environmental Facility (GEF) for a Partial Risk Sharing Facility (PRSF) to initiate the Energy Service Performance Contracting market for Energy Efficiency projects in large scale industries. Its objective is to achieve energy savings by catalyzing the market for energy service companies (ESCO) implemented energy efficiency projects in India.

The PRSF comprises of a risk-sharing fund corpus of USD 35 million implemented by SIDBI, the Project Execution Agency (PEA) and funded from the CTF contribution of USD 25 million and a GEF contribution of USD 10 million (Component 1) and a TA and capacity building component from a GEF component of USD 8 million, with USD 6 million implemented by SIDBI & USD 2 million implemented by EESL (Component 2) (SIDBI 2014).

Such initiatives aiming at lower cost financing can help make more projects financially viable, bring advanced renewable energy investments closer to grid parity faster and reduce payback periods of energy-efficient investments.

Special Funds at the Sub-National Level

A formal mandate to setup state energy conservation funds is mentioned in the Energy Conservation Act 2001 (EC Act 2001) that requires each state to designate an agency to implement the Act, and establish the State Energy Conservation Fund (SECF). The establishment of SECF is for the purposes[6] of promotion of efficient use of energy and its conservation within the state. The Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India, provides a contribution of INR 4 crore (approx. USD 0.66 million)[7] to those states willing to set up an SECF managed by a designated agency in the individual states. (BEE undated)

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[6] Paragraph 16, Energy Conservation Act, 2001

[7] The government scheme is for contribution by the Ministry of Power to all the State/UTs with a maximum ceiling of INR 4 crore (approx. USD 0.67 million) for any State/UT provided in two instalments of INR 2.00 crore (approx. USD 0.33 million) each. The second instalment of contribution to SECF was released only after the states have provided a matching contribution to the BEE's first instalment.

Some of state-level energy conservation initiatives are as follows:

- Urja Ankur Fund in Maharashtra (conceived in 2006)
- Gujarat Green Energy Fund (conceived in 2011)
- Rajasthan State Energy Conservation Fund (conceived in 2010)
- Haryana State Clean Energy Fund (conceived in 2010)
- Kerala State Energy Conservation Fund (conceived in 2010)

Apart from the above mentioned state energy conservation funds, states such as Odisha, Uttar Pradesh, and Punjab among others have also constituted their energy conservation funds so that they could receive the fund disbursed by the BEE to invest in energy efficiency projects.

The Urja Ankur Fund was designed to promote power generation using bagasse as a source during the first phase and small hydro, municipal waste and geothermal energy in the second phase. It helps project development by placing 20 per cent equity and providing project development support. The Urja Ankur fund is an example of a fund created by collecting an additional amount in electricity bills but without any contribution from the energy charges development. The fund was created to support large renewable energy projects in Maharashtra with a legislative mechanism, allowing an additional charge to be levied on industrial consumers in the state (IIEC 2012).

The focus of operation of these funds has been the promotion of medium to large renewable energy projects.

Special Financing Institutions Under Public Finance

There is a need to facilitate public sector investment for low carbon growth, build carbon market access, accelerate technological innovation, and support adaptation to mitigate the impacts of climate change. Support for development and commercialization of low carbon technologies (LCTs) needs to be significantly augmented by targeted public sector financing interventions, directly by the Indian government, through its agencies or indirectly through universities or research institutes. Public sector funding would reduce the risks of investing in LCTs and demonstrate their commercial viability so as to create a scaled-up, commercially viable business activity. This in turn would stimulate and mobilize private finance and investment to scale up their deployment over time.

The Indian government, realizing the barriers associated with financing renewable energy projects, under its strategy to develop sustainable energy, created the Indian Renewable Energy Development Agency (IREDA) in 1987. IREDA's resources have mostly come from international assistance and domestic borrowings in the form of credit from other banks and issuance of long-term bonds.

IREDA has intended to lend INR 14,000–16,000 crore (approx. USD 2.333–2.666 billion) in 2014 over the next three years (Upadhyay, 2014); equivalent to as much as it has disbursed for the past 28 years it has existed, illustrating the growing interest of investors in clean energy business. It launched its first green bond in February 2014 worth INR 500 crore (approx. USD 83.33 million) total (with an option to extend to INR 1,000 crore [approx. USD 166.67 million]) to support renewable energy projects. At the end of 2014, the US EXIM bank agreed to provide medium and long-term loans for up to USD 1 billion for IREDA affiliated projects. This credit facility can be utilized during commercial development activities, within the clean energy sector by IREDA, to import US technologies, products and services, and finance up to 30 per cent of domestically manufactured components.

Given the magnitude of the required resources, IREDA would have to be significantly strengthened to be capable of responding to, and in many areas anticipating, the needs and complexities of the low carbon transition, and thereby designing new and efficient financial instruments to meet these needs. Therefore, there is a need to broaden the sources of funds for financing such investments as well as the manner in which these funds are intermediated. Effective long-term availability of funds for facilitating the shift to low carbon investment would necessitate large-scale, well-constructed involvement of public financial institutions with specific focus on driving the transformation to low carbon energy.

2.2.2 Traditional Finance

Banking

Traditional finance in India has not managed to come up with a common framework to encourage companies to go green. However, despite the absence of green credit guidelines, some banks have taken initiatives independently.

There is the case of the State Bank of India, the country's largest bank, which introduced a 'Green Home' loan, with special concessions (reduced margin, softer interest rate, and zero processing fees) for environment-friendly housing projects. The other well-known bank which finances green projects is SIDBI (Small Industries Development Bank of India). It provides micro, small and medium enterprises financial assistance for technology innovative projects, with a preference being given to the green sector. Thanks to special lines of credit given by international agencies (JICA, KFW, AFD), SIDBI is able to grant loans with relatively low interest rates compared to those of commercial banks. By October 2012, SIDBI had provided assistance worth approximately INR 3,000 crore (approx. USD 500 million) to around 6,000 MSME units for green and energy-efficient technologies (MMR Online Foundry Review, 2012).

The Infrastructure Development Finance Company (IDFC) is the only Indian bank that has joined the Equator Principles—an internationally accepted credit risk management framework for determining, assessing, and managing environmental and social risks in project finance transactions.

The issuance of the Green Credit Guidelines by China's banking regulatory commission in February 2012 marked a milestone in China's commitment to sustainable banking practices and in helping address environmental challenges. The guidelines promote the implementation of Green Credit policies to a new level. It is a kind of financial innovation for achieving sustainability objectives.

These guidelines have been formed to encourage banking and financial institutions to promote green credit, effectively fend off environmental and social risks, boost the transformation of the economic growth mode and the adjustment of the economic structure, and hence, better serve the real economy. Thus, they encourage Chinese banks to lend more to energy-efficient and environmentally sustainable companies and less to polluting and high energy-consuming enterprises. The guidelines show the banks how to integrate sustainability thinking into their lending cycle and will be applied to all lending—both domestic and overseas.

The Chinese Green Credit Guidelines require the board of directors or the supervisory board of banking institutions to build and promote green credit concepts concerning energy saving, environmental protection and sustainable development; be committed to giving play to the functions of facilitating holistic, coordinated and sustainable economic and social development; and establish a sustainable development model that will benefit the society at the same time (Article 6, Green Credit Guidelines).

The Reserve Bank of India (RBI) which is India's central banking institution controls the monetary policy for the country. The institution is responsible for regulating and supervising the financial system and prescribes broad parameters for banking operations within which the country's banking and financial system functions.

The RBI guidelines on loans and advances provides a framework of rules, regulations, and instructions issued to scheduled commercial banks on statutory and other restrictions on loans and advances. Commercial banks should implement these instructions and adopt adequate safeguards in order to ensure that the banking activities undertaken by them are run on sound, prudent, and profitable lines(RBI 2014). The restrictions pertain to the following:

- Statutory restrictions
- Regulatory restrictions
- Restrictions on other loans and advances
- Transfer of borrowal accounts from one bank to another
- Guidelines on Fair Practices Code for lenders
- Guidelines on recovery agents engaged by banks

RBI guidelines with respect to loans and advances, non-performing assets, interest payments, prudential norms, capital adequacy, and know your customer (KYC) norms are very well-structured and set according to international standards. RBI revised its priority sector lending norms in April 2015 and notably accorded priority sector lending status to renewable energy (RBI 2015). Banks can now provide loans up to INR 15 crore (approx. USD 2.5 million)to borrowers for purposes like solar-based power generators, biomass-based power generators, wind mills, micro-hydel plants, and for non-conventional energy-based public utilities viz.street lighting systems and remote village electrification. For individual households, the loan limit will be INR 10 lakh (approx. USD 0.016 million) per borrower. However, there is a lack of a mechanism that would make the banks invest more to support a green and low carbon economy. There is absence of green credit guidelines or guidelines on similar lines in India that prescribes banking institutions to establish and constantly improve the policies, systems, and processes for environmental and social risk management, and identify the directions and priority areas for green credit support.

Recently banks and financial institutions in India have submitted Green Energy Financing Commitments for financing upto 2021–22 in the recently held RE-INVEST 2015. The submissions amount to a total of INR 352,640 crore (approx. USD 58.8 billion) as depicted in the Table 2.3.

In the banking sector, there have been several innovations in traditional banking around the world. The Republic of Korea, for example, has designed traditional financing instruments targeted at both individuals and companies. Such innovations can be seen as a

Table 2.3: Green Financing Commitments for Renewable Energy upto 2021–22

S. No.	Name of the Company	Capacity (GW)	Amount (INR crore)	Amount (USD million)
1	State Bank of India	15.00	75,000	12,500
2	ICICI Bank	7.50	37,500	6,250
3	L&T Finance Holdings Limited	6.50	32,500	5,417
4	Indian Renewable Energy Development Agency Ltd	6.00	30,000	5,000
5	PTC India Financial Services Ltd	6.00	30,000	5,000
6	Yes Bank Pvt. Ltd	5.00	25,000	4,167
7	Indian Infrastructure Finance Co. Ltd	4.00	20,000	3,333
8	IDBI Bank Ltd	3.00	14,700	2,450
9	Power Finance Corporation	3.00	15,000	2,500
10	Bank of Baroda	2.50	12,500	2,083
11	Axis Bank	2.00	10,000	1,667
12	Bank of India	2.00	10,000	1,667
13	Union Bank of India	1.50	7,500	1,250
14	Bank of Maharashtra	1.50	7,500	1,250
15	Andhra Bank	1.00	5,000	833
16	South Indian Bank Ltd	0.60	3,000	500
17	HDFC Bank	0.40	2,000	333
18	Indian Overseas Bank	0.40	2,000	333
19	Punjab National Bank	0.50	2,500	417
20	Canara Bank	0.32	1,600	267
21	State Bank of Mysore	0.29	2,000	333
22	State Bank of Travancore	0.25	1,250	208
23	Indian Bank	0.22	1,100	183
24	Dena Bank	0.20	1,000	167
25	United Bank of India	0.20	1,000	167
26	Vijaya Bank	0.20	1,000	167
27	Lakshmi Vilas Bank	0.20	1,000	167
28	State Bank of Patiala	0.10	500	83
29	Oriental Bank of Commerce	0.08	240	40
30	Bhartiya Mahila Bank	0.05	250	42
	Total	**70.51**	**352,640**	**58,773**

Source: MNRE (2015)

step to promote individual behaviour change as well as incentivize low carbon industries around energy efficiency and renewables. Box 2.2 depicts innovations around traditional financing.

Box 2.2: Green financing instruments in the Republic of Korea

For individuals, the principle is that every type of financing instrument offers the benefits of higher interest rate on deposits, lower interest rate on loan, or other fee discounts related to personal green activities. Green financing instruments for individuals include:

- Savings accounts
- Credit cards
- Funds
- Insurance
- Personal loans

Green finance for companies is about seven times that given to individuals in respect to total loan size. The finance products are also mainly public products and include the following:

- Ordinary loan
- Public loan
- Public guarantee
- Public fund
- Public insurance

Analyses show that green loans for both individuals and companies have witnessed an increase in the period September 2009 to February 2010.

Source: Compiled from Oh (2011)

All in all, the two main—and almost only—ways of financing a green project in India today are equity and debt. However, with the growing need for green investments, no doubt, financial innovations including issuance of guidelines by the central banking regulatory body will contribute in stimulating financing for low carbon development.

Innovation in Financial Products

The Bombay Stock Exchange (BSE) has two indices to promote investment that considers environmental sustainability and also climate change considerations; these include the S&P BSE Greenex and the S&P BSE Carbonex.

The Greenex, launched on February 22, 2012, is an index which is licensed for the development of green financial products including mutual funds, exchange-traded funds (ETF), and structured products. It calculates the energy intensity of a company (total emissions upon total revenue) and publicly disseminates it on a real-time basis. For Carbonex, which was launched on November 30, 2012, the areas in which the companies are assessed include reporting and disclosure, strategy and governance, performance and achievement, and ecosystem action.

The S&P Greenex index now comprises the top 25 companies with energy efficient practices from the S&P BSE 100 index as compared to comprising the top 20 companies when it was conceived. All the constituents of the S&P BSE 100 form part of the S&P Carbonex. Tables 2.4 and 2.5 present the sector-wise distribution and market capitalization for Greenex and Carbonex, respectively.

Table 2.4: BSE Greenex: Sector-wise Distribution and Market Capitalization in 2015

S. No.	Index/Sectors	Index market capitalization (%)
1	Transport equipments	22.81
2	Healthcare	20.93
3	Finance	12.35
4	Fast moving consumer goods (FMCG)	11.19
5	Telecom	5.81
6	Capital goods	5.63
7	Information technology	5.49
8	Metal, metal products, and mining	5.02
9	Housing related	3.56
10	Power	2.09
11	Oil and gas	1.82
12	Consumer durables	1.70
13	Agriculture	1.58
	Total	**100**

Source: S&P BSE (2015a)

Table 2.5: BSE Carbonex: Sector-wise Distribution and Market Capitalization in 2015

S. No.	Index/Sectors	Index market capitalization (%)
1	Finance	30.11
2	Information technology	13.60
3	FMCG	10.01
4	Oil and gas	9.57
5	Transport equipments	9.21
6	Healthcare	6.38
7	Capital goods	6.10
8	Metal, metal products, and mining	3.90
9	Power	2.68
10	Housing related	2.47
11	Telecom	2.46
12	Chemical and petrochemical	1.07
13	Diversified	0.51
14	Textile	0.49
15	Consumer durables	0.41
16	Media and publishing	0.36
17	Agriculture	0.34
18	Transport services	0.32
	Total	**100**

Source: S&P BSE (2015b)

Green Bonds

Green bonds are an innovative financing mechanism which can help in raising long-term and low-cost debt capital to fund 'green' projects involving emission reduction such as improvement in energy efficiency, and production of renewable energy. They can prove to be extremely useful to fund India's ambitious target of building 175 GW renewable energy capacity by 2022 (MNRE, 2015). In the next five years, proposals are likely to generate business opportunities of the order of USD 160 billion in the renewable energy sector (MOF, 2015).

Although, the Green Bond Principles (GBPs)—voluntary process guidelines that recommend transparency and disclosure and promote integrity in the development of the Green Bond market by clarifying the issuance process—do mention the broad categories wherein the proceeds from the sale of the green bonds should be allocated; determination of projects under 'green' category remains ambiguous because of the lack of a standard definition of green bonds.

In India, examples of green bonds include—green bond launched by IREDA in February 2014, Green Infrastructure Bond launched by YES Bank India in February 2015, Reg S Green Bond issued by the Export–Import Bank of India in March 2015, etc. The following content and Table 2.6 provides details on the bonds issued.

IREDA launched its first green bond to support renewable energy projects in February 2014. They offered it to both private and public investors and issues at INR 1,000 each, totaling to INR 500 crore (approx. USD 83.33 million) with an option to extend it to INR 1,000 crore (approx. USD 166.67 million). The tenure of the bonds is 10, 15, 20 years with interest rates at 8.16 per cent, 8.55 per cent, and 8.55 per cent, per year, respectively. This green bond received an AAA rating from two top Indian rating agencies, CARE and Brickworks.

YES Bank issued the first ever Green Infrastructure Bonds raising an amount of INR 1,000 crore, twice the original issue amount of INR 500 crore with green shoe option. The bonds are for a tenure of 10 years. YES Bank intends to finance Green Infrastructure Projects in Renewable Energy including Solar Power, Wind Power, Biomass, and Small Hydel Projects from the proceeds of this green infrastructure bond.

EXIM Bank of India launched a 5 year Reg S Green Bond issue of USD 500 million on March 24, 2015, at a coupon of 2.75 per cent per annum. The issue attracted subscription of around 3.2 times the issue size led by strong demand, across 140 accounts. Majority participation was from fund managers (58 per cent) followed by banks (20 per cent) and sovereign wealth funds/insurance companies (18 per cent). The issue was distributed 60 per cent to Asian investors, 30 per cent to Europe, Middle East, and Africa and balance to offshore US investors. S&P rated EXIM Bank of India at 'BBB-'and Moody rated it at 'Baa3'.

Table 2.6: Green Bonds Issues in India

Name	Date issued	Amount raised	Maturity	Rating
IREDA Green Bond	February 17–March 10, 2014	INR 500 crore total (with the option to extend to INR 1,000 crore)	10, 15, and 20-year terms	AAA rating from Indian rating agencies: CARE and Brickworks

Yes Bank Green Infrastructure Bond	16–24 February 2015	INR 1,000 crore	10 years	AA+ (Indian credit rating)
EXIM Bank 5-year Eurodollar Reg S Green Bond	March 24, 2015	USD 500 million	5 years	Rated as 'BBB-' by Standard and Poor's and 'Baa3' by Moody's, same as the rating of Govt. of India.

Sources: YES Bank (2015), EXIM Bank of India (2015), and Upadhyay (2014)

EXIM Bank's bond issue was India's first USD denominated green bond while Asia's first benchmark-sized green bond in 2015 and also the third ever green bond outside Asia. EXIM will use the net proceeds from the sale of the notes to fund eligible green projects in countries including Bangladesh and Sri Lanka (EXIM Bank of India 2015).

According to the Climate Bonds Initiative, an organization seeking to mobilize the world's USD 100 trillion bond market for climate-change solutions, green bonds raised USD 36.6 billion globally by the end of 2014, which is triple the 2013 figure. However, the market for green bonds is still at a very nascent stage. A study by the Bloomberg New Energy Finance, titled Green Bonds Market Outlook, 2014, mentions that the global green bond issuance in 2013 was just about 1 per cent of the value of the US corporate bond issuance, which was over USD 1.4 trillion (BNEF, 2014). The forecast done by the Climate Bonds Initiative is encouraging though. The market is expected to reach USD 100 billion in 2015 and to treble again in 2018 (Wong 2015) .

Currently, options for investing in clean energy are limited. Also, a joint Climate Policy Initiative-Indian School of Business study found that high interest rates and unattractive terms under which the debt is available in India, raises the cost of renewable energy by 24–32 per cent compared to the US and Europe (CPI-ISB, 2012). Capability of green bonds to tackle these issues has been proven to some extent. The recently launched green bonds not only received better sovereign ratings than their unclassified predecessors issued some time back but were also offered over larger tenures. Consequently, they met with great investor euphoria.

With lower than expected bank credit for renewable energy projects, Non-banking financial companies can fill the gap for the required credit. Tata Cleantech, the clean energy lending arm of Tata Capital, for instance, is looking to become an infrastructure finance company so that it can obtain foreign funding for renewable power projects (Upadhyay 2015). Other such companies, like L&T Infrastructure

Finance and PTC Financial have similar plans and their capacity to offer faster financial closure than traditional banks can act to their advantage. Indian companies can also learn from countries which have developed the municipal bond market. Municipal bonds can help city corporations raise funds without looking for grants from state or central government or loans from international agencies. The municipal bond market in India, albeit more than a decade and a half old, is still at a nascent stage. After 2010, no municipal bonds were issued and the market has been dormant due to low ratings, reluctant investors, and unclear regulations (Chakrabarti 2014). On a positive note though, the rating agency, CARE, estimates that INR 1,000–INR 1,500 crore (approx. USD 166.67–250 million) could be raised by way of municipal bonds every year over the next five years by the larger urban local bodies with investment grade. Thus, municipal/local bonds hold large untapped potential waiting to be explored to bring about sustained development in infrastructure and fund green projects.

Although larger issues of standardization, credibility, and proper classification of bonds as 'green' are yet to be taken care of, credit enhancement and larger participation from other eligible entities could still help India leverage the early mover position in the burgeoning green bonds market. Under that scenario, India should remain hopeful of the opportunity green bonds provide to raise capital to fund its green ventures.

2.2.3 Risk Management Tools

Two-thirds of the Indian population depends on agriculture to live, which is a sufficient reason to demonstrate the importance of crop insurance in this country. In 2013, the National Crop Insurance Program (NCIP) was introduced which merged Modified National Agricultural Insurance Scheme (MNAIS), Pilot Weather Based Crop Insurance Scheme (WBCIS), and Pilot Coconut Palm Insurance Scheme (CPIS), existing at that time.

MNAIS provides for insurance cover and financial support to the farmers in the event of prevented sowing and failure of any of the notified crops as a result of natural calamities, pests, and diseases. WBCIS aims to reduce hardships faced by insured farmers on account of financial loss caused due to crop loss resulting from incidences of adverse weather conditions. CPIS assists coconut growers in insuring coconut palms against natural and other perils.

The NAIS which started in 1999 has been quite successful in insuring farmers and is sponsored by the Indian government. Any farmer can apply for this insurance, whatever the size of his holding, at an interest rate ranging from 1.5 per cent to 3.5 per cent, depending on what he grows. The insurance can be either area-based or individual-based (viz., for widespread or localized calamities) (Raju & Chand, 2008). In the case of an area-based insurance, an average yield of this particular area is defined (based on previous years' data) and if the actual yield is below the historical level, the insured farmers in this unit can ask for indemnification (70, 80, or 90 per cent, respectively, for high, medium, and low risk areas).

In total, some 25 million farmers have been insured, thanks to the NAIS, which makes it the largest crop insurance programme in the world. However, India has around 121 million farmers, out of which 80 per cent do not receive any help from financial institutions but rely on themselves to meet their financial needs—a lot of efforts remain to be made to meet the demand.

The Ministry of Micro, Small and Medium Enterprises, Government of India, and Small Industries Development Bank of India (SIDBI), established a Trust named Credit Guarantee Fund Trust for Micro and Small Enterprises (CGTMSE) to implement the Credit Guarantee Fund Scheme for Micro and Small Enterprises. The scheme was formally launched on August 30, 2000. The corpus of CGTMSE is being contributed by the GoI and SIDBI in the ratio of 4:1, respectively, and INR 2,295.30 crore (approx. USD 382.55 million) had been contributed to the corpus of the Trust up to August 31, 2014. According to CGTMSE, this scheme reassures the lender that in case a MSE unit fails to discharge its liabilities to the lender, the Guarantee Trust would cover for the loss incurred by the lender up to 75/80/85 per cent of the credit facility. SIDBI has been able to cover over 14 lakh units under that scheme for MSMEs for loans of about INR 70,000 crore (approx. USD 11.66 billion).[8]

A risk sharing mechanism that has been introduced under the National Mission on Enhanced Energy Efficiency (NMEEE) of the National Mission on Climate Change (NAPCC) is Partial Risk Guarantee Fund (PRGF). It provides commercial banks with partial coverage of risk exposure against loans issued for energy efficiency projects by substituting a portion of the risk of the borrower by providing guarantees.

On March 31, 2015, the World Bank and the Government of India have signed a USD 43 million grant and guarantee agreement

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[8] http://www.thehindu.com/news/cities/Coimbatore/sidbi-supports-msmes-through-collateralfree-loans/article6092332.ece

towards the Partial Risk Sharing Facility for Energy Efficiency Project. The project has the potential to leverage funds and unlock private sector financing to over three-times of the World Bank funds. It will also help build the capacity of ESCOs to structure and seek financing; and that of financial institutions to finance EE projects on a commercially-sustainable basis.[9]

Although the atmosphere surrounding financing for low carbon transitioning technologies is improving, yet it is still fraught with uncertainties and risks which are preventing lending at a larger scale. There is a need to look out for more risk management tools for low carbon development in India.

2.2.4 Climate Change and Market-based Instruments

International Carbon Markets

The global carbon market grew rapidly from 2005 until 2011, from an initial value of USD 11 billion to USD 176 billion after which prices in the major existing markets were at a historic low. Prices in the EU ETS—the largest carbon market—remained in the depressed range of about USD 5–9 in 2013 as compared to USD 13 three years ago. Similarly, Kyoto credit prices also reached their lowest in 2013 and 2014, with Certified Emission Reductions (CERs) worth just USD 0.51. The private sector experienced significant losses and as they remain reluctant to engage, robust consensual and international solutions are required to revive private sector confidence in the global carbon market. 3.2

Progress across the globe is however steadily increasing; eight new carbon markets opened their doors in 2013 alone. According to the World Bank (2014), about 40 national and over 20 sub-national jurisdictions are putting a price on carbon. It estimates the world's emission trading schemes to be USD 30 billion (it doesn't include the Kyoto Protocol international emission trading) in 2013. Point Carbon at Thomson Reuters estimates that the global carbon market is set to near Euro 70 billion (approx. USD 79.1 billion)[10] in 2015 after strong growth in 2014 when it reached Euro 45 billion (approx. USD 50.85 billion).

Flexible mechanisms were established, under the Kyoto Protocol (KP), to provide industrialized countries alternatives to reducing

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[9] Press release, The World Bank. Available at http://www.worldbank.org/en/news/press-release/2015/03/31/partial-risk-sharing-facility-energy-efficiency-singing

[10] For currency conversion purposes: I Euro = 1.13 USD

greenhouse gas (GHG) emissions domestically. The three KP mechanisms include:

- International Emissions Trading
- Joint Implementation (JI)
- Clean Development Mechanism (CDM)

A second commitment period to the Protocol was negotiated at the 17th Conference of the Parties (COP17) in Durban in 2011 implying that the KP flexible mechanisms will continue until 2020 at least.

A number of new market mechanisms are being considered to scale up carbon offsetting in developing countries, namely bilateral and sectoral mechanisms, the Reducing Emissions from Deforestation and Forest Degradation (REDD+) mechanism and credited Nationally Appropriate Mitigation Actions (NAMAs). All these new mechanisms aim to scale up the CDM significantly. Table 2.7 lists the new market mechanisms.

Table 2.7: New Market Mechanisms

New market mechanisms	Description	Status	Private sector involvement
Bilateral offsetting crediting mechanism	Agreement between a country with international emissions reduction targets and developing countries without such a target. The scheme will have similar objectives to the CDM, yet with a simplified administrative process and on a larger scale.	Japan is currently funding pilot projects.	As with CDM, the private sector has a similar role to play through investments in return for offsets.
REDD+	Mechanism to stop global deforestation by offering developing countries financial incentives to preserve forests in return for carbon credits.	COP16 in Cancún delivered an international agreement on the formation of the REDD mechanism. However, the design has not been established. The mechanism is currently only operational in the voluntary carbon market.	The key issue in the design is finance. Public finance will not be adequate for this kind of funding, which means that much depends on the private sector. At present, financials are mainly involved in the carbon market forestry sector, financing projects in return for carbon credits for speculative or CSR purposes.

Sectoral crediting mechanisms	The design is not established; however, the common idea is to credit emissions reductions achieved on aggregate in a specific sector below a certain predefined baseline. The scope could either be on sectors within one country or across sectors internationally.	Subject to design and negotiations.	As with CDM, the private sector has a role to play through investments in return for offsets.
Sectoral trading mechanisms	A (developing) country commits to legally binding emissions reduction targets for specific sectors under the UNFCCC umbrella. Rules and requirements would be comparable to an ETS.	Subject to design and negotiations.	Companies would be subject to a compliance regime such as through an ETS.
NAMAs	Very broad definition for voluntary emission reduction measures undertaken by developing countries that meet the needs of their specific national circumstances. NAMAS are expected to be one of the main vehicles for mitigation action in developing countries under a future climate agreement, and can take the form of policies or actions implemented at national, regional or local levels. They can be project-based (like the CDM), sectoral, or nationwide (for instance, as an ETS). Possible inclusion of carbon crediting mechanisms.	Scope and design unclear.	As funding is essential, and public finance is limited, the private sector has an important role to play. Potential to present vast opportunities for companies.

Source: Ernst & Young (2012)

3.2

In India, to date, the CDM has been the main international mechanism for mitigation. Data analysis of CDM-registered projects in India reveals that the projects are concentrated in states that are more industrialized, such as Gujarat and Maharashtra. China, in contrast, has central and provincial governments offering institutional support to CDM project developers across provinces. The slow bureaucratic process, complex design, and costs related to CDM in India have also drawn criticism.

Domestic Carbon Market

At present, there are a number of sub-national, national, and supra-national voluntary and mandatory cap-and-trade schemes active in the EU, the US, Australia, New Zealand, and Japan. Developing countries such as China and South Korea are following suit (Ernst & Young 2012). Regional schemes are in operation in China and Korea launched its carbon market in January 2015. These schemes are usually designed within domestic climate change policy frameworks and mostly involve the private sector, including business and industry.

India has not shown propensity towards designing a domestic carbon emission trading system. Upadhyay (2010) and Sterk & Mersmann (2011) explain that this is because of two reasons: first, there is political reluctance; second, there seems to be an institutional overlap between existing policy mechanisms, including CDM CERs which have been successful in India. In this regard, lessons can be learnt from the Chinese experience of implementing domestic trading schemes.

China's domestic carbon markets are part of China's strategy to cut its greenhouse gas emissions per unit of GDP to 40–45 per cent, below 2005 levels, by 2020 as the country seeks to limit climate change, address future energy security issues, and stave off international criticism for being the world's biggest emitter. Table 2.8 depicts a comparison of emissions coverage under the emission trading scheme (ETS) pilots.

Enterprises and buildings that emit more than they have permits to cover can buy additional permits in the form of emissions allowances or use offset credits issued by the central government, known as Chinese Certified Emissions Reductions (CCERs). China's National Development and Reform Commission (NDRC) developed the first batch of 52 CCER methodologies for voluntary greenhouse gas emissions reduction in March 2013. The CCER methodologies are based on the evaluation of Clean Development Mechanism (CDM) methodologies approved by the UN Executive Board, and adapted to China's need. The 52 CCER methodologies align with China's traditional focus on renewable energy, energy efficiency and fuel switch, and methane.

Shenzhen became China's first city to launch the pilot. By the end of 2013, Shenzhen, Shanghai, Beijing, Guangdong Province, and Tianjin had all launched carbon emission trading markets. In the second quarter of 2014, Hubei Province and Chongqing followed.

Table 2.8: A comparison of emissions coverage under the ETS pilots in 2010

Region	GHGs	Covered CO_2 emissions (Mton)	Share of total emissions	Direct or indirect emissions	Number of covered entities	Emissions threshold for coverage (tonnes CO_2/year)	Historical emissions period
Beijing	CO_2	58	50%	Direct and indirect	approx. 490	>10,000 (average [stationary emissions])	2009–12
Tianjin	CO_2	112	45%	Direct and indirect	197	>20,000 for industry;>10,000 for other sectors	2010–11
Shanghai	CO_2	90	60%	Direct and indirect	191	>20,000	2009–12
Chongqing	CO_2	No data	Not yet available	Direct and indirect	No data	>20,000 (or 10,000 tce)	2008–10
Hubei	CO_2	117	33%	Direct and indirect	107	>Approx.120,000 (or 60,000 tce)	2010–11
Guangdong	CO_2	209	42%	Direct and indirect	830	>20,000 (or 10,000 tce)	2010–12
Shenzhen	CO_2	32	40%	Direct and indirect	635	>5000	2009–11
All ETS pilots	CO_2	>620	7% of China's total	Direct and indirect	>2535	-	-
EU-ETS (Phase I)	CO_2	2014	47%	Direct	11,500	>10,000	1996–2004

Duan (2013), International Carbon Action Partnership (ICAP) (2013), European Commission (2013), Qiu (2013), and Xu (2013)

Source: Zhang *et al.* (2014)

The pilot provinces and cities have taken measures, including formulating relevant laws and regulations, setting the total amount of carbon emissions and the coverage, establishing measurement, reporting and verification (MRV) system for greenhouse gases, determining quota allocations, establishing trading system and rules, developing a registration system, setting up special administrative organs, establishing a market regulation system, training staff, and enhancing the capacity building.

By the end of October 2014, the total trading volume of carbon dioxide in the carbon emissions trading markets of seven pilot provinces and cities reached 13.75 million tonnes of CO_2 and the turnover was more than RMB 500 million. A total of 15.21 million tonnes of carbon quota have been sold at auction for RMB 760 million (China's Policies and Actions on Climate Change 2014).

Other Market-based Innovations

There are two domestic market-based innovations in India: Renewable Energy Certificates (REC) trading system; and the Energy Saving Certificate (ESCerts) trading system. These are described below.

Renewable Energy Certificate (REC) in India

According to the Power Exchange of India Limited (PXIL), an REC is a market-based instrument which provides evidence that a generator has produced a certain amount of electricity from a renewable energy resource. The Electricity Act, 2003, the policies framed under the Act, as also the National Action Plan on Climate Change (NAPCC) act as key policy drivers that provide a roadmap for increasing the share of renewable energy in the total generation capacity of the country. Thus, an REC signifies the environmental attribute of renewable energy.

RECs can be traded in the market to meet Renewable Purchase Obligation (RPO) which is mandated by the State Electricity Regulatory Commission (SERCs) and Central Electricity Regulatory Commission (CERC) (Terms for Issuance and Recognition of Renewable Energy Certificates for Renewable Energy Generation Regulations 2010). PXIL secured permission for trading in RECs in September 2010. The National Load Despatch Centre (NLDC) has been designated as the central agency for the REC scheme. Table 2.9 depicts the accredited renewable energy source break up under REC in terms of percentage of total capacity.

Table 2.9: Accredited Renewable Energy Source Break Up Under REC (% of total capacity)	
Renewable energy source	**Capacity (% share of total)**
Wind	49.18
Urban or municipal waste	0.16
Solar thermal	0.05
Solar PV	11.81
Small hydro	6.37
Others	0.03
Biomass	13.92
Bio-fuel cogeneration	18.46
Total	**100**

Source: Renewable Energy Certificate Registry of India (2015); Data as on May 5, 2015

According to the Renewable Energy Certificate Registry of India, the total signed up RE generators till now is 2,672 (Renewable Energy Certificate Registry of India 2015). The REC market summary for the year 2015 until now is depicted in Table 2.10. It is seen that there is a gap between RECs issued and RECs redeemed.

Table 2.10: Renewable Energy Certificate (REC) Market Summary for 2015				
Month, Year	**Opening balance**	**REC issued**	**REC redeemed**	**Closing balance**
May, 2014	6,968,438	568,843	31,375	7,505,906
June, 2014	7,505,906	471,982	141,108	7,836,780
Jul, 2014	7,836,780	1,485,060	38,442	9,283,398
Aug, 2014	9,283,398	702,700	51,844	9,934,254
Sep, 2014	9,934,254	859,795	49,013	10,745,036
Oct, 2014	10,745,036	1,074,046	94,381	11,724,701
Nov, 2014	11,724,701	731,207	222,619	12,233,289
Dec, 2014	12,233,289	1,087,197	398,182	12,922,304
Jan, 2015	12,922,304	411,590	615,234	12,718,660
Feb, 2015	12,718,660	593,085	850,103	12,461,642
Mar, 2015	12,461,642	453,091	737,510	12,177,223
Apr, 2015	12,177,223	810,257	72,697	12,914,783
Total	–	**22,651,840**	**9,737,057**	–

Source: Renewable Energy Certificate Registry of India (2015); Data as on May 5, 2015

Energy Saving Certificates (ESCerts):

Energy Saving Certificates will be introduced in India under the Perform Achieve Trade scheme (PAT) propelled by the Bureau of Energy Efficiency (BEE) under the National Mission of Energy Efficiency (NMEE) of the National Action Plan on Climate Change. The genesis of the PAT mechanism comes from the Energy Conservation Act, 2001. Eight energy-intensive industries have been selected (namely aluminium, cement, choralkali, fertilizer, iron and steel, pulp and paper, textiles, and thermal power plants). Each industry has three years to reach a Specific Energy Consumption (SEC) and will get ESCerts that can then be sold to those who failed. With this mechanism, India hopes to unlock energy efficiency opportunities, estimated to be about INR 74,000 crore (approx. USD 12.33 billion), as well as avoid an electricity capacity addition of 19,000 MW and mitigate 98 million tonnes of CO_2 emissions per year by 2014–15. The energy saving targets of eight sectors covered under PAT cycle I (April 1, 2012 to March 31, 2015) is 6.686 million toe distributed among 478 Designated Consumers (DCs). Under cycle II, the DCs undertake measures to reduce their energy consumption. Within three months of the end of the cycle I, they have to submit Performance Assessment Document to State Designated Agency and BEE. BEE then verifies the report and sends it to Accredited Energy Auditor. Currently the cycle II is underway, following which ESCerts will be issued and trading can begin on electricity exchanges such as IEX. The EC Act details the notified industrial units and other establishments consuming more energy than the defined threshold energy consumption. The ESCerts will be issued by the Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India to eligible DCs.

An ESCert is an instrument issued by an authorized body to a DC who guarantees that a stipulated amount of energy savings has been achieved under the PAT scheme. It is a tradable commodity that gives property rights over benefits created by energy saved above the baseline level. The monitoring and verification would be done by Designated Energy Auditors (DENA) who will be notified by BEE in due course. Table 2.11 depicts the authority and their action with regard to the process of issuing ESCerts.

Table 2.11: Authority and Action for Issuance of Energy Saving Certificates

Authority	Action
Energy Conservation Act, 2001	• Determination of targeted designated consumers

Bureau of Energy Efficiency (BEE)	• Computation of baseline • Determination of target reduction
Obligated entities	• Installation of energy efficiency measures
Designated energy auditors (DENA)	• Third party verification of savings by accredited auditors • Determination of savings
BEE and EESL (Energy Efficiency Services Limited)	• Certification of ESCerts eligible projects • Issuance of ESCerts
Power Exchange (PXIL and IEX)	• Trading of ESCerts
BEE and EESL	• Tracking ownership of ESCerts • Retirement of ESCerts

Source: Adapted from Bhattacharya and Kapoor (2012)

The important question for future policies for incubation is how existing market mechanisms on energy efficiency and renewable energy in India can be coordinated with an emissions trading system, especially to avoid double counting.

2.2.5 International Climate Finance

The international climate finance architecture comprises actors, including the donor countries, recipient countries, multilateral organizations, bilateral organizations, and the private sector. The architecture of international climate finance is depicted in Figure 2.3. 3.2

One such international fund established to provide deeply concessional funding to promote low-emission and climate resilient development in eligible developing countries is the Green Climate Fund (GCF). GCF was established on December 11, 2010, in Cancun, Mexico. Under the UNFCCC, developed country heads of state formally committed to jointly mobilize USD 100 billion per year by 2020 to advance the global paradign shift towards low-emission and climate resilient development pathways (Green Climate Fund 2015). GCF is a step taken to achieve that goal. It places equal emphasis on allocating its resources for adaptation as well as mitigation. Total pledges of contributions to the fund is USD 10.2 billion equivalent so far. Till April 30, 2015, USD 4 billion equivalent has been signed in contribution, representing 42 per cent of the amount that was committed during the fund's initial pledging conference in 2014 (GCF Press Release 2015). As soon as at least 50 per cent of the total amount pledged at GCF's High-Level Pledging Conference in Berlin in November 2014, i.e., USD 4.7 billion equivalent is available, the Fund is authorized to allocate resources and start having any positive impact on the global climate.

Multilateral climate funds in India are anchored in the Ministry of Environment, Forest and Climate Change, Government of India, with the United Nations Development Programme (UNDP) and the World Bank being key implementing agencies.

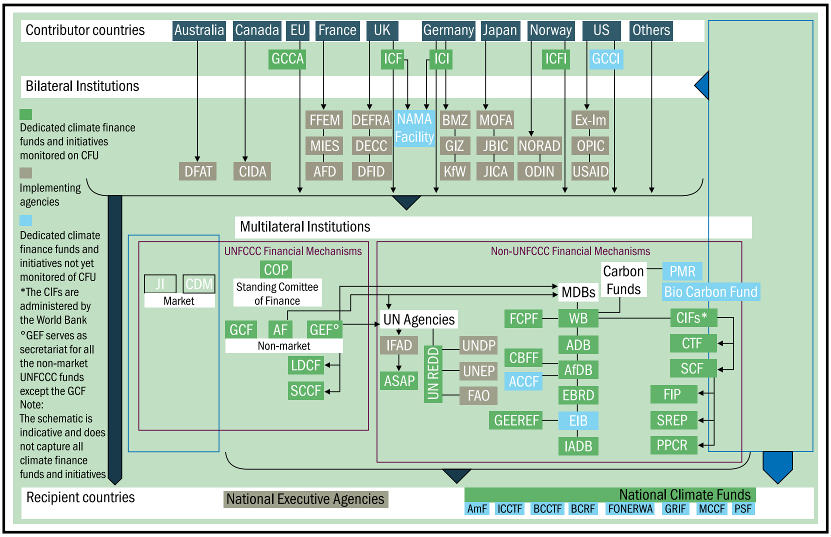

Figure 2.3 Architecture of international climate finance
Source: http://www.climatefundsupdate.org/about-climate-fund/global-finance-architecture

Multilateral funds such as the Clean Technology Fund have been operational in India. The Ministry of Environment, Forest and Climate Change lists four supply side initiatives for Phase I financing under the Clean Technology Fund; these include:

- Himachal Pradesh: Development Policy Loan on Environmental Sustainability and Climate Change
- Support for the National Mission for Enhanced Energy Efficiency (NMEEE)
- Partial Risk Guarantee for Energy Efficiency Technologies
- Support to the Jawaharlal Nehru National Solar Mission (JNNSM)

It can be seen that one initiative is also at the sub-national level while the other three are inclined towards the missions under the National Action Plan on Climate Change (NAPCC). International finance in climate and sustainability areas have sought to leverage and attract private finance. However, according to Climate Funds Update, as of the beginning of 2012, globally, for every USD 1 spent between 2010 and 2012, only USD 0.25 of private finance had been drawn. In terms of climate finance initiatives in India, there is also scope for private sector funding in a national climate fund.

2.2.6 Public–Private Partnerships

Effectively engaging the private sector is crucial to filling the financing gap for mitigation. Therefore, a mechanism is required to deploy limited public funds in such a manner that private low carbon capital can be mobilized at scale. Public-private partnerships (PPPs) represent an option to augment the government's infrastructure delivery standards.

At the national level, the Indian government has laid out a well-defined framework for undertaking PPP projects. The viability gap funding (VGF) mechanism, formation of the India Infrastructure Finance Corporation Limited (IIFCL), and the India Infrastructure Project Development Fund have been designed to meet specific requirements of PPP projects, and provide the framework and incentives for urban local governments to promote PPP.

The Union Cabinet in April, 2015 approved the Smart Cities Mission and the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) with outlays of INR 48,000 crore (approx. USD 8 billion) and INR 50,000 crore (approx. USD 8.33 billion), respectively. Under Smart Cities Mission, the government would give an assistance of INR 100 crore (approx. USD 16.67 million) per year for five years so that 100 smart cities to be developed to promote adoption of smart solutions for efficient use of available assets, resources, and infrastructure with the objective of enhancing the quality of urban life and providing a clean and sustainable environment. But considering the enormous amount of infrastructure needed to raise such cities, INR 100 crore is a small amount and substantial efforts would be needed to supplement city development with other sources of financing. The Smart Cities project is expected to be achieved through active public private participation wherein the government will provide VGF and act as facilitator (Prime Minister's Office 2015). In addition, the second phase of the Jawaharlal Nehru National Urban Renewal Mission (JNNURM), renamed as AMRUT, which is a 10-year programme slated to rejuvenate 500 towns and cities, led by the Ministry of Urban Development, Government of India is also expected to promote PPPs in urban India. Minimum investment of over INR 2 lakh crore (approx. USD 33.33 billion) would flow into urban areas over the next five years for promoting urban reforms. It is envisaged that to meet this massive requirement, substantial private investment will have to be mobilised by states and urban local bodies through PPP model, as required, to meet the project cost.

PPP mechanisms in India utilize a number of public finance instruments that can help remove barriers to private investment. The policy rationale for PPP, in India, is often limited to the use of PPPs as a source of investment capital when the public sector lacks fund. Consequently, on ground, they seldom deliver efficient service and value for consumers and taxpayers. The instruments in PPPs include loan guarantees, which allow lower interest rates for borrowers as the lender is protected against default; mixed equity funds, which lower the risks for private equity investors by subordinating the public capital in the fund, thus giving private investors their returns first and again protecting against the risk of project default or lower than expected financial performance (KPMG 2011).

The present Finance Minister of India, Mr Arun Jaitley, during his Union Budget 2014–15 speech, had mentioned that India has emerged as the largest PPP market in the world with over 900 projects in various stages of development. However, weaknesses of the PPP framework have also been quite evident. Delays in 110 central infrastructure projects, due to regulatory hurdles have resulted in over INR 1.57 lakh crore (approx. USD 26.17 billion) cost overruns (Outlook India 2014).

Private sector has called for improvement in India's enabling environment including transparency in the bidding process, standardization of procurement procedures and transparency in the entire PPP project cycle. For public private partnerships to work, both sectors need to work collectively and keep the focus on project and outcomes rather than fulfilling self-interests. There is need to build capacity for evaluation and oversight. A set of policy, regulatory, and capacity issues need to be addressed to use PPPs more widely for better infrastructure service delivery.

2.2.7 Philanthrophy

The private sector's participation through financial and technical contribution in India is through corporate social responsibility (CSR) and philanthrophy. The Companies Act of 2013 mandates that a company having net worth of rupees five hundred crore or more (approx. USD 83.33 million or more), or turnover of rupees one thousand crore or more (approx. USD 166.67 million) or a net profit of rupees five crore or more (approx USD 0.83 million or more) during any financial year shall constitute a Corporate Social Responsibility Committee to implement CSR activities.

According to the World Giving Index Report[11] of 2014, India ranked 52nd in terms of donating money to charity; overall, India ranks 69th (Charities Aid Foundation 2014). Table 2.12 lists philanthropic causes and contribution in India for the year 2014. It is seen that philanthropic contribution for the cause of environment is negligible (0.06 per cent of total philanthropic contribution) for the year 2013–14. It can be thus said that there is wide scope for activities around environmental sustainability in terms of both CSR and philanthropic activities.

Table 2.12: Philanthropic Causes and Contribution in India (2013–14)

Rank	Cause	Total contribution (INR Crores)	Total contribution (USD million)	% (total)
1	Education	15,791	2,361.83	78.89
2	Social & rural development	2,333	388.83	12.98
3	Healthcare	1,447	241.12	8.05
4	Environmental protection	12	2	0.07
	Total	**19,583**	**2,993.78**	**100.00**

Note: Values are rounded, and past figures are subjected to exchange rate fluctuations.
1 USD = INR 60.
Source: Hurun Research Institute (2014)

2.3 Sectors and Finance

3.2

Finance plays a crucial role in resource allocation towards an economic activity. The role of finance is no different in economic activities concerning low carbon development. However, the challenges are far greater. A study by Infrastructure Development Finance Company suggests that the lack of familiarity of financial institutions to low carbon space and consequently, the inability to assess risks make financing of low carbon space difficult and inadequate (IDFC 2010). It adds that there is a prevalence of high transactions costs in such activities, which also require initial high capital outlays and long payback periods. The tendency of financial institutions to ask for recourse finance and the absence of specific funds for low carbon space make the challenge even more daunting. These add to making economic activities concerning low carbon development extremely policy dependent. With public finance becoming ever scarce, and the demand for public finance for other strategic areas increasing, low carbon space may be found

[11] The World Giving Index (WGI) was compiled by the Charities Aid Foundation, using data gathered by Gallup, and ranks 153 countries in the world according to how charitable their populations are.

wanting for more. The silver lining however is that, for India, for energy security reasons, renewable energy and energy efficiency projects have become an important area of engagement. Renewable energy initiatives are showing promising results in terms of financial resource allocation, particularly as investments are helped by proactive policy making.

While it is difficult to have an overall figure for financial allocations towards low carbon space, it is possible to get sector-specific figures or trends. We will later on in this chapter seek to understand the financial scenario of nine sectors relevant to low carbon development. Financial indicators and case studies are a part of the sectoral overview. The quantum of public finance allocations or the closest approximate of that figure or trend is given. Moreover each sectoral analysis tries to see if there are financial indicators other than public finance indicators which can help to understand the trends in low carbon development in those sectors. It must be emphasized that investment grade finance is as important as public finance.

2.3.1 Renewable Energy

Renewable energy resources are, by definition, non-exhausting and clean energy sources. According to the Ministry of New and Renewable Energy, Government of India, energy generation based on biomass, wind, hydropower (Small Hydro Power (SHP) projects up to 25 MW), solar, geothermal, and tidal are renewable energy sources. India has an estimated renewable energy potential of about 900 GW from commercially exploitable sources viz. Wind—100 GW (at 80 metre mast height); Small Hydro—20 GW; Bio-energy—25 GW; and 750 GW solar power, assuming 3 per cent wasteland is made available (MNRE 2015). Concerns about sustainable development, energy security, access to energy and adverse impact of climate change are major drivers for the Government of India to accelerate the deployment of renewable energy harnessing technologies.

At a global level, renewable energy investments have had a very interesting growth story as Figure 2.4 explains. The figures are for new investments in renewable energy. The projected growth in RE investments is also noteworthy. The compounded annual growth rate (CAGR) for the total new investment in the renewable energy sector was 20 per cent for 2004–14. In 2014, the global investment in renewable power & fuels (excluding large hydro-electric projects) was USD 270.2 billion which is nearly 17 per cent higher than the previous year; it was also the first increase in the last three years and reflected influences from investments in China, Japan, and Europe.

In terms of new financial investments in clean energy in 2014 (Table 2.13), Asia was the leader in clean energy investments ahead of North America and Europe. The year 2014 also witnessed the continous spread of renewable energy to new markets. Investment in developing countries, at USD 131.3 billion, was up by 36 per cent over the previous year and came closest ever to beating the total for developed economies, at USD 138.9 billion, up just 3 per cent in the year. It can be deciphered that the emerging economies have seized the importance of renewable energy investments. BNEF (2012) also found that with improvements in technology in solar energy and cost reduction, India and China will reach grid parity for solar electricity by 2025.

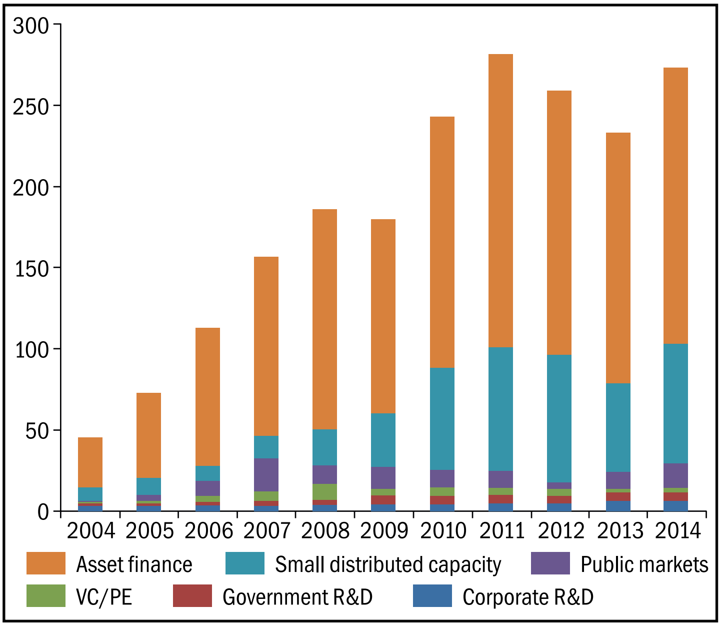

Figure 2.4 Global new investment in renewable energy by asset class, 2004–14 (USD billion)
Source: Compiled from Global Trends in Renewable Energy Investment Report (GTR), www.ren21.net/gsr

Table 2.13 outlines the global investment flows into renewable energy over the years. A country-wise break-up is also shown.

Table 2.13: Global new investment in renewable energy by region, 2004–14 (USD billion)

Region/ Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
United States	5.4	11.6	29.1	33.0	35.1	24.3	35.1	50.0	38.2	36.0	38.3
Brazil	0.8	3.1	5.2	11.8	12.1	7.9	7.7	10.1	7.2	3.9	7.6
Americas (excl. US & Brazil	1.7	3.3	3.9	5.0	5.8	5.8	12.2	9.2	10.2	12.2	14.8
Europe	23.6	33.6	46.7	66.4	81.6	81.2	111.1	120.7	89.6	57.3	57.5
Middle East & Africa	0.6	0.8	1.1	2.4	2.3	1.7	4.2	2.9	10.4	8.7	12.6
China	3.0	8.2	11.1	16.6	25.7	39.5	38.7	49.1	62.8	62.6	83.3
India	2.7	3.1	4.9	6.3	5.6	4.3	9.0	12.7	7.4	6.4	7.4
Asia-Oceania (excl. China & India)	7.2	9.2	10.0	12.5	13.6	13.7	19.3	24.1	30.5	44.7	48.7
Total	**45.1**	**72.9**	**112.1**	**153.9**	**181.8**	**178.5**	**237.2**	**278.8**	**256.4**	**231.8**	**270.2**

Source: Compiled from Global Trends in Renewable Energy Investment Report (GTR), www.ren21.net/gsr

It can be observed that China had a CAGR of the ten-year investment in renewable energy of 39.43 per cent (USD 3.0 billion to USD 83.3 billion) and India had a CAGR of 10.61 per cent (USD 2.7 billion to USD 7.4 billion) in renewable energy investment during the same period. For India, there was a steady increase from 2004 to 2011 but it declined in 2012 and 2013. However, investment in RE sector has caught up again with setting up of massive renewable power production of 175 GW by 2022.

The Government of India and the state governments have been promoting the use of renewable energy technologies through a variety of promotional schemes, policies, and regulatory measures. Some of the measures, such as capital subsidies to users and manufacturers, low interest loans, duties and taxes exemptions, and net metering form part of the fiscal and financial incentives. While other mandatory initiatives such as renewable energy purchase obligations are part of the regulatory measures.

Other methods of revenue creation for RE developers include tax incentives like accelerated depreciation while others are public finance-based incentives like generation-based incentives. It should be noted that the financial and business models are dependent primarily on granular details, very specific to the project sites, the state (or province), and the kind of RE in question like wind, solar or any other type. There can also be independent power purchase agreements (PPAs) which can be beneficial to both RE developers and obligated buyers. A list of policies and regulations concerning renewable energy is given in Table 2.14.

Table 2.14: Policy instruments for renewable energy in India

Capital subsidies	To popularize the use of solar water heating and solar lighting equipment in homes, MNRE offers suitable incentives in form of capital subsidies for purchase and installation of solar equipment which results in their reduced cost. MNRE has previously been running similar capital subsidy schemes to promote small capacity SPV systems under JNNSM.
Low interest loans	Lending at concessional rates is beneficial to bring down the cost of funds for RE projects, One such instrument is being provided under IREDA NCEF Refinance Scheme in which scheduled commercial banks and FIs are eligible for refinance from IREDA with funds sourced from NCEF. With several organizations showing willingness to raise low-cost and long term funds by selling tax-free bonds, the lending to RE developers should come at lower interest rates.
Taxes and duties exemption	To accelerate generation of RE, Government of India has either exempted or reduced various duties on the machinery, equipment and other associated components involved in renewable energy generation. Undertakings engaged in generation/ distribution of RE have been offered a 10-year holiday as well.
Renewable Purchase Obligations	RPOs (Renewable Purchase Obligations) are part of the government's policy initiatives wherein the government is making it mandatory for power consumers to buy a certain percentage of its required power consumption from power produced using renewable energy sources. These obligations are for utilities (also known as DISCOMs—Distribution Companies) and consumers who use captive power or who buy power from generators directly and not through utilities. The RPOs are part of the Electricity Act 2003 (EA 2003) which is the basis for the development of the regulatory framework in the power sector in India.
Preferential tariff scheme/ Feed in Tariff	Under the preferential tariff scheme (also known as Feed-in-Tariff), the utilities or central agency appointed by the government buys renewable electricity at a preferential tariff decided by the regulatory commission. This tariff is designed to give the required return on investment for RE generators without putting a strain on the government or consumers.
Net metering	Net metering allows a solar PV user to sell surplus solar energy generated to the utility and get compensated for that or buyback the deficit energy from the utility. The net import of electricity will be chargeable to the consumer. Net metering can increase the energy in the grid and make-up for the peak hour demand helping states facing power shortages.

Renewable Energy Certificate Scheme	Renewable energy resources, such as wind, or solar, are not equally distributed across India. Moreover, small states like Delhi do not have areas to tap enough renewable energy resources. This would lead to unequal distribution of obligations. To avoid this situation, CERC (Central Electricity Regulatory Commission) has introduced the REC (Renewable Energy Certificate) scheme wherein, the renewable energy generator can sell electricity at a price decided by the respective regulatory commission. The REC registry issues one REC for each MWh of electricity sold. The certificate can then be purchased by the obligated entities that are not able to buy renewable electricity directly.
Accelerated depreciation	Accelerated depreciation is a useful tool for deferring corporate income taxes by reducing taxable income in current yearsby considering the amount of depreciation each year as higher during the pioneering years of an asset's life. Reintroduction of AD, which was withdrawn in 2012, is already giving a significant fillip to wind energy generation.
Generation Based Incentives	GBI incentivises actual generation of power. The GBI scheme for Grid Interactive Wind Power projects was extended in 2013 for the whole Twelfth Plan period. Under this scheme, INR 0.50 is provided to wind electricity producers per unit of electricity fed into the grid for a period not less than four years and a maximum of 10 years with a cap of INR 100 lakh per MW. The total disbursement in a year will not exceed one-fourth of the maximum limit of the incentive.

Source: Author's compilation

Distribution companies	Renewable energy generators
• Meet RPO by self generation • Purchase renewable energy power from third parties • Purchase RECs	• Sell renewable energy power at Feed-in-Tariff • Sell renewable energy power at Average Pooled Purchase Cost (APPC) and RECs and the REC market • Contract directly with obligated entities through power purchase agreements

Figure 2.5 Options available for distribution companies and renewable energy generators
Source: CPI and ISB (2013)

Figure 2.5 gives a summary of the options available for RE developers and the buyers (distribution companies).

Given the importance of renewable energy, there have been various innovations and one such policy innovation is captured later in this section in a short case study on the concept of 'solar cities' in India (see Box 2.3).

Currently, the available business models for RE generators are as follows:

- Sale to utility at preferential tariff/feed-in-tariff (RPOs cannot be met in this method)

- Sale of power under REC scheme (RPOs can be met)
- Captive power consumption (RPOs can be met)

Box 2.3: Solar cities in India

Rapid urbanization is increasing the demand for power quite drastically in India. The conventional system is not keeping pace with the energy demand. Therefore, the concept of 'solar cities' fit the Indian context well. The Ministry of New and Renewable Energy launched the 'Solar Cities' programme (sometimes also referred to as Green Cities) which aims to support and encourage urban local bodies (ULBs) to prepare a roadmap to guide their cities in becoming 'solar cities' (TEDDY 2012). Under the scheme, 60 cities/towns are proposed to be supported for development as 'Solar/ Green Cities'. According to the Status Note on Solar Cities by MNRE, till January 15, 2015, 48 cities have been issued the sanctions, out of which 44 have prepared their master plans, seven have been given 'in-principle' approvals after which their respective corporations/state nodal agencies are in the process of engaging consultants for preparation of master plans. Eighteen cities have also provided their Detailed Project Reports (DPRs) which are under consideration.

Chandigarh is one such designated solar city. A sum of INR 16.25 crore had been allocated to the union territory administration for implementing the Model Solar City Programme in financial year 2013-14. According to Mr Santosh Kumar, CEO of Chandigarh Renewable Energy, Science and Technology (CREST), overall capacity of 5 MWp rooftop SPV plants have been commissioned on more than 75 government buildings of UT Chandigarh and the UT administration has also decided to enhance its solar energy target to 30 MW by 2022 from the earlier target of 10 MW. Though at the moment, Chandigarh's financial allocation is completely public financed, private investments can soon find its way in the solar cities programmes across India. Urban areas of India have the financial resources to absorb the risks of trying out new technologies, such as the ones envisaged in solar cities. Learning may be drawn with mobile telephones in India. Though mobile phones are now all pervasive and can be found in every corner of India, they were first deployed in urban areas. Urban areas may well be the necessary platform for solar projects to be implementable on a large scale throughout India.

2.3.2 Non-renewable Energy

India's installed electricity generation capacity reached 272.7 GW in 2015 (CEA 2015). The share of the different resources in India's installed capacity is given in Figure 2.6. Power generation is the single largest source of CO_2 emissions in India and thermal power plants are the single largest sources of these emissions. India is and will remain dependant on thermal power plants for quite some time. Coal, in particular, is expected to remain the mainstay of India's power sector in the near future, with most of the 100 GW of power capacity addition planned in the Twelfth Five-Year Plan (2012–17) coming from coal-based power. With respect to low carbon development strategies, all future capacity addition is expected to be increasingly based on super-critical technology, with 50 per cent of the capacity in the Twelfth Plan period targeted to be through super-critical units, and all coal-based plants in the Thirteenth Plan period to be based on super-critical technology.

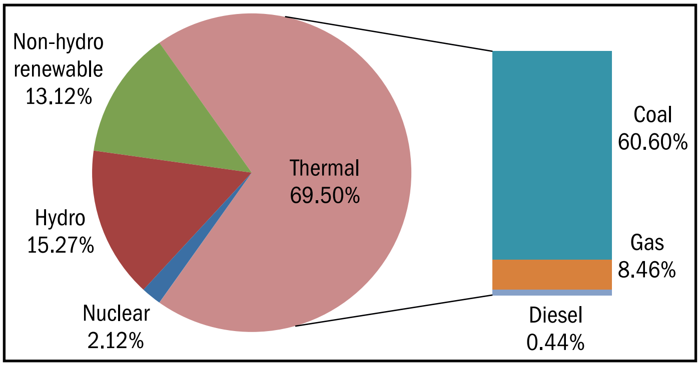

Figure 2.6 India's installed electricity generation by type
Source: CEA (2015)

In keeping with the requirement of providing additional power, sixteen super-critical technology-based Ultra Mega Power Plants (UMPPs), each generating about 4000 MW, have been prioritized as a thrust area by the Ministry of Power, Government of India, in 2005–06. These UMPPs will be of two types—either pithead projects with dedicated captive coal blocks, or coastal projects using imported coal. Nine such projects have been identified to be taken up. They are awarded to developers under the tariff-based competitive bidding path on a build, own, and operate basis. The Power Finance Corporation (PFC), which is the nodal agency for the development of these projects, sets up (as is the procedure) Special Purpose Vehicles (SPVs) for each UMPP to act as authorized representatives of the procuring distribution companies. Once the bidding process for selection of the project developer is completed, the SPVs are transferred to the selected bidders.

Given that there will be a continued dependence on coal-based thermal power plants, low carbon development pathways will depend on two things, specifically for coal-based power plants—first, the use of super-critical technologies; second, as a pure mitigation action, the deployment of carbon capture and sequestration. Carbon Capture and Sequestration/Storage (CCS) refers to "the separation of CO_2 from industrial and energy-related sources, transport to a storage location and long-term isolation from the atmosphere" (IPCC 2005). It is one among the portfolio of measures being considered for reducing greenhouse gas (GHG) emissions with a view to mitigating climate change. While no single measure may alone be sufficient for climate change mitigation, CCS, along with energy efficiency improvements, renewable energy, enhancement of biological sinks, and other measures, may be able to achieve the emissions reductions needed to achieve climate stabilization.

While there are various methods of arriving at the costs of CCS, according to a scoping study by TERI & IISD, the most important financial indicators are not the absolute values of costs but the increase in the cost of electricity entailed as a result of CCS activity. It should also be noted that the costs of CCS are very specific to projects. Therefore, average values will not be a good indicator. CCS deployment makes most sense in case of large thermal power plants or other large point emission sources, but since no such CCS project exists in India, a normative case was considered of a UMPP. Other than the variety of coal, all other plant specifications were considered to remain the same. In Table 2.15, we can see a 50 per cent increase in the cost of electricity with CCS. A monitoring cost was also incorporated in this study. The other cost heads for CCS were standard costs of capture, transport, and storage.

Table 2.15: Cost of electricity with CCS for imported coal and Indian coal

Indicator	Imported coal	Indian coal
CoE without capture (Rs/kWh)	5.26	4.84
CoE with capture (Rs/kWh)	7.52	6.97
CoE with CCS (Rs/kWh)	7.67	7.12
CoE with CCS and monitoring (Rs/kWh)	7.98	7.43
Increase in CoE due to CCS and monitoring	52%	53%

Source: TERI & IISD (2013)

2.3.3 Transportation

According to the International Energy Agency (IEA), the transport sector contributed approximately 23 per cent of the global CO_2 emissions due to fuel combustion in 2012. The fast emission growth in transport is driven largely by emissions from the road sector. Transport sector in India contributed 216.2 million tonnes of CO_2 in 2012 which is nearly 11 per cent of its total CO_2 emissions from fuel combustion (IEA 2014).

Looking for trends in financing low carbon development in the transport sector is a challenge. This is because defining low carbon space for transport is difficult. One good area for trends is to look at financial indicators for public transport in urban areas. It might not be necessary to look into rural areas in India as rural transport by all parameters is low carbon. Moreover, rural areas which are seeing rapid development into mechanized transport might have moved from rural to urban areas. Another thing to note will be that currently, in India, car ownership is extremely low; although, the ownership will increase significantly in urban areas in the future (MoUD 2008). From the observation of trends of financial indicators in the low carbon space for transport in India, two aspects emerge—first, public transport in urban areas and second, low carbon space in non-public modes of travel (electric vehicles, i.e., EVs).

The National Electric Mobility Plan (NEMMP-2020), released in January 2013, laid down an aspirational target of 6–7 million hybrid and electric vehicles per year by 2020. Based on this target, the Union Minister of Heavy Industries and Public Enterprises, in April 2015, launched a scheme for Faster Adoption and Manufacturing of Hybrid & Electric Vehicles (FAME), India with an outlay of INR 795 crore (approx. USD 132.5 million) for its phase I (2015–17).This will cover all forms of hybrid (Mild/Strong/Plug-in) and pure electric vehicles. The broad range of demand incentives available for different categories of vehicles can be found in the Table 2.16 below:

Table 2.16: Demand incentive available for different categories of vehicles under FAME

Vehicle Segment	Minimum incentive (INR)	Maximum incentive (INR)
2-wheeler scooter	1,800	22,000
Motorcycle	3,500	29,000
3-wheeler auto-rickshaw	3,300	61,000
4-wheeler cars	11,000	138,000
LCVs	17,000	187,000
Bus	3,000,000	6,600,000
Retro fitment category	15% or INR 30,000 if reduction in fuel consumption is 10-30%	30% of kit price or INR 90,000 if reduction in fuel consumption is more than 30%

Source: Ministry of Heavy Industries & Public Enterprises, Government of India (2015)

Noting that urban areas and urban population in India are both increasing, the need for sustainable public transport is also high.

The financial cost estimated by the Ministry of Urban Development was INR 4,353.8 billion (approx. USD 87 billion). This estimate covered 87 cities (MoUD 2008). More recent investment requirements as estimated by the Urban Ministry are given in Table 2.17.

Table 2.17: Financing required for public transport during the Twelfth Five-Year Plan period (2012–17)

Public transport	INR crores	USD million (approx.)
Buses	13,759	2,293
Bus rapid transit system	29,603	4,934
Metro rail	130,726	21,787
Commuter/regional rail	19,780	3,296
Bus infrastructure	8,760	1,460
Total	**202,628**	**33,771**

Source: MoUD (2011)

The important challenge with respect to finance can be broken into two parts. First, figuring out the sources of finance; and second, given that most of these projects will need substantial amounts of capital, each project might have multiple sources of financing which in turn would need co-ordination. This co-ordination has become popular under the name 'public–private partnerships' (PPPs). These two aspects will be discussed in more detail in the following section. 3.2

Traditionally, the urban public transport was funded by the government. Part of the finance was made available from the central government and then the state government, and finally the urban local body. However, this form of financing—a traditional public finance method—is fast being replaced by PPPs.

Other sources are multilateral agencies like the World Bank, the Global Environment Fund (GEF), and bilateral agencies like the Japan International Cooperation Agency (JICA). Of course, the private sector itself is also a source of finance and predominantly as an equity player. There has been an increase in structured finance in this sector, with various financial institutions pitching in with various financial products like subordinated debt, that is, mezzanine financing, commercial exploitation of land and air rights over land used for transport infrastructure, and enhanced levies on real estate projects near these transport infrastructure projects. All this is to create a method by which positive externalities can be monetized.

As explained earlier, evolving space for financing public infrastructure needs a framework where divergent sources of finance can combine together to create synergies in providing public infrastructure which is efficient, robust, and long-term.

JNNURM phase I, which ended in 2014, is a good example of the government acknowledging the need to address issues associated with urbanization. However, while assessing the method, it is important to look at how JNNURM has fared. According to the Ministry of Urban Development, Government of India, till March 31, 2014, only 42.19 per cent, i.e., 227 of the total sanctioned projects (538) in India could get completed. A major criticism of JNNURM has been that it has followed a structure of a PPP model which has failed to deliver. However, it is also important to understand the reasons behind the failure of PPP. It may be reasonable to say that there is no tool to understand the financial implications of public finance and investment-grade finance involved in a common framework; nor is there one to understand financial returns and also the implications for sustainability. It is, hence, important to fully understand the interactions within PPP as a business model.

2.3.4 Buildings

A burgeoning population, escalating economic development and internal migration to urban centres from rural areas has resulted in India's cities bursting at the seams. The cities are also plagued with numerous environmental problems which negatively impact the health and well-being of its residents. Contiguously, the increasing scarcity of environmental resources has transformed them into economic goods, with people willing to pay more for better environmental quality. One of the sectors where environmental quality is explicitly traded is real estate; buyers bid up the prices of residential properties that enjoy proximity to and/or have a provision for facilities that reduce environmental pollution and wastage (energy efficiency, water conservation, and waste management processes).

A green building refers to a building created by using processes that are environmentally responsible and that is resource-efficient throughout its life cycle. This requires the close cooperation of various stakeholders involved in the creation of a green building comprising the design team, the architects, the engineers, and the client, at all stages of the project. In India, there are mainly two rating systems for green buildings, namely GRIHA (Green Rating for Integrated Habitat Assessment), and LEED (Leadership in Energy and Environmental

Design). GRIHA has been conceived by TERI and developed jointly with the Ministry of New and Renewable Energy (MNRE), Government of India.

The Green Rating for Integrated Habitat Assessment (GRIHA) is an evaluation tool to help design, build, operate, and maintain a resource-efficient built environment. It emphasizes end-use energy optimization (within specified comfort levels) and integration of renewable energy; therefore, it provides a framework which looks at long-term policy options, both on the supply and demand sides, consistent with the aspirations of economic growth.

MNRE has been implementing a scheme on 'Energy Efficient Solar/Green Buildings' since February 2009 which aims at promoting the widespread construction of energy-efficient solar/green buildings, in the country, through a combination of financial and promotional incentives. Government buildings are exempted from the registration-cum-rating fee for acquiring the GRIHA ratings developed by TERI, capacity building, awareness, and other promotional activities.

The Ministry has endorsed GRIHA compliance, which is mandatory for buildings of the Central government and public sector undertakings. The central public works department has also adopted and integrated GRIHA into their standard operating procedure. To further provide an impetus to the green buildings movement, the Ministry has launched a host of financial incentives on registration fees, awards, and incentives (see Box 2.4).

Box 2.4: Incentives for GRIHA rated projects

The Ministry of Environment, Forest and Climate Change, Government of India issued a memorandum to facilitate fast track environmental clearance for GRIHA pre-certified projects. The MNRE grants the following incentives to various stakeholders of GRIHA projects under its "Energy-efficient solar/green buildings scheme" in the Eleventh Five-Year Plan period.

- Building owners: Reimbursement of 90 per cent of the registration-cum-rating fee for projects up to 5,000 sq. m built-up area with minimum 3-star rating and for projects > 5,000 sq. m built-up area with minimum 4-star rating.
- Architects / design consultants: INR 250,000 for projects up to 5,000 sq. m built-up area with minimum 3-star rating and INR 5,00,000 for projects > 5,000 sq.m built-up area with minimum 4-star rating.
- Municipal corporations/urban local bodies: INR 5,000,000 to municipal corporations and INR 2,500,000 to other urban local bodies that announce rebate in property tax for green buildings; make it mandatory for new buildings under the government and the public sector to be rated under GRIHA.

- Annual awards: Awards of INR 5,000,000 to municipal corporations and INR 2,500,000 to other urban local bodies who performs best.
- Annual awards to 5-star rated buildings under GRIHA.
- Promotional activities: Up to INR 200,000 for each activity to specialized institutions for organizing workshops/ seminars/ training / publications/ awareness campaigns, etc.

Source: MNRE (2009)

Since buildings account for 40 per cent of the greenhouse gas emissions worldwide, the realty sector has the greatest potential for reducing emissions. Currently, 20 projects are underway in Pune and the Pimpri-Chinchwad Municipal Corporation (see Box 2.5), which incidentally, has made it mandatory for all new projects to conform to GRIHA.

Box 2.5: Initiatives by Pimpri-Chinchwad Municipal Corporation for green buildings

The Pimpri-Chinchwad Municipal Corporation has decided to grant rebate in property tax for GRIHA-rated buildings. The developers in Pimpri-Chinchwad Municipal Corporation will get the following discounts on the premium amount of building permission charges, as per the rating awarded by GRIHA.

Points scored	Rating	Discount in premium
50–60	1	10%
61–70	2	20%
71–80	3	30%
81–90	4	40%
91–100	5	50%

Moreover, once the construction is complete, the developer will hand over the green building to flat owners, and the flat owners of the green building will get a discount of 5–10 per cent on property tax.

Source: GRIHA (2012)

There are other forms of incentives as well. In March 2009, the State Bank of India (SBI) announced various incentives (see Table 2.18) under green home loans.

Table 2.18: Financial Incentives Given by SBI for Green Home Loan

Product feature	Values for SBI Green Home Loan
Margin	5% less than the margin stipulated for ordinary SBI home loan, subject to the condition that the margin does not go below 15% under any condition
Interest rate	0.25% concession (Instead of 0.10% being offered presently); maximum cumulative interest rate concession will be within the ceiling prescribed from time to time (presently 0.25%)

Note: Concession shall not be applicable on the 8% interest rate under the SBI Happy Home Loan Offer, nor the 8.5% and 9.25% rates under the SBI Special Loan Offer
Source: GRIHA (2012)

The Ministry of Environment and Forests (MoEF) in 2011 has given special consideration to pre-certified LEED India and GRIHA projects by having a separate queue for clearance. This is supposedly with the assurance that green rating agencies have carried out the due diligence of these project designs and will be accountable for the environmental performance of such projects. However, pre-certification is only a pledge and there is no legal provision for requiring the project proponents to achieve the level of rating promised in the pre-certification application.

2.3.5 Demand Side Management

The Energy Conservation Act, 2001, provides the legal framework, institutional, and regulatory mechanism for energy efficiency initiatives, in India, at both the national and sub-national levels. The Act led to the formation of the Bureau of Energy Efficiency (BEE) to implement the provisions of the Act in the form of new policies on energy conservation and energy efficiency. The State Energy Conservation Fund (SECF) which is required to be constituted at the sub-national level was set up under section 16 of the Energy Conservation Act with the objective of promoting energy conservation and energy efficiency within the state. SECF was established in the Eleventh Five-Year Plan with an outlay of INR 66 crore and is continuing in the Twelfth Five-Year Plan with a budget outlay of INR 50 crore. Till date, 26 states have constituted SECF, out of which 16 have also provided matching contribution and an amount of INR 82 crore has been disbursed under the SECF scheme (MoP 2015).

Despite being technically and economically viable, certain Demand Side Management (DSM) programmes do not get implemented due to lack of adequate finance. Power utility companies in India are often reluctant to undertake DSM measures because of the uncertain nature of the outcomes and the difficulty in arranging necessary funding.

Some of the barriers in implementing DSM measures in India include lack of necessary institutional capacity and funds, lack of clarity about baseline data and monitoring and verification (M&V) protocol, and non-availability of financing options to develop a practical approach for undertaking energy efficiency and demand-side management initiatives. Thus, regulatory interventions to ensure adequate funding for design, development, and implementation of DSM initiatives by utility companies are essential.

Currently, the tariff regulation for determining the Aggregate Revenue Requirement (ARR) in India does not have an exclusive provision under which the state utilities can book the expenses incurred by it for various DSM initiatives. The State Commission could consider providing suitable provisions under the tariff regulations to allow recovery of DSM related expenditure as part of the ARR. This would create the necessary funding for the design and implementation of DSM initiatives by the states. For instance, a certain percentage of the ARR could be utilized for DSM programmes—this percentage could be worked out on the basis of the indicated savings from the power purchase costs and peak clipping. In this way, the utility will be certain of recovering the costs through consumer tariffs, and will, therefore not be reluctant to undertake DSM measures which would benefit the state.

Financing many of the DSM initiatives through commercial banks remains challenging, as they often do not meet the standard investment criteria, such as collateral requirements. Energy Service Companies (ESCOs) can be helpful here. An ESCO provides a wide range of comprehensive energy solutions to the client company/utility which includes design and implementation of energy savings projects, energy infrastructure outsourcing, and risk management. The ESCO typically signs a contract with the client company/utility to finance and implement DSM projects; it may borrow the amount required for the project and repay it from project revenues which it gets back over the contract period. In case a project does not provide returns on the investment, the ESCO is responsible for paying the difference. The different energy services that ESCOs provide include energy audits, energy management, energy or equipment supply, etc., to the client company/utility. ESCOs may also provide or arrange financing. A full-service ESCO business model includes designing, financing and implementation of the project. Here the ESCO verifies energy savings and shares an agreed percentage of the actual energy savings over a fixed period with the client company/utility.

Leasing or vendor financing are viable financing options for many energy efficiency projects and DSM initiatives. A special fund to provide equity capital for these projects is now available through the Venture Capital Fund for Energy Efficiency (VCFEE) under the National Mission for Enhanced Energy Efficiency (NMEEE). This fund invests in the form of equity. A single investment by the fund does not exceed INR 2 crore (approx. USD 0.33 million). The fund provides last mile equity support to specific energy efficiency projects and is limited to INR 2 crore or a maximum of 15 per cent of the total equity required through Special Purpose Vehicles (SPVs), whichever is less. However, during the Twelfth Plan, revision of rules and its notification is under process to slightly modify the operational structure of the VCFEE .

NMEEE has been adopted by India for the role it is expected to play in meeting the country's energy demands. The Mission seeks to promote market-based approaches to unlock the potential of energy efficiency, which is estimated to be about INR 74,000 crore (approx. USD 12.33 billion). It will help achieve fuel savings of around 23 million tonnes per year, total carbon dioxide gas emissions reductions of 98 million tonnes per year, and avoid capacity addition of 19,000 MW by 2014–15 (Bureau of Energy Efficiency).

The Energy Efficiency Financing Platform (EEFP) is one of the four initiatives under the NMEEE. Some of the key objectives of this initiative include to ensure availability of finance at reasonable rates for energy efficiency project implementation by including financial institutions, and public and private sector banks; help stimulate necessary funding for ESCOs based delivery mechanisms for energy efficiency; create demand for energy efficiency products, goods, and services through awareness, public policy; ensure credible monitoring and verification protocols to capture energy savings; and capacity building of banks and financial institutions.

Another initiative by the Government of India to develop fiscal instruments to promote energy efficiency is the Framework for Energy-Efficient Economic Development (FEED). This includes innovative fiscal instruments and policy measures like the Partial Risk Guarantee Fund (PRGF) and the Venture Capital Fund for Energy Efficiency (VCFEE), public procurement of energy efficient goods and services, and utility-based demand side management. FEED supports electricity regulatory commissions to stimulate utility based demand side management by incentivizing utilities for DSM including time-of-day tariffs and load management directives. It also develops guidelines for evaluating DSM options and integrating these with supply side options.

FEED provides tax exemptions for promotion of energy-efficient appliances by promoting income and corporate tax incentives for ESCOs/venture capital funds in energy efficiency and providing infrastructure status to ESCO business.

2.3.6 Agriculture

India's National Action Plan on Climate Change (NAPCC) highlighted that the thrust areas of the National Mission for Sustainable Agriculture (NMSA) would be dry land agriculture; access to information; bio-technology; and risk management. The Department of Agriculture and Cooperation (DAC) and the Department of Agricultural Research and Education (DARE) under the Ministry of Agriculture (MoA), Government of India, has been identified by the Prime Minister's Council on Climate Change to plan and implement NMSA in India (MoA, undated).

The NMSA caters to key aspects such as 'Water use efficiency', 'Nutrient Management' and 'Livelihood diversification' through adoption of sustainable development pathways by progressively shifting to environmental friendly technologies, adoption of energy efficient equipment, conservation of natural resources, integrated farming, etc.

The NMSA has four major programme components or activities, namely:

(a) Rainfed Area Development (RAD)
(b) On Farm Water Management (OFWM)
(c) Soil Health Management (SHM)
(d) Climate Change and Sustainable Agriculture: Monitoring, Modelling and Networking (CCSAMMN)

As depicted in Table 2.19, it has been estimated that up to the end of the Twelfth Five-Year Plan, the adaptation and mitigation strategies proposed under NMSA would require additional budgetary support of about INR 1,08,000 crores (USD 18 billion).

Table 2.19: Budgetary Support Requirement of National Mission for Sustainable Agriculture (NMSA) for the Twelfth Plan Period (2012–17)

Cost head	Amount (INR, crore)	Amount (USD, billion)	% share of total project cost
Technology, products and practices to help mitigate risks related to climate change	65,000	10.833	60
Infrastructure development (including insurance)	31,500	5.250	29

Research and development in the field of sustainable agriculture	6,500	1.083	6
Capacity building	5,000	0.83	5
Total	**108,000**	**18**	**100**

Source: MoA (2012)

The Department of Agriculture & Cooperation was earlier implementing 51 schemes for development of agriculture and welfare of farmers in the country. These schemes have recently been restructured into five Centrally Sponsored Missions, five Central Sector Schemes, and one State Plan Scheme as given in Table 2.20 below:

Table 2.20: Schemes Under the Department of Agriculture, GoI, for Development of Agriculture and Welfare of Farmers

Centrally Sponsored Schemes	Central Sector Schemes	State Plan Scheme
National Food Security Mission (NFSM)	National Crop Insurance Programme (NCIP)	Rashtriya Krishi Vikas Yojna (RKVY)
National Mission on Sustainable Agriculture (NMSA)	Integrated Scheme on Agriculture Cooperation (ISAC)	
National Mission on Oilseeds and Oil Palm (NMOOP)	Integrated Scheme for Agriculture Marketing (ISAM)	
National Mission on Agricultural Extension and Technology (NMAET)	Integrated Scheme on Agriculture Census, Economics & Statistics (ISACE&S)	
Mission of Integrated Development of Horticulture (MIDH)	Secretariat Economic Service (SES)	

Source: Ministry of Agriculture (2014)

NABARD's rural innovation fund (RIF) extends support to agricultural communities after evaluating the environmental aspects associated with the activities funded with the loan amount. Specifically, preference is given to sectors such as dry land or rain-fed farming; rural energy from agricultural wastes; and storage devices for agricultural and rural products. The farmers' technology transfer fund (FTTF) by NABARD facilitates the adoption and dissemination of better and clean technologies in the agriculture sector.

NABARD, in its capacity of National Implementing Entity (NIE) for Adaptation Fund (see Box 2.6 for brief introduction about Adaptation Fund), had submitted four proposals with financial outlay of USD 5.96 million to Adaptation Fund Board (AFB), out of which two proposals with a financial assistance of USD 3.2 million were accorded approval by the AFB during its 24th meeting held at Bonn, Germany on 9–10 October 2014 while clarifications were sought on two projects. This was the first time the AFB sanctioned projects in India. These two proposals are expected to enhance adaptive capacity of the coastal community in Krishna district of Andhra Pradesh and increase resilience of small and marginal farmers in Purulia and Bankura districts of West Bengal.

The recently concluded 25th meeting of the AFB on 9–10 April, 2015, sanctioned another proposal from NABARD in India worth USD 1,790,500 which is expected to build adaptive capacities of small inland fisheries for climate resilience and livelihood security in the state of Madhya Pradesh, while it rejected the other two submitted proposals.The trend of contract farming (CF) has also been emerging significantly in the agriculture sector of India. Private sector companies such as Satyam, ITC Limited, and PepsiCo, Rallis, and Bharti Walmart have been involved in contract farming with small farmers. These and other such companies provide technical knowledge and guidance to farming communities to ensure quality in the production of output. Contract farming provides assured income and financial support to the farmers and has been identified as a potential policy intervention to promote economic development in the agriculture sector. However, contract farming is often accused of inculcating agricultural practices involving excessive use of fertilizers, pesticides, and water—thereby, causing environmental degradation. This, at the same time, also presents the opportunity of using responsible contractual farming models to help farmers adopt sustainable agriculture practices. These private sector firms could also help mobilize funds for the farming communities to help them adopt eco-friendly technologies.

There is a need to invoke technologies that promote environment protection, energy savings, and satellite mapping for the agriculture sector of India. Countries like China, Brazil, and various Southeast Asian countries have been able to leverage technologies by bringing in private sector investments into the agriculture sector. The average land holding size in India for a majority of landholdings is less than two acres. Therefore, it becomes essentially important to explore economically viable solutions with the involvement of the private sector to improve farmers' incomes. So far, the private sector has largely remained outside the purview of agricultural capital expenditure. Thus, in order to augment private sector investments in the agriculture sector to help farmers adopt clean environment-friendly practices, there is a need to relax the existing legal and policy framework to some extent (Mittal 2012). Literature also points towards the need to mobilize increased government investment in the agriculture sector all-together, which at present is scarce. Government funding is considered a crucial component in creating an enabling environment to attract private investments in the sector (FAO 2012). There is also a need to ensure careful use of subsides in the agriculture sector, including the fertilizer subsidy, to be able to plough back the subsidy savings—this could then be used for the development of agricultural practices which are low carbon in nature.

The agriculture sector in India can also make use of the funding available under the Adaptation Fund to implement adaptation measures as a response to negative impacts of climate change. Box 2.6 gives highlight of the adaptation fund.

Box 2.6: Adaptation Fund under UNFCCC

The Adaptation Fund (AF) was established in 2001 to finance concrete adaptation projects and programmes in developing country Parties to the Kyoto Protocol that are particularly vulnerable to the adverse effects of climate change. It is financed with a share of proceeds from the CDM project activities and other sources of funding. The share of proceeds amounts to 2 per cent of CERs issued for a CDM project activity. The fund also receives contributions from governments, the private sector, and individuals. The AF is supervised and managed by the Adaptation Fund Board (AFB) which is composed of 16 members and 16 alternates.

One unique feature of the Adaptation Fund is its direct access mechanism, which enables accredited national implementing entities (NIEs) and regional implementing agencies (RIEs) in developing countries to directly access climate adaptation financing. The National Implementing Entities (NIEs) prepares and submit projects to the designated authority of the national government for endorsement to the AFB Secretariat for consideration and sanction. India is eligible to seek financial support under the AF. It can undertake climate adaptation activities at national and regional level. NABARD has been accredited by the Adaptation Fund Board of UNFCCC as National Implementing Entity (NIE) in India. The NIE bears full responsibility for the overall management, all financial, monitoring, and reporting responsibilities for the project. It may appoint Executing Entities to execute projects and programmes under its oversight.

2.3.7 Industry

India's industry sector consists of both large industries that are at par with world standards and scale, as well as small units which are primarily unorganized and constrained in being able to access and make gainful use of knowledge, processes, and mechanisms that allow technological progress. In terms of primary energy consumption, industry remains the largest consumer of energy in India, accounting for over 50 per cent of the total energy consumption in the country. Energy-intensive industries namely fertilizers, aluminium, textiles, cement, iron and steel, pulp and paper, and chloralkalis consume around 65 per cent (TERI 2013) of the total industrial energy.

Performance, Achieve, and Trade (PAT) is a market-based mechanism that was launched under the National Mission on Enhanced Energy Efficiency (NMEEE). The mechanism has a goal to mandate specific energy efficiency improvements for industrial units known as Designated Consumers (DC) (see Box 2.7 for an overview on PAT mechanism).

Box 2.7: Performance, Achieve, and Trade (PAT) Mechanism

The Government, in March 2007, identified certain units in nine industrial sectors, namely aluminium, cement, chlor-alkali, fertilizers, iron and steel, pulp and paper, railways, textiles and thermal power plants as DCs. The DCs in the industrial sectors were shortlisted based on their annual energy consumption expressed in terms of tonnes of oil equivalent (TOE). A total of 478 DCs across eight sectors were notified in the first phase. Each DC has been mandated to achieve a prescribed reduction in its specific energy consumption. The reduction targets were notified in March 2012. Overall, all the plants together are to achieve a 4.05 per cent reduction in the average energy consumption by 2014-15.

At present, the second phase of the scheme is under progress wherein empanelled accredited energy auditors (EmAEA) perform independent evaluation of each activity the DC undertook to comply with energy reduction targets.

PAT is expected to accelerate the adoption of low carbon technologies among Indian industries. The policy will also complement the efforts being made under various multilateral/bilateral processes to promote adoption of low carbon technologies. The unit-specific Specific Energy Consumption (SEC) benchmark established under PAT can serve as a baseline for new international mechanisms and schemes.

While large industry sub-sectors such as cement, iron and steel, aluminium, and fertilizers have made significant progress in terms of improved efficiency in energy use and adoption of cleaner technologies, there is a need to focus on the challenges faced by the Micro, Small, and Medium Enterprises (MSMEs) in terms of access to technology and finance and therefore, their challenges in pursuing green growth. The MSME sector have been playing a pivotal role in the country's overall economic growth. They have achieved steady progress over the last couple of years. This sector contributes 8.7 per cent of the country's GDP, 45 per cent of the manufactured output, and 40 per cent of its exports. The MSMEs provide employment to about 60 million persons, through over 26 million enterprises, producing over six thousand products (MSME 2011). They can make a substantial contribution to achieving a low carbon economy, provided the barriers to the growth of the MSME sector can be addressed appropriately.

Iron and steel

To supplement R&D in the steel sector, the Government had decided, in 1997–98, to fund up to INR 150 crore (approx. 25 USD million) per year from the interest proceeds of the Steel Development Fund (SDF) for R&D projects in the sector. The Empowered Committee on R&D under the Chairmanship of Secretary (Steel) under the Steel Development Fund has so far approved 83 research projects costing INR 696.27 crore (approx. USD 116 million), including SDF component of INR 389.63 crore (approx. USD 65 million) of these 47 projects have been completed. Research results of several R&D projects have already been implemented by the steel plants, resulting in improvement in productivity, reduction in energy consumption and pollution (MoS, 2015). In the Eleventh Plan (2007–12), a new scheme for 'promotion of Research & Development in Iron and Steel sector' was included with a budgetary provision of INR 118.00 crore (approx. USD 19.67 million) for promotion of research & development in the domestic iron and steel sector. The scheme has been continued in the Twelfth Five Year Plan with a budgetary provision of INR 200 crore (approx. USD 33.33 million). Under the scheme, a total of ten (10) R&D projects have been approved. Total cumulative amount of INR 34.63 crore (approx. USD 5.77 million) has been released under the scheme up to December, 2014, during the Twelfth Five-Year Plan.

In BE 2015–16, which is the fourth year of the Twelfth Five-Year Plan (2012–17) INR 15.00 crore (approx. USD 2.5 million) has been earmarked for the scheme. For new components, i.e. Development of Technology for Cold Rolled Grain Oriented (CRGO) Steel Sheets and other value added innovative steel products a budgetary provision of INR 1.00 crore (approx. USD 0.16 million) has been provided and budgetary provision of INR 14.00 crore (approx. USD 2.33 million) has been provided for new projects under the existing scheme.

Cement

The Indian government has adopted some policy measures to support and aid the growth of the Indian cement industry. The demand for cement in India has been influenced mainly by the housing, infrastructure, and irrigation. The Government of India plans to increase its investment in infrastructure to USD 1 trillion in the Twelfth Five-Year Plan (2012–17) as compared to USD 514 billion expected to be spent on infrastructure development under the Eleventh Five-Year Plan (2007–12). Further, infrastructure projects such as the dedicated freight corridors, upgraded and new airports and ports are expected to enhance the scale of economic activity, leading to a substantial increase in cement demand. Measures to upgrade existing plants and research in new technologies include funding from a corpus of clean energy fund, for cement sector, for development of processes for using alternate fuel and municipal and solid waste and energy efficient technologies (Twelfth Five-Year Plan 2012–17).

Fertilizer

The fertilizer sector attracted large investment during the 1970s and 1990s. However, there has been hardly any investment during the Tenth and Eleventh Five Year Plans. The total investment in the fertilizer sector by the end of 2010–11 was INR 27,247 crore (approx. USD 4.54 billion). With the accelerated growth in the Indian economy, other sectors had high rates of return on investment, but the fertilizer sector has failed to attract more investment due to low returns. To increase the capacity of urea by about 12 million tonnes to a total of 33.7 million tonnes by 2016–17, India will need to invest at least INR 40,000 crore (approx. USD 6.66 billion) in the sector at current capital costs.

In the context of rapidly increasing foodgrain production in the country, suitable amendments to the new investment policy in the urea sector are required for creating a conducive incentive-based environment for new investments in the urea sector. Besides this, investment in potash and phosphate assets/ mines for raw materials and joint ventures for finished fertilizers is required to ensure long-term supply of P and K fertilizers.

The new investment policy declared in 2008 needs to be made more investor friendly. There is a need to attract new investments to special economic zones where fiscal benefits are provided. Besides fiscal benefits (including exemptions from various taxes and duties), the fertilizer industry could be provided incentives in the form of: (*i*) viability gap funding for investment in new projects, (*ii*) facilitating long-term contracts for gas, and (*iii*) securitization of subsidy receivables to ensure regular cash flow.

The New Pricing Scheme-III is aimed at promoting further investment in the urea sector to maximize urea production from the existing urea units, including through conversion of non-gas based units to gas, incentivizing additional urea production, and encouraging investment in joint venture projects abroad. The policy is aimed at establishing a more efficient urea distribution and movement system in order to ensure availability of urea in the remotest corners of the country.

Micro, Small and Medium Enterprises (MSMEs)

Only about 7 per cent of all MSMEs have access to finance from institutional/non-institutional sources, while close to 92 per cent operate without access to finance/through self-financing. Over the last decade, while the quantum of bank credit given to medium and small enterprises by public sector banks has increased, the share of credit to the MSE sector in Net Bank Credit (NBC) has declined from 12.5 per cent to 10.9 per cent and the share for the micro sector has decreased by nearly 3 per cent (GoI 2010).

A number of initiatives to boost the MSME sector have been taken up by government agencies as well as by the private sector. An INR 50 billion (approx. USD 0.83 billion) India Opportunities Venture Fund with the Small Industries Development Bank of India (SIDBI) has been established with the aim of enhancing the availability of equity to MSMEs, among other schemes supporting technology upgradation by the government. The Twelfth Five-Year Plan outlays three new schemes with an allocation of over INR 75 billion (approx. USD 1.25 billion) that would infuse funds into the sector through different paths which include equity financing to supplement promoter contribution, venture capital funds to encourage start-ups, and MSME exchange to facilitate equity access and spread awareness. 3.2

The Working Group on MSME's growth has also proposed a budget allocation of INR 40 billion (approx. USD 0.67 billion) under the Scheme for Technology Acquisition and Development in the TFYP (Twelfth Five-Year Plan). Furthermore, the Group has recommended systematically leveraging the National Clean Energy Fund to increase the uptake of clean energy technology in the MSME sector. Besides this, a fund of INR 3 billion (approx. USD 50 million) has been proposed for technology collaboration and acquisition.

Technological modernization is the key to high industrial growth. There are a large number of energy-intensive MSME clusters (around 178 clusters manufacturing about 15 product categories like castings, forgings, glass and ceramics, food processing, textile processing, and so on) in the country where energy efficient and cleaner technologies can be facilitated. Yet, only a few programmes have targeted development and demonstration of cleaner technologies at cluster level. Hence, there is a need to focus greater attention in this area.

A preliminary review undertaken by TERI of 390 MSME clusters, covering 12 product categories, suggest the presence of at least 175 energy-intensive clusters in India. TERI has recently collated preliminary energy data for 43 clusters under SAMEEEKSHA. It was found that the energy consumption of these 43 clusters alone account for 6.6 million tonnes of oil equivalent (mtoe) (nearly 4 per cent of the country's commercial energy consumption in the industrial sector). There is a need to institutionalize data collection on energy consumption patterns in the Indian MSME sector as a whole. Energy consumption data is important for policymakers and other agencies working in the MSME sector for initiating programmes and activities in energy-intensive clusters.

State governments would also need to take steps to create an investor-friendly climate. It is essential to ensure that delays in land registration, water and utility connections, environmental and other clearances are minimized through a single window clearance of applications for establishment of industrial units.[12] If the MSME sector has to take its rightful place as the growth engine of Indian economy, it is necessary to support the sector with resources—both human and economic—to help it keep pace with global developments.[13]

2.3.8 Forestry

Increasing the density of forestry and tree cover on forest and community lands has been identified as one of the key low carbon strategies for India's forestry sector. To achieve the goals of low carbon growth in the forestry sector, the Green India Mission (one of the eight missions under the National Action Plan for Climate Change (NAPCC)) has been acknowledged as a powerful instrument through its interventions relating to climate adaptation & mitigation, food security, biodiversity conservation, livelihood conservation, and others. The time frame for implementation of the mission is ten years (FY 2010–11 to FY 2019–20). The total mission cost is estimated to be INR 46,000 crore (approx. USD 7.66 billion) for treatment of approximately 10 million ha of land. This cost is an indicative figure for the country as a whole; there would be variance according to state-specific situations. Table 2.21 discusses the

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12 Approach paper for Twelfth Five-Year Plan
13 http://www.smechamberofindia.com/

major costs that are to be incurred to implement the activities stated in the Green India Mission (GIM). The mission also aims at enhanced CO_2 sequestration by 50–60 million tonnes in the year 2020.

Table 2.21: Costs under Green India Mission

S. No.	Activities	Costs (INR, crores)	Costs (USD, millions)
1.	Resources needed for the mission to meet specific objectives and activities	34,000	5,666.67
2.	Resources for support activities (including research, outreach, GIS, livelihood improvement, strengthening local level institutions etc.)	12,000	2,000
	Total mission costs (1+2)	**46,000**	**7,666.67**

Source: Adapted from MoEFCC (2013)

GIM has been approved by the Cabinet Committee on Economic Affairs (CCEA) in February 2014 with a projected cost of INR 13000 crore (approx. USD 2.167 billion) and one year spill over in Thirteenth Five Year Plan. This includes INR 2,000 crore (approx. USD 333.33 million) from Twelfth Plan Outlay, INR 400 crore (approx. USD 66.67 million) from Thirteenth Finance Commission grant, and convergence with CAMPA to the tune of INR 6,000 crore (approx. USD 1 billion), and MNREGS to the tune of INR 4,000 crore (approx. USD 666.67 million). At the national level, the mission would seek convergence with other missions, programmes, and schemes such as Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), Compensatory Afforestation Management and Planning Authority (CAMPA), National Afforestation Program (NAP), National Rural Livelihood Mission, and Integrated Watershed Management Program. The Ministry of Environment, Forest and Climate Change (MOEFCC) has already issued guidelines for convergence of GIM with MGNREGS and CAMPA. Table 2.22 discusses the various sub-missions and components, stated in the GIM.

Table 2.22: GIM Interventions and Tentative Costs

S.No.	Sub Mission	Category	Area to be worked upon (ha)
1	Enhancing quality of forest cover and improving ecosystem services		4.9 m

		(a) Moderately dense forest cover, but showing degradation	1.5 m
		(b) Eco-restoration of degraded open forests	3 m
		(c) Restoration of grasslands	0.4 m
2	Ecosystem restoration and increase in forest cover		1.8 m
		(a) Rehabilitation of Shifting Cultivation areas	0.6 m
		(b) Restoring scrublands	0.8 m
		(c) Restoring/planting seabuckthorn	0.1 m
		(d) Restoration of mangroves	0.1 m
		(e) Ravine reclamation	0.1 m
		(f) Restoration of abandoned mining areas	0.1 m
3	Enhancing tree cover in Urban and Peri-Urban areas (including institutional lands)		0.2 m
4	Agro-forestry and social forestry (increasing biomass and creating carbon sink)		3 m
5	Restoration of wetlands		0.1 m

Source: MOEFCC (2013)

Forests provide us with a range of ecosystem goods and services such as carbon sequestration and storage, climate regulation, food production, and sociocultural services. Forests also play a fundamental role in the preservation of global ecological systems. However, with the recent phase of forest degradation and deforestation, the critical functions provided by the forest ecosystems are being increasingly threatened (FAO 1997). To address these issues and in order to safeguard forest ecosystems, it is important that forestry resources and services are valued appropriately. Viable financial mechanisms need to be used to promote sustainability across forest ecosystems. The Fourteenth Finance Commission rightly identified the need to '*balance management of ecology, environment and climate change consistent with sustainable economic development*' and added the new criterion of forest cover for devolution of central taxes to the states. This would encourage states to take up afforestation and reforestation activities on their land and still compensate for the opportunity cost loss in terms of area which could have otherwise been used for generating economic activities. Table 2.23 outlines the new horizontal formula for inter-se determination of the shares of taxes to the states:

Table 2.23: Criteria and Weights for Inter-se Determination of the Shares of Union Tax Revenues to States

Criteria	Weight
Population	17.5
Demographic change	10
Income distance	50
Area	15
Forest cover	7.5

Source: MoF (2014)

An estimated 100 million forest dwellers depend on Minor Forest Produce (MFP) for food, shelter, medicines, cash income, etc., yet the price of MFP (or NTFPs) is most often decided by traders rather than by demand/supply (barring few high revenue items nationalized by the state governments). Thus, the Government of India has introduced the scheme of 'Mechanism for marketing of MFP through Minimum Support Price (MSP) and development of value chain' as a social safety net for improvement of livelihood of MFP gatherers. Under this scheme, 12 different MFPs have been identified by the Ministry of Tribal Affairs, Government of India. The scheme has been implemented in states having areas under the Fifth Schedule of the Indian constitution, i.e., Andhra Pradesh, Chhattisgarh, Gujarat, Jharkhand, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, and Telangana. However, since Andhra Pradesh and Telangana have put all the MFP under monopoly of the state, the scheme has not been implemented in these two states so far (MoTA 2015).

Clean Development Mechanism (CDM)

As provided under Article 12 of the Kyoto Protocol, CDM enables developing countries to issue certified emission reductions (CERs) to developed economies who invest in these developing countries to reduce their GHG emissions in order to meet their targets stated in the Kyoto Protocol (UNFCCC, "What is CDM", undated). A part of the investments received by developing countries go towards afforestation activities and to promote sustainable forestry. The CDM is also the main source of income for the UNFCCC Adaptation Fund, which was established to finance adaptation projects and programmes in developing country Parties to the Kyoto Protocol that are particularly vulnerable to the adverse effects of climate change. The Adaptation Fund is financed by a 2 per cent levy on CERs issued by the CDM. However, the number of registered CDM projects and requests for new registrations in India are minuscule. Not only this, the share of forestry related projects in the total CDM projects for India is almost negligible (UNFCCC, undated; Earthwatch, undated).

Financial Mechanism of REDD+

The UN financial mechanism of Reducing Emissions from Deforestation and Degradation (REDD+) incentivizes avoided deforestation and sustainable management of forests with the view to reduce GHG emissions. REDD+ aims at compensating forest owners in developing countries for conserving forests by assigning value to the forest carbon stock, one of the ecosystem services provided by the forests.

India continues to play an important role in REDD+ negotiations and has been guiding current international negotiations relating to REDD+. India's position on REDD+ underscores the need for reducing emissions through sustainable management of forests, and enhancement of forest carbon stocks, in addition to reducing emissions from deforestation and forest degradation (TERI 2009). India also released its draft National Policy on REDD+ in 2014 to provide a roadmap for effective implementation of REDD+ projects and programmes across the country and create financial incentives for the local communities who are at the forefront of forest conservation efforts (MOEFCC 2014). Even though the number of REDD+ pilot initiatives is rapidly rising in India, comprehensive financial arrangements for full-scale implementation of REDD+ projects are yet to be made (Lang 2011; Carbon Market Watch 2013).

Ecosystem services funding mechanisms

Payments for ecosystem services or PES mechanism is a broad term used for a variety of financial arrangements made between the beneficiaries of ecosystem services and providers of those services. This mechanism for the forestry sector is particularly considered as a useful instrument to preserve forest ecosystems (UNEP 2011). It has the potential to ensure effective provisioning of forest ecosystem services such as carbon sequestration, nutrient storage, and recreational services.

However, the applicability of PES mechanisms is limited only to the areas where property rights over the forest resources are identified clearly—unlike the case for many of India's forest ecosystems (See Box 2.8 for example). The PES mechanism relating to issues of upstream–downstream pollution in the forests, soil hill nutrient management, biodiversity conservation, and others have been implemented across the forests of India; however, many of these arrangements have not remained viable in the long run due to weak institutional set-up and policies (Singh 2008).

Box 2.8: Payments for ecosystem services in Himachal Pradesh

The Government of Himachal Pradesh (GoHP) in November 2013 came out with the 'State Policy on Payments for Ecosystem Services'. The policy is targeted at protection and management of natural resources for sustained production of ecosystem services; and provision of economic incentives to the communities for conserving natural ecosystems. The state government is committed to institutionalize ecosystems approach and put in place PES mechanism in the state. The PES policy mentions the various ecosystem services that will be eligible for the PES models; these include soil erosion control, carbon sequestration, sediment load reduction, fire control, rehabilitation of weed infested areas, organic and conservation agriculture, conservation horticulture, and biodiversity conservation. The policy envisages to develop partnerships amongst different departments, research and civil society organizations; and is envisioned to build capacities at all levels in the process for effective ecosystems and natural resource management (GoHP 2013).

2.3.9 Waste Management

Solid waste is often regarded as an indicator of the level of urbanization achieved in any country. The generation of solid waste in the country is increasing over the years due to changing lifestyles and increasing consumerism resulting from rapid urbanization and economic growth. These rising levels of waste generation without efficient collection, processing, and disposal are posing an environmental threat, impacting human health as well as the ecosystem.

According to a study, about 960 MT of solid waste is being generated per year in India from industrial, mining, municipal, agricultural, and other sources (Pappu *et al*. 2007). Of this, about 290 MT is inorganic wastes from industrial and mining sectors, 62 MT is municipal wastes, 8.3 MT is hazardous wastes, and about 350 MT is organic wastes from agricultural sources (TEDDY 2011/12). With rapid development in India, the generation of solid wastes is expected to rise dramatically.

According to the latest data available from the World Bank, urban India generates 0.34 kg per capita per day of municipal solid waste, resulting in a daily waste quantum of 109,589 tonnes (TEDDY 2012/13).

The increasing generation of solid waste is a growing problem in all Indian cities. Lately, dumping garbage into landfills is not a preferred option in our land-scarce cities. It is to be noted that the overall requirements of funds for municipal solid waste management (MSWM) is unattainable if only the internal resources of urban local bodies (ULB) are available. The scale of investment needed in this sector is substantial. Financial support from government agencies either in the form of grants and/or subsidies is needed to accelerate the efforts of ULBs to modernize the MSWM system in their respective cities.

The Fourteenth Finance Commission, responsible for devolution of funds to state governments for five years from 2015–20, has worked out the total size of the grant to be INR 2,87,436 crore (approx. USD 47.9 billion) for the period 2015–20, constituting an assistance of INR 488 per capita per annum at an aggregate level. Of this, the grant recommended to panchayats is INR 200,292.2 crore (approx. USD 33.38 billion) and that to municipalities is INR 87,143.8 crore (approx. USD 14.52 billion). These grants will be in two parts—a basic grant and a performance grant. For gram panchayats, the division between basic and performance grants will be on 90:10 basis and for municipalities it would be on 80:20 basis.

The basic grant provided should be used to improve basic civic services including water supply, sanitation including septage management, sewerage and solid waste management, storm water drainage, maintenance of community assets, maintenance of roads, footpaths and street-lighting, and burial and cremation grounds. The Thirteenth Finance Commission had even linked the performance-related funds to improvements in Service Level Benchmarking (SLBs)[14], including SWM. It had also recommended that of all the grants given to the ULBs, 50 per cent should be for SWM.

The CPCB 2012–13 report suggests that 30 per cent of the municipal solid waste generated is not even collected and of the

[14] Service Level Benchmarking is an initiative of the Ministry of Urban Development (MoUD), Government of India to increase accountability for service delivery in sectors such as water and sanitation (which includes solid waste management), e-governance and urban transportation. It involves measuring and monitoring of service provider performance on a systematic and continuous basis. Source: http://moud.gov.in/servicelevel

70 per cent that gets collected, only 12.45 per cent is treated or processed. It is observed that smaller towns, where the main activity is solid waste management (SWM), spend up to 70 per cent of their budget on the same. Metropolitan cities, on the other hand, due to a wider resource base and the responsibility of providing a larger number of services, spend only around 10 per cent of their budget on solid waste management. A majority of urban centres, however, spend 5–40 per cent of their budget on solid waste management. This is approximately between INR 50 to INR 250 (approx. USD 0.83 to USD 4.17) per capita per year. It is observed that a large proportion of this expenditure is incurred for salaries and only a limited amount is spent on operation and maintenance (O&M) and development works.

One of the priority areas within first phase of JNNURM, which ended in March 2014 and is now being replaced by the Atal Mission for Rejuvenation and Urban Transformation (AMRUT), was solid waste management. Since the inception of JNNURM in 2005–06, Indian cities have witnessed widespread infrastructure development linked to municipal services. One of the sets of benchmarks established by the MoUD for Smart Cities also talks about achieving 100 per cent efficiency in collection and treatment of waste water and sewerage network. It also ambitiously targets at achieving 100 per cent collection, segregation, and recycling of solid waste.

Another new initiative with the target to make the country clean by 2019 is the Swachh Bharat Mission launched by the Government of India on October 2, 2014. Its specific objectives include elimination of open defecation, modern and scientific municipal solid waste management, and eradication of manual scavenging, among others. The estimated cost of implementation of SBM (Urban) based on unit and per capita costs for its various components is INR 62,009 crore (approx. USD 10.33 billion). The Government of India's share, as per approved funding pattern, amounts to INR 14,623 crore (approx. USD 2.43 billion). In addition, a minimum additional amount equivalent to 25 per cent of GoI funding, amounting to INR 4,874 crore (approx. USD 0.81 billion) shall be contributed by the States as State/ULB share. The balance fund is proposed to be generated through various other sources of fund which are, but not limited to:

(a) Private sector participation
(b) Additional resources from State government/ULB
(c) Beneficiary share
(d) User charges
(e) Land leveraging

(f) Innovative revenue streams
(g) Swachh Bharat Kosh
(h) Corporate social responsibility
(i) Market borrowing
(j) External assistance

The Government of India sanctioned the implementation of the programme on energy from urban, industrial, and agricultural wastes/residues in 2013 during the Twelfth Plan period. It aims to promote setting up of projects for recovery of energy from urban, industrial, and agricultural wastes; and to create conducive conditions and environment, with fiscal and financial regime, to develop, demonstrate, and disseminate utilization of wastes and residues for recovery of energy.

Table 2.24 illustrates the capital subsidy available to the promoters:

Table 2.24: Capital Subsidy Available to the Promoters

Waste/Processes/Technology	Capital Subsidy
Power generation from Municipal Solid Waste	INR 2.00 crore/MW (Max. INR 10 crore/project)
Power generation from biogas at Sewage Treatment Plant or through biomethanation of Urban and Agricultural Waste/residues	INR 2.00 crore/MW or bio-CNG from 12,000 m^3 biogas/day (Max. INR 5 crore/project)
Biogas generation from Urban, Industrial and Agricultural Wastes/residues	INR 0.50 crore/MWeq. (12,000 m^3 biogas/day with maximum of INR 5 crore/project)
Power Generation from Biogas (engine/gas turbine route) and production of bio-CNG for filling into gas cylinders	INR 1.00 crore/MW Or bio-CNG from 12,000 m^3 biogas (Max. INR 5 crore/project)
Power Generation from Biogas, Solid Industrial, Agricultural Waste/ residues excluding bagasse through Boiler + Steam Turbine Configuration	INR 0.20 crore/MW (Max. INR 1 crore/project)

Source: MNRE (2013)

Apart from the above incentives to the promoters, there are monetary incentives for the state nodal agencies, financial assistance for promotional activities and financial support for R&D activities as well.

Apart from the above-mentioned programmes and subsidies provided by the central/state governments, various incentives are also available for financing of infrastructure related to solid waste management in India. A tax holiday for the project 'Entity for Solid Waste Management' has been provided according to the Union Budget 2001/02, provision for deduction has been made under Section 801A of the Act in respect to profits, and gains of the undertaking/or enterprise engaged in infrastructure facilities relating to solid waste management, which is allowed at 100 per cent of such profits for ten consecutive assessment years out of the first twenty years of the project under certain conditions.

PPPs (Public–Private Partnerships) in solid waste management in India are involved in waste collection, transportation, and treatment. As may be known, a PPP is a contract between a public sector authority and a private party which is funded and operated by both the parties, and in which the private party provides a public service or project and assumes substantial financial, technical, and operational risk in the project. Table 2.25 showcases the scope of activities and implementation frameworks that are prevalent in the MSWM space.

The role of the private sector in municipal solid waste management is taking off rapidly in the country. Metro cities like Chennai, Hyderabad, etc., were the first to witness large-scale private sector participation sometime during the mid-1990s. During the late 1990s, the urban local bodies (ULBs) gradually realised the need for processing/ recycling solid waste to reduce the burden on landfills. Along with this, came the notification of MSW Rules (Management and Handling), 2000, that made waste processing and development of sanitary landfill mandatory. There was an increased involvement of private operators during the mid-2000s driven mainly due to technical, financial, and managerial constraints at the ULBs.

It has been observed that since the late 1990s, the private sector is eager to invest and manage projects on primary collection and transportation, which was earlier limited to only local contractors. A few integrated projects have also been successfully developed on PPP formats including integrated processing and disposal in the cities of Coimbatore, Bengaluru, Chennai, Delhi, Kolkata, and Ahmedabad. Integrated MSWM systems for the entire value chain, provided by a single private operator, have come up in the cities of Guwahati (Box 2.9) and Hyderabad.

Table 2.25: Prevalent PPP Formats in MSWM

S. No.	Scope of services	PPP format
1	Door-to-door collection	Service Management Contracts
2	Street sweeping	Service Contracts
3	Construction and maintenance of community bins	BOT(Build—Operate—Transfer) and its variance and/or separate EPC (Engineering, Procurement and Construction) and O&M Contract

4	Transportation of waste to integrated, processing and disposal facility	Concession and/or O&M Contract
5	Design, development, operations and maintenance of processing and treatment facility for MSW including special waste like vegetable market and/or abattoir waste.	BOT and its variance and/or separate EPC and O&M Contract
6	Design, development, operations and maintenance of sanitary landfill site.	BOT and its variance and/or DFBOT and/or separate EPC and O&M Contract

Source: MoUD (2011)

More than half of the waste budget of Indian cities is typically spent in collection alone (mainly on labour and fuel); still, the collection rate remains low and the transport of waste inefficient. Spending on other segments of the waste management chain such as appropriate treatment, recovery, and disposal technologies and facilities requires attention. Increased investment in basic collection services, the transport of waste and cleaning up of dump sites is a starting point for greening the waste sector.

Box 2.9: Integrated solid waste management in Guwahati, Assam

Guwahati city has a characteristic low-lying topography and mountains on all sides, which has created a bad situation for solid waste accumulation and management. The situation is further worsened by floods every year. There is no proper system for collection, transportation, disposal, and treatment processes for solid waste. In view of this, the need was felt to adopt a scientific and integrated approach to tackle the solid waste problem. The scope of the project was to structure and develop an end-to-end integrated solid waste management system with a single private operator having complete responsibility for the entire value chain starting from primary collection, storage, transportation, processing and disposal. MSW was to be processed for energy recovery before final disposal into the landfill site. Processing and disposal would be developed at Boragaon and would consist of:

RDF plant to handle 500 TPD MSW – mixed MSW to be converted into Refuse Derived Fuel (RDF) in the RDF plant.

Compost plant to handle 50 TPD of organic waste – Organic components of MSW segregated during RDF process will be treated in the compost plant to produce manure.

Power plant – Power plant boiler will be fed with 180 TPD of RDF having a calorific value in the range of 2,500–2,800 kcal/kg and 57 TPD of biomass, up to the limit laid as per the MNRE Policy/ guidelines to use supplementary fuel for such plants as fuel and will generate 6 MW of electricity.

The project also entails development and management of sanitary landfill. The selected private operator was M/s Ramky Enviro Engineers Limited (REEL).

The estimated project cost was INR 102 crore (approx. USD 17 million). The total project cost approved under JNNURM is INR 36.34 crore (approx. USD 6.06 million). The contribution of the private player is INR 65.66 crore (approx. USD 10.94 million). The involvement of community and informal sectors was considered while structuring the project, though the overall responsibility lies with a SPV named Guwahati Waste Management Company Pvt Ltd (GWMCL) for smooth coordination and implementation.

Source: MoUD (2011)

Because of the paucity of funds to render solid waste management services in an effective manner on the lines of integrated solid waste management principles, most ULBs are struggling to meet the mandates of the MSW Rules. The challenge is, therefore, to improve service delivery with a focus on LCD strategies for the waste sector. The key elements of LCD with reference to MSW management is to put the waste reduction policy and measures in place, maximize waste reuse and recycling, organize effective organic waste processing (composting or energy recovery from waste), minimize land disposal and if land disposal is inevitable, provision of landfill gas harvesting to reduce the GHG burden. The Ministry of Urban Development has proposed service level benchmarks for solid waste management services which address many of these issues. The present funding mechanism therefore needs to consider if these elements of efficient waste management have been incorporated in project implementation plans.

2.4 The Way Forward

Attracting investments for low carbon development has been challenging. Although progress is being made; there is an still unmet need to achieve low carbon development. The global community recognizes the need to create an enabling environment for low carbon development. After the 2002 Monterrey Consensus and the 2008 Doha Declaration, the Heads of State and Government and High Representatives, gathered in Addis Ababa from 13 to 16 July 2015, to reaffirm their political commitment to address the challenge of financing for sustainable development. The Addis Ababa Action Plan suggests that "solutions can be found, including through strengthening public policies, regulatory frameworks and finance at all levels, unlocking the transformative potential of people and the private sector, and incentivizing changes in financing as well as consumption and production patterns to support sustainable development".

Low carbon development (LCD) provides a solution in the larger debate of economic growth vis-a-vis environmental conservation. The path to LCD holds several advantages including achieving energy security as well maintaining sound state of the environment. But transition to low carbon space would require significant flow of finance. The fund flow in this space gets impeded due to a number of factors, including inadequate policy environment, unfamiliarity with risks associated with low carbon initiatives, and longer payback periods of low carbon projects. Despite the barriers, transition is gaining momentum in India, which is evident in the increased investments in low carbon space, particularly renewable energy sector, and initiatives such as levy of coal cess, trading of renewable energy certificates, and changes in the structure of devolution of funds to states.

It is generally understood that projects in low carbon space possess higher risks because of their longer payback periods, high initial capital outlay, and lack of familiarity of lenders with this concept. Financial constraints, inadequate policy provisions, and system complexity often does not allow funds to flow as freely in low carbon projects as it would have flown for their conventional alternatives. Banks, micro-finance institutions, and non-banking financial companies (NBFCs) require risk offsets to invest in low carbon development projects. In this light, funds created to cover for such risks, such as the Partial Risk Guarantee Fund and the Partial Risk Sharing Facility, should be further strengthened to boost investment for low carbon growth.

Inclusion of renewable energy as one of the priority sectors by the Reserve Bank of India (RBI) is a welcome move which could encourage renewable energy industry. However, there is a need for concerted effort to spread awareness regarding this banking provision among stakeholders, especially project developers and investors. Also, low carbon interventions in sectors other than renewable energy, such as buildings, transport, agriculture, industry, waste, and forestry should also be given due consideration under RBI norms. For many low carbon technologies, there is a need to better study and research to discern their long-term viability before launching them on a large scale. For instance, carbon capture and storage needs a careful contemplation to determine its cost-competitiveness and safety in longer time horizon. Some other such technologies require more research & development and adequate incentives for their commercialization, e.g., promoting the use of hybrid vehicles requires more effort in terms of technology, geographical suitability, and infrastructure for charging needs of the cars.

Public sector financing has a definite role to play in pushing LCD further. Targeted public sector financing interventions need to be augmented. This is crucial not just from the point of view of scaling up and commercializing LCD activities but also to stimulate and mobilize private sector investment in LCD. Public and private sector institutions need to be strengthened to respond and anticipate the complexities and needs emerging in the low carbon space.

Effectively engaging the private sector is crucial to filling the financing and implementation gap for LCD. Provisions to facilitate PPPs through providing framework and incentives for urban local governments in India include the viability gap funding (VGF) mechanism, formation of the India Infrastructure Finance Corporation Limited (IIFCL), and the India Infrastructure Project Development Fund. Risk reduction mechanisms in PPPs for low carbon development projects are needed, including loan guarantees and mixed equity funds. There is also a need for a mechanism for enhanced coordination between public and private sector.

LCD requires capital availability for which it is required to broaden the sources of funding as well as the way in which these are intermediated. Traditional finance has not been able to successfully capture the opportunity to fund the emerging requirements in low carbon space. Initiatives taken by banks and financial institutions have not been large scale enough as there is no common framework or guidelines in India that banks can follow to offer credit for 'green' initiatives by organizations and reduce their risks. There has been some traction in the involvement of banks and financial institutions in the renewable energy sector; however, other low carbon development sectors (including MSMEs) need a similar participation from banks.

The RBI can take steps in the direction of bringing financial innovations, such as designing 'green' credit guidelines that can guide the Indian banks on lending to organizations that would want to be more sustainable. The guideline can also promote voluntary sustainability reporting by banks.

Investors should focus on new sources of funds like pension funds and sovereign wealth funds; burgeoning market of green bonds; access to capital markets and low cost debt which can help achieve the financial needs for low carbon development. They should also constantly evolve suitable policies to securely fund low carbon projects and streamline their existing policies on these aspects as per market requirements.

At the same time, building a suitable policy scenario at national level is equally important. Policymakers need to find vehicles for modifying existing consumer preferences to more sustainable practices. This could be done by creating awareness and building capacity towards voluntary sustainability initiatives.

Policymakers should devise ways that do not just generate interest among individuals and organizations towards adoption of green practices in their routine activities but also be able to sustain it. The Ministry of Finance, Government of India, the RBI, and the banks together can develop a suitable environment which can entice investors towards LCD.

Sectors like transport, habitat (or buildings), industries, waste, and others provide states huge opportunity to improve their low carbon scenario and simultaneously achieve better living conditions for its citizens. Policies in the state should promote organizations which work towards low carbon initiatives by extending them incentives such as tax credits. Through knowledge sharing of the lessons learnt at the subnational level, national policy scenario could be improved upon.

Local level government in India has better connect with the civil society and the businesses. It understands the actual scenario in their areas and would be in a better position to respond to the existing challenges in low carbon space. It will be up to the municipal corporations and panchayats to obtain funds to engage more in low carbon space and judiciously utilize those funds. It also has to ensure that the national or sub-national 'green' guidelines and/or policies are efficaciously followed.

Overall, the following recommendations emerge:

- The sustainable development community as a whole needs to recognize the importance of engaging with global financial regulatory frameworks such as the Bank for International Settlements, International Monetary Fund, and International Accounting Standards Board.
- Banks, micro-finance institutions, non-banking financial companies (NBFCs) require risk offsets to invest in low carbon development projects.
- RBI needs to spread awareness regarding the priority sector lending norms among other stakeholders. Also, sectors, other than renewable energy which can also contribute potentially towards environmental sustainability, such as buildings, transport, agriculture, industry, waste, and forestry should be given due consideration under RBI norms.

- Public finance will be crucial in helping stimulate investments for low carbon development. Apart from initiatives, such as the National Clean Energy Fund, there is need for more public spending on low carbon development initiatives.
- Institutions needs to be strengthened to respond and anticipate the complexities and needs emerging in the low carbon space.
- Private sector should be engaged to fill the financing and implementation gap for LCD. Coordination between private and public sector needs to be improved.
- RBI can take steps in the direction of bringing financial innovation like designing 'green' credit guidelines. It should also promote voluntary sustainability reporting by banks.
- The Ministry of Finance, Government of India, should actively monitor the usage of its fund flow towards various LCD activities. One such mechanism could be 'green budgeting'.
- Policymakers should devise ways that do not just generate interest among individuals and organizations towards adoption of green practices in their routine activities but also be able to sustain it.
- Policies in the state should promote organizations which work towards low carbon initiatives by extending incentives to them such as tax credits.
- There should be a knowledge sharing platform to document lessons learnt at the sub-national level which can feed into national level policymaking and improve national policy scenario.
- It will be up to the municipal corporations and the panchayats to obtain funds to engage more in low carbon space and judiciously utilize those funds. It also has to ensure that the national or sub-national 'green' guidelines and/or policies are efficaciously followed.
- Awareness about Carbonex and Greenex should be enhanced. These can also be extended to more companies.
- Market mechanisms in India will need to be strengthened for instruments such as the Renewable Energy Certificates (RECs) and Energy Saving Certificates (ESCerts). Trading of instruments under the Power Exchange India Limited can be further explored.
- In terms of international carbon market-related instruments, there is a need for institutional support to CDM project developers across various states in India. There is also a need to relook at the current institutional processes which are bureaucratic and complex in design.

- While international climate finance has sought to leverage and attract private finance, according to Climate Funds Update, as of the beginning of 2012, globally, for every USD 1 spent between 2010 and 2012, only USD 0.25 of private finance had been drawn. Green Climate Fund should be able to boost this gap.
- For improving the enabling environment for PPPs, there is a need for better transparency in the entire PPP project cycle, including bidding processes and standardization of procurement procedures. There is need to build capacity for evaluation and oversight. There is a need for clear policy and regulatory guidelines specifically targeted at addressing issues in low carbon development projects as these are perceived to have higher risks.
- According to the World Giving Index Report of 2014, India ranked 52nd in terms of donating money to charity; overall, India ranks 69th. Moreover, the money going for environmental activities is seen to be less. Apart from stepping up philanthropic resources, there is a need to pay greater emphasis in the environment sector.

CHAPTER 3

INFORMING SUB-NATIONAL ACTIONS: INDICATORS AND STATE CLIMATE POLICY

In June 2008, India launched its National Action Plan on Climate Change (NAPCC) that encompasses a multi-pronged, long-term, and integrated framework for addressing climate change as a core development issue. In its eight missions,[15] the NAPCC proposes an extensive range of measures, focusing on renewable energy, energy efficiency, clean technologies, public transport, resource efficiency, afforestation/reforestation, tax incentives and research, and generation of strategic knowledge. The Ministry of Environment, Forest and Climate Change (MOEFCC) coordinates the implementation of the NAPCC through its various missions which are nodalized by the respective administrative ministries.

It has been recognized that sub-national institutions could have a critical and far-reaching role in the process of transition to a low carbon economy. According to UNDP (2010), around 50–80 per cent of the investments for GHG mitigation (and up to 100 per cent for climate change adaptation) happen at the sub-national and local levels. Regional and local governments lead[16] the implementation of policies, programmes, and fiscal instruments 'in the areas of generation, supply and distribution of electricity, the regulation of the built environment, waste management, transport, and land-use planning'. Engaging sub-national and local actors in climate action could promote cross-sector policy interventions and create 'role models' which could be replicated/upscaled at the domestic and global levels. In the context of the international climate policy and discourse, the Cancun Agreement (COP 16) for the first time formally recognized[17] the indispensable role of local and sub-national governments as 'government stakeholders' in global climate action.

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15 Accessible from pmindia.gov.in/climate_change_english.pdf; last accessed February 15, 2015.

16 The Climate Group (2009).

17 Cancun Agreement, Decision 1/COP16 on "Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention (AWG-LCA)".

India is a federal country with 29 states and seven union territories. According to the federal system of the country, the responsibilities and areas of jurisdiction of the centre and the state governments are delineated through the Union List and the State List, respectively, elaborated in the Seventh Schedule of the Constitution of India.[18] This demarcation of responsibilities plays an important role in the context of environment federalism and climate policy in the country. The Union List consists of 97 subjects over which the national legislator has exclusive powers, some of which are relevant in the context of climate change. These include trade representation, United Nations organizations, agreements and conventions with foreign countries, atomic power, mineral and oil resources, and control of industries. Moreover, given the international context of the problem, and the constitutional proficiency of the union government for international agreements and treaties, the primary responsibility for climate change agreements lies with the union government (Jörgensen 2011).

On the other hand, the State List contains 66 subjects, including public health and sanitation, agriculture, water, fisheries, mines, and land use—areas which have a direct bearing on natural resources and climate change. These subjects are under the state government's exclusive jurisdiction. In addition, sectors such as selected industries and transport, which are critical in the context of climate policy making by virtue of being energy- and emission-intensive in nature, are also the constituents of the State List. Energy appears in the Concurrent List involving both levels of government (Jörgensen 2011). Thus, this clear definition of domains for operation of the central and state legislators and moreover, the nature of subjects covered under the State List clearly highlights the potential role and impact state actors have in designing and executing climate policy for the region (Mishra *et al*. 2011). Additionally, the states are responsible for implementing the policies and programmes framed by the central government. However, the degree and urgency of the climate change challenge necessitates enhanced roles for state actors to move beyond mere 'executers' to 'initiators and innovators'.[19] Taking a bottom-up approach and allowing active participation of states in the process of climate policy making could transform states into 'laboratories of invention' for technological and regulatory innovation (Kaswan 2007).

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[18] Seventh Schedule (Article 246) of the Indian Constitution, http://lawmin.nic.in/olwing/coi/coi-english/Const.Pock%202Pg.Rom8Fsss(35).pdf.

[19] Ibid.

Further, in light of the wide socio-economic and climate-geographic variations across different regions, the relevance of active involvement of states in policy formulation increases manifold. Besides, the states also differ in terms of mitigation potential (available opportunities to abate/avoid GHGs) and capacity (financial, technological, know-how, and awareness). Thus, it is imperative that a more decentralized, bottom-up climate policy making, resulting in actions customized to local contexts and needs, drives the country's response to climate change (Kaswan 2007; Burtraw & Shobe 2009).

3.1 State Action Plan on Climate Change: Process, Actors, and Status

As a corollary to NAPCC, in August 2009, the Prime Minister of India directed all the states to formulate their respective State Action Plan on Climate Change (SAPCC), guided by, and consistent with the structure and strategies of the NAPCC.[20] The individual SAPCCs should lay out sector-specific as well as cross-sector time-bound priority actions in light of state-specific risks, impacts, and opportunities, besides prioritizing areas for research and policy action in response to current and future vulnerabilities and projected impacts. The SAPCCs should also list indicative budgetary requirements, supplemented with details of the necessary institutional and policy infrastructure to support the operationalization of actions.

As the first step, MOEFCC, the coordinating agency for implementation of the NAPCC, developed a common framework with inputs from various multilateral and bilateral agencies like GIZ, UNDP, World Bank, ADB, and DFID, with an objective to decentralize the NAPCC objectives into local context (MoEF 2010). Besides harmonizing national and state level policies and actions with regional and site-specific variations, the common framework was also expected to enable proper coordination of the process of preparation of SAPCCs and its subsequent implementation under varied regional and local contexts.

Almost all the states (at various stages of development of SAPCCs) have adopted a participatory approach, although there is considerable variation among states in terms of the form and extent of stakeholders' participation undertaken/proposed. As in the case of any policy

3.3

[20] PM's address at the National Conference of the Ministers of Environment and Forests, August 18, 2009, PIB: Government of India, Online. Available at http://pib.nic.in/newsite/erelease.aspx?relid=51926

instrument, implementation of SAPCCs also requires suitable institutional arrangements. In line with this requirement, various states have come up with different institutional arrangements ranging from Climate Change Cells in a nodal department to a full-fledged Department of Climate Change as in the case of the state of Gujarat.

At the state level, the State Steering Committee, State Advisory Group, and Core Agency are the three pillars for developing the SAPCC. Their responsibilities and roles are outlined in Figure 3.1. After the SAPCC is prepared, the final endorsement and approval of the SAPCC is to be undertaken by the National Steering Committee (NSC) in the MoEFCC.

At the central level, the MoEFCC follows a two-stage process for granting final endorsement to the SAPCCs. The Ministry has constituted an Expert Committee (EC) with a mandate to review the draft document in line with the common framework and objectives of the NAPCC. In the first stage, the draft report received from the state agencies is reviewed by the EC. At the second stage, on receipt of the revised SAPCC incorporating suggestions/recommendations made

National Steering Committee on Climate Change (NSCCC)

The NSCCC has been set up under the chairmanship of Secretary, MOEF with Secretaries of various National Ministries as members to consider and endorse the SAPCC.

Expert Committee (EC)

EC reviews the draft documents and provides suggestions/recommendations to the States for incorporation in their final SAPCC reports.

State Steering Committee

SSC would be constituted under the chairmanship of Chief Secretary of the State and would also comprise representatives of relevant State government departments, academicians and NGOs. SSC would provide overall guidance, supervision and coordination for the preparation of SAPCC.

State Advisory Group (SAG)

SAG would be responsible for reviewing the technical quality of data and robustness of analysis apart from the feasibility of recommendations of the SAPCC.

Core Agency

Core Agency/Agencies would be designated by the State government for actual preparation of SAPCC.

Figure 3.1 Process of Preparation of SAPCCs by the EC, the National Steering Committee (NSC) on Climate Change considers and endorses the SAPCC.

The challenge of climate change is multi-dimensional and cannot be addressed in isolation by one department; it requires active inter-departmental cooperation. Generally, the preparation of SAPCCs in India has witnessed line departments providing primary inputs to the nodal department, which in consultation with technical experts has sought to develop a coherent policy document. Cross-department integration of strategies has been attempted in varying ways: while in some states, presentation of the SAPCC before a high-level Committee of Secretaries has enabled quick iteration and consensus-building, in others, the process[21] has been tedious and often superficial.

By the end of the year 2014, all Indian states had prepared at least a draft of the action plan. As of June 2015, the NSCC at the MoEFCC has endorsed 19 state action plans, including Andaman and Nicobar Islands, Andhra Pradesh, Arunachal Pradesh, Chhattisgarh, Himachal Pradesh, Jammu and Kashmir, Lakshadweep, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Puducherry, Punjab, Rajasthan, Sikkim, Tripura, and West Bengal. Three SAPCCs (Haryana, Jharkhand, and Karnataka) have been considered by the EC. As the next step, the SAPCCs endorsed by the NSCC will be considered for integration in the respective state annual development plans and will seek financial support through various sources such as the Niti Ayog, MoEFCC, and other national ministries and agencies.

The various SAPCCs propose a host of strategies that would help the states achieve their adaptation and mitigation objectives. The common rules followed by the various states in formulating SAPCCs include 'principles of territorial approach to climate change, sub-national planning, building capacities for vulnerability assessment, and identifying investment opportunities based on state priorities'. Appendix A presents a review of the key sectoral priorities in the SAPCCs of eight states.

3.2 Socio-economic Considerations and Equity

Notions around equity have been anchored on the principles of 'equal rights', 'polluter pays', and 'equal per capita emissions' (Ghosh 1993; Baer *et al*. 2000; Ghosh 2013). In his discussion on equity, Ghosh (2013) leaves three issues open for debate:

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[21] Based on TERI's experience in the SAPCC preparation process; TERI was engaged in the SAPCC preparation of states like Rajasthan, Assam, Karnataka and Gujarat

- Articulation of capability
- Boundaries for considering greenhouse gas emissions
- Timing for considering historical responsibility

Ambitious targets for human development in the post-2015 development agenda need to embed a strong focus on moral concepts such as equity (Melamed & Samman 2013). According to Sen (1987: 36), capabilities refer to notions of freedom and opportunities in life. In line with this, the metrics developed for socio-economic capability include elements around opportunities that result from performances linked to public infrastructure, income, education, and empowerment of local institutions.

In this section, we will first see the key indicators relevant to emissions and low carbon development for the world, OECD, India, and China. We, then, attempt to articulate 'capability' in the context of socio-economic and low carbon development performance for the states in India.

Table 3.1 depicts population and key emissions indicators for the world, China, India, and OECD for the year 2010. It can be seen from the table that according to the latest available data of the International Energy Agency (IEA), the world average for per capita CO_2 emissions is 4.44 tonnes with China's per capita average exceeding the world average while India's per capita emissions lower than the global average. Both countries however had lower per capita emissions compared to the OECD. It has also been analysed that net emission transfers via international trade is a significant factor in explaining the rise in emissions in countries including China (Peters & Hertwich 2008; Peters *et al*. 2011).

Table 3.1: Emissions Indicators: World, China, and India (2010)

Region/country	Population (million)	CO_2 emissions (Mt)	Per capita CO_2 emissions (tonnes)
World	6,825	30,326	4.44
China	1,338.30	7,269.85	5.43
India	1,170.94	1,625.79	1.39
OECD	1,232	12,440	10.10

Source: IEA (2012)

It is intended that we start the debate on capability at the sub-national level in India by developing a metrics that include indices for socio-economic performance, low carbon development performance, and carbon footprint. Table 3.2 summarizes the indicators used in arriving at socio-economic performance, low carbon development performance, and carbon footprint indices for the 27 states in India. Socio-economic performance index is based on poverty, literacy, public infrastructure (electrification and health), and capacity of local institutions to implement social programmes. For low carbon development (LCD) performance index, we take performance in interventions related to grid and off-grid clean energy and also the change in forest cover at the state level. For carbon footprint index at the sub-national level, per capita emissions is not used as states with lower population may also be the states that are not faring well in terms of socioeconomic indicators.

Table 3.2: Indicators and data sources used for developing indices

Index category	Indicators	Basic data source
Adaptive capacity index	Health	Average population served per government bed; Central Bureau of Health Intelligence; National Health Profile of India (2011)
	Institutional capacity	Total availability of funds and expenditure at Panchayat level for execution of MG-NREGS; nrega.nic.in
	Non-BPL population	Ministry of Rural Development; available at http://pib.nic.in/newsite/erelease.aspx?relid=49731
	Female literacy rates	Census 2011
	Electrification	Ministry of Power; available at http://rggvy.gov.in/rggvy/rggvyportal/electrification_status.jsp
Low carbon development capacity (LCD) index	Grid: Solar RPO performance	Solar RPO requirement and compliance for 2012–13; available at http://www.mnre.gov.in/information/solar-rpo/
	Off-grid: Biogas	National biogas programme; basic data from http://www.mnre.gov.in/related-links/decentralized-systems/schems-2
	Forest cover	Forest Survey of India (2011)
Carbon footprint index	Difference between CO_2 emissions and storage in Gg	Ramachandra & Shwetmala (2012)

Further to identifying and collecting basic data, computation and standardization of indicator values is done so that it falls in the range of 0–1. This procedure makes the respective values of the chosen indicators (as mentioned in Table 3.2) unit less, so that indicators are comparable for construction of an index. In the index, the best performer hence gets a value of 1, while the worst performer gets a value of 0. Moreover, all values become uni-directional.

3.3

The standardization procedure using x as a variable is as follows:

$$x - index = [x - \min(x)]/[\max(x) - \min(x)]$$

Here min(x) and max(x) were the lowest and highest values for the variable x. The scores received by each state with respect to each indicator are then averaged. These are then depicted graphically in the following sections.

Figure 3.2 depicts the socio-economic performance indices for 27 states in India. Among the 14 major states—Kerala, Gujarat, Tamil Nadu, Maharashtra, and Karnataka fare well in terms of socioeconomic indicators.

Figure 3.3 depicts the low carbon development (LCD) performance indices for 27 states in India. Among the 14 major states – Rajasthan, Punjab, Gujarat, Tamil Nadu, and Odisha fare well in terms of LCD capacity indicators.

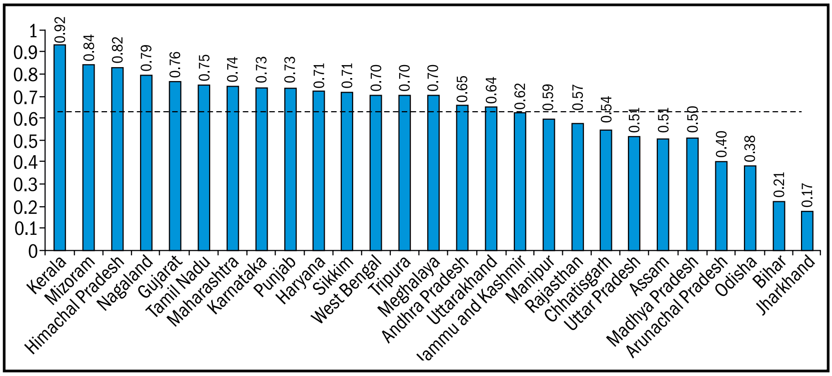

Figure 3.2 Adaptive Capacity Indices for 27 States of India

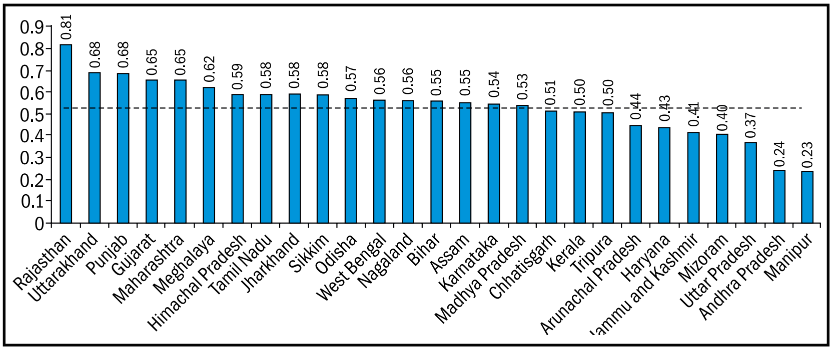

Figure 3.3 LCD Capacity Indices for 27 States of India

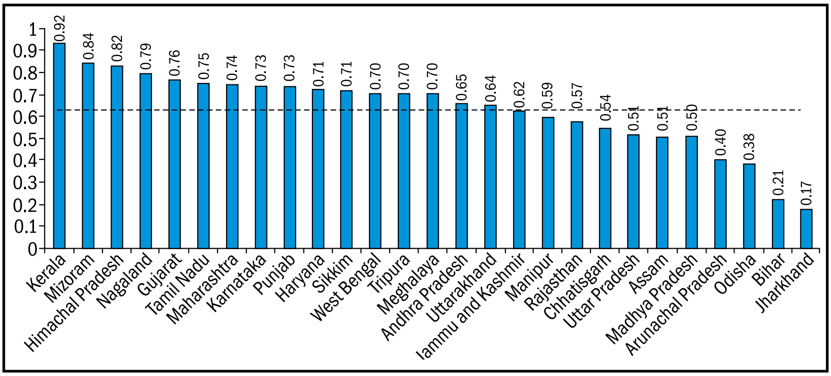

Figure 3.4 Carbon Footprint Indices for 27 States of India

Figure 3.4 depicts the carbon footprint indices for 27 states in India. Among the 14 major states—Maharashtra, Uttar Pradesh, Gujarat, Andhra Pradesh, and Tamil Nadu have higher carbon footprints; this is also owing to factors such as higher industrialization and demographics.

Table 3.3 depicts the composite index score values for the 14 major states[22] with their respective ranks. It is interesting to observe that although Rajasthan ranks first in terms of LCD performance, it ranks in the bottom five in terms of socioeconomic performance. This implies that adaptive capacity could be weaker for the state. Similarly, while Kerala ranks first in terms of socio-economic performance, it ranks lower in terms of LCD performance. LCD performance of a state also depends on policy approaches by the state government and existing, potential resource endowments of respective states. It is seen that the states of Bihar and Odisha which rank low in terms of socioeconomic performance and also have low carbon footprints, still rank higher up in terms of LCD performance and there can be optimism in terms of states choosing alternate development paths.

With regard to its implications for policy incubation in low carbon development and equity space, it must be emphasized that the LCD strategies considering the sub-national context of India must consider not only mitigation of carbon emissions; it must also factor in socio-economic capability and adaptive capacity. A policy framework for low carbon development strategies rooted in the 'co-benefits approach'

[22] The 14 major states are based on the achieved growth of the states of India in terms of their gross state domestic product during the pre (1980–81 to 1990–91) and post-reform period (1991–92 to 1998–99) in India (see Ahluwalia 2000).

Table 3.3: Indices for LCD Performance, Carbon Footprint and Socioeconomic Performance for 14 Major States in India

State	LCD capacity index		Carbon footprint index		Adaptive capacity index	
	Standardized scores	Rank	Standardized scores	Rank	Standardized scores	Rank
Rajasthan	0.8086	1	0.5730	7	0.5690	10
Punjab	0.6791	2	0.4974	9	0.7286	6
Gujarat	0.6523	3	0.8033	3	0.7632	2
Maharashtra	0.6521	4	1.0000	1	0.7375	4
Tamil Nadu	0.5832	5	0.7199	5	0.7470	3
Odisha	0.5682	6	0.2962	13	0.3770	13
West Bengal	0.5578	7	0.7151	6	0.7025	8
Bihar	0.5526	8	0.2512	14	0.2121	14
Karnataka	0.5360	9	0.5322	8	0.7334	5
Madhya Pradesh	0.5344	10	0.4365	10	0.5045	12
Kerala	0.5044	11	0.3009	12	0.9244	1
Haryana	0.4333	12	0.4078	11	0.7143	7
Uttar Pradesh	0.3672	13	0.8039	2	0.5068	11
Andhra Pradesh	0.2382	14	0.7951	4	0.6538	9

framework that considers human development and socio-economic capability will be equitable. Proactive sub-national players must be rewarded and there should exist a knowledge-based process that facilities sharing of good practices to enable adaptation and incubation of relevant policies.

3.3 About China's Low Carbon Pilots

In July 2010, the National Development and Reforms Council initiated a low carbon pilot province and city programme, including five provinces (Yunnan, Guangdong, Hubei, Shaanxi, and Liaoning) and eight cities (Tianjin, Baoding, Hangzhou, Chongqing, Nanchang, Guiyang, Xiamen, and Shenzhen) across the country. In November 2012, another 29 provinces and cities have been selected as the second batch of low carbon pilots. Details of the two batches of low carbon pilots are shown in the Table 3.4.All these pilot cities and provinces occupy 57 per cent of China's GDP, 42 per cent of China's population, and 56 per cent of energy related CO_2 emissions.

Table 3.4: Provinces and Cities Selected Under the Low Carbon Pilot Province and City Programme of China

Low carbon pilot batch	Year	Provinces	Cities
Batch 1	2010	Guangdong, Liaoning, Hubei, Shaanxi, Yunnan	Tianjin, Chongqing, Shenzhen, Xiamen, Hangzhou, Nanchang, Guiyang, Baoding
Batch 2	2012	Hainan	Beijing, Shanghai, Shijiazhuang, Qinhuangdao, Jincheng, Hulunbuir, Jilin, Daxing'anling, Suzhou, Huai'an, Zhenjiang, Ningbo, Wenzhou, Chizhou, Nanping, Jingdezhen, Ganzhou, Qingdao, Jiyuan, Wuhan, Guangzhou, Guilin, Guangyuan, Zunyi, Kunming, Yan'an, Jinchang, Urumqi

Source: National Center for Climate Change Strategy and International Cooperation

The nominated pilot cities and provinces were expected to undertake the following tasks:

- Develop and propose a low carbon development plan
- Formulate supportive policies for low carbon green growth
- Establishing a low carbon industrial system
- Establishing a greenhouse gas emission statistics and data management system
- Encouraging low carbon lifestyle and consumption patterns
- Capacity development in the cities on data of GHG emissions

Of the first five pilot provinces and eight pilot cities, the key targets are carbon intensity and energy intensity. Shenzhen city is the first to propose to arrive at an emissions peak between 2017 and 2020. The second batch of 29 low carbon pilot provinces and cities has announced to curb the total amount of carbon emissions or the peak year for carbon emissions. Cities were given flexibility to determine their targets, for e.g., Xiamen has chosen a carbon emission target. See Figure 3.5 for targets of pilot cities.

Yunnan Province established an annual provincial special fund of RMB 30 million, running from 2011 to 2015, to drive low emissions intensity infrastructure industry. Guangdong Province also set up a special fund of RMB 30 million towards institutional mechanisms for low carbon development management systems and demonstration projects.

Hangzhou is one of the first cities in China to place the natural environment at the centre of its development agenda. It has focussed its efforts toward retrofitting existing buildings rather than the common approach of seeking energy savings in new construction. The Hangzhou

Municipal Government has been actively pursuing retrofitting, along with rooftop gardens and renewable energy, and views this as a way to stimulate large-scale building efficiency programmes. Hangzhou's green transportation programmes are also among the most advanced in China. In 2008, the city introduced a public bicycle programme covering most urban areas in its jurisdiction. The government supplies some 50,000 bicycles, which are available for use at little or no cost, depending on usage. The bike programme in Hangzhou city is very effective and has become a model for other cities to follow. Another area Hangzhou is focusing its efforts on is eco-tourism. Hangzhou typically has a lot of tourists visiting the West Lake in the centre of the city. In an attempt to tackle the lake's pollution problem, Hangzhou has passed a series of legislative measures by regulating the tourism market. The government has developed and renovated a number of other tourist attractions in the city in order to address the tourism demand.

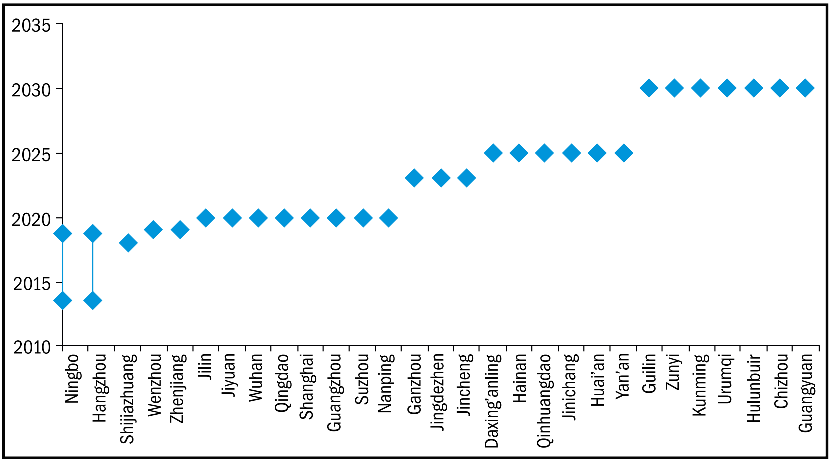

Figure 3.5 Targets of Pilot Cities and Provinces for Emissions Peak
Source: National Center for Climate Change Strategy and International Cooperation

3.4 The Way Forward

The State Action Plan on Climate Change (SAPCC), which is aligned around the National Action Plan on Climate Change (NAPCC), is well placed to serve as a development tool. Analytics which form the basis of SAPCC recommendations include current and future development scenarios and likely impact of climate change; and identify vulnerable areas, sectors and communities, and their associated risks. In the state-specific SAPCCs, each state comes out with its own agenda of activities to address issues related to climate change in specific sectors in a manner that these activities also align with the eight missions listed under the National Action Plan on Climate Change (NAPCC). However, the implementation of the SAPCCs for the states has not yet taken place—it is perceived that the progress of states towards achieving the goals listed in SAPCCs is likely to falter due to lack of adequate financing available for specific targets.

Out of the eight national missions under the NAPCCs accruing to the National Mission for Sustainable Agriculture (NMSA), Green India Mission (GIM); and National Mission for Enhanced Energy Efficiency (NMEEE), there is better availability of funding to the state for sectors like agriculture, forestry, and energy. However, for other sectors including renewable energy and infrastructure (buildings) which are crucial for low carbon development at the state level, there is absence of adequate financing. To be better able to implement the SAPCCs, synergies between central expenditure and state finances and actions needs to be explored.

The lack of adequate financing for the well-written SAPCCs also highlights the need for appropriate institutional mechanisms which can support centre–state disbursements of public (domestic) funds. Especially for sectors like improving energy efficiency and promoting renewable energy, involvement of private sector funding needs to be encouraged.

This would also require states to prioritize their actions depending on the objectives, which may include economic gains, social equity, and reduction in GHG emissions. Prioritization and institutional mechanisms would help channelize better funds towards the specific objectives around the SAPCC process. Actors including the Planning Commission, Ministry of Environment, Forest & Climate Change, state governments, and the United Nations Development Programme, can be engaged with regard to creating local funds for state-specific low carbon development initiatives that can be implemented through the SAPCC.

With regard to policies for incubation, there are learning's from the experience of low carbon pilot initiatives in China. Low carbon development at the sub-national level—both at the state and city level—in India can benefit from the experience in China. In this regard, inspirations from other sub-national models around the world become relevant. The previous section discussed the low carbon pilots of China. A crucial question is how can initiatives modelled around China's low carbon pilots be integrated in existing SAPCC processes? In terms of analytics, the metrics discussed could be strengthened to help in tracking and informing equitable low carbon development strategies. To strengthen actions at the sub-national level, a deeper engagement with stakeholders in required for understanding how sub-national initiatives can be further strengthened on the basis of other models around the world and through knowledge-based processes.

Appendix A: State-wise Sectoral Priorities in Key SAPCCs[23,24]

Sector → / State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
Andhra Pradesh	• Promotion of renewable energy like solar, biomass, hydro and wind • Generation of power using waste • Subsidy on solar power systems and LED lighting systems • Development of non-conventional sources like geothermal and tidal energy	• Underground coal gasification and carbon capture and sequestration implementation in coal mines • Establishment of industry wise energy usage benchmarks and making energy audits compulsory	• Integrated spatial planning and logistics for mixed land use, to provide all kinds of services locally for inhabitants • Bus rapid transit (BRT) • Promotion of non-motorized transport (NMT) mode like walking and cycling • Rail-based mass transit systems	• Development of energy efficient housing • Spatial planning of cities to reduce movement and energy use • Utilization of the solar energy in housing	• Composting of organic wastes for enhancing soil quality and fertility • Establishment of specific centres for critical climate analysis and to study likely impacts of climate change on crops • Researches on breeding of heat and photo insensitive crop varieties, erection of polyhouses, alternative cropping patterns capable of withstanding extremities in weather	• Restoration of old breached tanks, contour trenching, construction of permanent rock fill dams across streams in forests, digging of kuntas, desilting saucer pits to arrest reoperation of water, etc. • Integrated Afforestation and Eco-development Project (IAEP) set up for checking forest degradation, loss of biodiversity	• Integrated waste management system • Use of waste for power generation • Toilet facilities in urban slums • Proper city drainage system to accommodate sudden surge of water due to excess rainfall, etc. • Improved sanitation facilities in urban slum areas and in rural areas	• Increased number of cyclone shelters with all-weather connectivity • Beach nourishment/ recharging to nullify losses due to erosion • Dikes/surge barriers /sea walls at exposed frontages • Port upgrade (raising elevation) in line with rising sea level • Building codes/ flood wise buildings

23 A review of eight SAPCCs namely, Andhra Pradesh, Arunachal Pradesh, Madhya Pradesh, Manipur, Mizoram, Rajasthan, Sikkim, and West Bengal.

24 The review only includes primary sectors in the context of climate change mitigation. Therefore, sectors such as health, livelihood, knowledge creation/management have been excluded.

Sector → / State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
	• Promotion to nuclear energy for larger plants instead of coal-based technologies • Promoting biomass-based energy generation in villages • R &D for new cleaner coal technologies		• Incentive programmes for cleaner fuel usage (like CNG, LPG, electric vehicles) • Strategic tie up with manufacturing companies to supply CNG / LPG fuelled vehicles at cheaper rate • Conversion of public vehicles into CNG fuelled vehicles		• Establishment of biotechnology R&D centres • Promotion of bio-fertilizers • Credit provision for farmers so as to provide small and short loans and other benefits to them • Enhanced crop insurance • Creation of climate data bank by agriculture universities to • Water harvesting check dams, dug out farm ponds and soil and water conservation measures • Interlinking of rivers/canals	• Revitalization of community based initiatives like joint forest management • Forest fire management • Creation of biodiversity registers		• Restoration and plantation of new mangrove belts across the coast • Judicious use and control abstraction by industrial units and aquaculture units • Recharging wells to recharge depleting aquifers with fresh water • Better and more efficient drainage system both for rainwater and agricultural runoff • Stricter norms and monitoring programme for disposal of untreated industrial and municipal waste into the oceans

State ↓ / Sector →	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
Arunachal Pradesh	• Installation of amorphous core transformers or energy efficient transformers which use high grade • Upgraded conductors to withstand over-loading on the line, thus reducing losses; and replacement of time barred conductors • Distribution system to be converted to high voltage distribution system (HVDS) to reduce losses • Defective meters to be replaced; providing meters to un-metered consumers • Providing low-cost light emitting diode base lamps for space lighting		• Metro Cable System to reduce traffic congestion, noise pollution, etc. • New buses under JNNURM, CNG buses • Urban roads improvements by widening, re-carpeting, blacktopping and construction of drains, storm water drains and pedestrian paths, etc. • Avenue plantations is proposed on both sides of all urban roads	• Green City concept, Land Use Assignment Zoning Plan • Creation of Master Plan Preparation Cell under the Department of Town Planning for preparation of master/ zonal plans • Use of modern data sources such as satellite data, total station, GIS software to generate a comprehensive 3-tier GIS database • Micro-zonation and risk assessment of landslide affected areas • Sustainability schemes to augment and share water resources	• Rehabilitation of shifting cultivation areas through terraced rice cultivation, etc. • Improvement in current practices like use of high temperature tolerant varieties, rain water harvesting, crop diversification, etc. • Water conservation structures, rainwater harvesting • Introduction of fodder preservation techniques • Installation of feed block machine • Disease surveillance and monitoring cell and continuous research on emergence of newer pathogens	• Conducting preliminary studies to identify locations for implementing vulnerability reduction measures • Anticipatory planting of species across latitudinal and longitudinal gradient • Promotion of natural regeneration and mixed species planting • Sustainable harvesting of timber and non-timber products • Protected Areas (PAs) management (securing corridors for species migration) • Reduced forest fragmentation by conserving contiguous forest patches (use of landscape/ sub-landscape approach	• Solid waste management • Sewerage lines urban settlements • Storm water draining in urban settlements • Plastic free zone in settlements	

3.3

Sector → / State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
	• Replacement of old reflectors in existing street lights • Providing low-cost CFL to BPL under Bajat Lamp Yojana • Establishment of State Electricity Regulatory Commission (SERC) to promote use of renewables • 0.25% Renewable Purchase Obligation (RPO) from renewables • Mandatory use of solar water heaters initially in government buildings • The State Renewable Energy Agency needs to be upgraded to a fully-fledged Renewable Energy Department • Framing of State Solar Policy			• Source protection, gully plugging, check dam, catchment area protection, contour trenching, impounding reservoirs and artificial recharge • Introduction of reasonable pricing of water and Swajaldhara/NRDWP • Rationing could be introduced in rural areas to avoid over-extraction of the water source • The 'Water, Use it wisely' campaign	• Research for development of low-cost, eco-friendly housing design to mitigate heat stress • Changes in nutritional regime to reduce enteric fermentation • Development of horticulture specific forecasting tools	• Promoting preparation of Peoples Biodiversity Registers (PBRs) • Developing micro-enterprises and promoting alternate livelihood measures for forest-dependent communities through eco-tourism • Promoting agro-forestry with multiple native species • Watershed protection by afforestation		

State ↓ / Sector →	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
	• Earmarking a marginal amount from the cess/ surcharge of revenue collected from the electricity consumers for promotion of renewable sources and energy conservation							
Madhya Pradesh	• Enhancing efficiency in power generation through promotion of green technologies, renovation and maintenance of existing power plants • Reduction of transmission and distribution losses, feeder separation, energy-efficient service delivery systems, etc. • Market capitilazation for energy efficiency projects	• Climate change aspects to be integrated in the industrial policy to promote low carbon technologies • An integrated water management plan for industrial clusters • Industrial waste management to be strengthened through enhanced networking between different organizations, using more efficient technologies, strict implementation of norms	• Improving road networks—both quality and connectivity • Efficient and quality mass transportation systems with stress on route optimization	• Municipal demand side management, promotion of green, effective implementation of building by-laws, ECBC, National Building Code of India and promotion of energy-efficient household appliances • Strict regulations and their implementation to bring down energy usage, energy audit of commercial and government buildings to be	• Development of watersheds and small catchments that would increase biomass production and increase the fertility of the soil • Measures like SRI for rice, raised bed cultivation, plastic mulching, use of cultivars using lower water, etc. • Use of micro/ drip irrigation to be extended to crops like cotton, fruits, and vegetables	• Development of Sustainable Forest Management Plans • Enhancing the levels of forest conservation/ afforestation/ reforestation activities through proper demarcation of forest boundaries, connecting forest/ wildlife corridors, etc. • Developing centres of excellence' to undertake research on impacts of CC on forest ecosystem	• Awareness generation among people about best practices, waste segregation at sources, development of sites to explore waste-to-energy potential, more investment in research activities for developing different cost-effective models to convert waste to energy • Wastewater management through reduce, reuse, and recycle	• Development of a comprehensive water data base for better management of action plans, and assessment of water availability and demand by various sectors in the future • Command area development through completion and renovation of canal systems, field channels and land levelling, rejuvenation of lakes, village ponds, collection

3.3

Sector → State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
	• Enhanced investment in solar, wind and biomass energy to ensure achievement of Renewable Purchase Obligation (RPO) targets • Capacity building of different stakeholders on generation, handling, maintenance, operations of RE projects • R&D to develop cost-effective RE technologies, e.g., use of silicon rather than thin film technologies for solar energy • Institutionalizing biomass, biogas energy generation	• Capacity building of different industries focused on carbon and water footprints and devising audit systems in all organizations to monitor their usages per unit of production • Industries to pool the resources in research activities to develop state-specific eco-friendly technologies		made compulsory to bring down the consumption • Credit availability for rural infrastructure development and insurance against climate induced vulnerabilities • Regular monitoring and documentation of urban landscape (including change in land-use pattern), population growth, settlements (especially slums) to ensure sustainable habitat development	• Planning cropping systems suitable for each agro-climatic zone • Promotion of indigenous varieties of crops which are water stress/flood/ heat tolerant • Agriculture Information management: For maximizing productivity even in the context of challenges posed by climate change. Establishment of an integrated data centre whereby data related to all aspects of agriculture, such as weather and climate information, crop biodiversity, research, technology, markets, and policy for maximizing productivity are	• Capacity building of forest managers, officers and workers • Vulnerability mapping of the forest ecosystem and livelihood of forest dependents with reference to climate change with the help of indicators like forest cover map, wasteland atlas, vulnerability maps, watershed atlas, socioeconomic atlas, ethnicity, poverty index etc. • Promoting the use of alternate source of energy in forest villages • Protecting and enhancing sustainable forest based livelihoods through focus on NTFP, eco-tourism, silviculture, lac		of rainwater for domestic water use in rural areas, etc. • Recharge of ground water with special focus on over-exploited areas; promoting soil conservation to avoid soil runoff, soil degradation; enhancing water conservation • Establishing water authority to set up a pricing and regulatory mechanism for water management • Developing ideal PPP models for recycling waste water • Research on effective water purification technologies, mapping of areas likely to experience floods, etc.

Sector → State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
					available through a single window, with the back-end linked to various agencies that actually produce the data • Creation of rural business hubs for generating additional employment and diversification of livelihoods • Ensuring availability of adequate feed, fodder and water, nutrient solvency for livestock • Training and capacity building of rural communities for development of skills and for alternate income generation activities to reduce climate induced vulnerabilities	culture, honey collection, etc. • Enhancing green cover outside forests through social forestry, agro-forestry and under trees outside forests (TOFs) mainly along roads, canals, railways, etc.		

3.3

Sector → / State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
Manipur	• Encouraging rural households to adopt fuel wood efficiency devices like improved chulas, biogas, etc. • Encouraging grid interactive power generation option using renewables • Promoting off-grid intervention of solar energy technology • Promoting small and medium hydro power project • Drafting of State Energy Policy • Reduction of AT&C losses • Promoting demand side energy efficiency and management measures • Capacity building towards promotion of EC measures		• Promoting fuel conservation in transport sector • Improvement of rural–urban connectivity • Encouraging public transport system, non-motorized transport system and cycle tracks	• Reduction/ minimization of distribution loss of water supply and efficient demand side management including water budget auditing • Enhancement of water sources/ catchment/forests and improvement of river/ stream basin health on priority basis with peoples participation • Watershed management, water harvesting (including rainwater) at community level • Conservation of water resources (wetland, lakes, rivers, major water bodies) and encouragement of indigenous and community pond / lake through PPP model	• Integrated pest management, mixed farming • Conservation of native crop varieties with scientific approach • Paddy-cum-pisciculture at hill regions • Medicinal plants and farm production through community with qualification and scientific definition of the species • Promotion of indigenous traditional knowledge (ITK) with skill development • Rain-fed agriculture with climate and pest resistant crops • Organic farming • Macro management mode of agriculture with top-to-bottom approach, i.e., from agronomist to farmer level	• Inclusion of multipurpose tree species to provide timber, fuel wood and fixing nitrogen		

Sector → / State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
				• Waste to bio-energy like domestic waste to biogas, electricity, etc. • Climate sensitive architectural urban infrastructures (water distribution system, lighting at street, public places, offices, etc.) and public transport system including green and low carbon footprint pathways • Green buildings designs • Implementation of rain water harvesting as part of building bye-laws • Capacity building of ULBs on climate change strategies, CDPs (City Development Plan), existing master plans, etc. • Improvement of drainage system	• Encouragement of indigenous fish culture and climate resistant breed at fishermen level • Encouragement of indigenous and climate resistant livestock R&D, HRD, more information, new technology including monitoring on agriculture • Enhancing quality of forest covers and improving ecosystem service through GIM, NAP and CAMPA, JFMC, etc. • Rehabilitation of shifting cultivation through eco-restoration • Promotion of agro forestry, social forestry • Forest fire management			

3.3

Sector → / State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
				• Zoning of industrial sites (zoning atlas) and shifting of industrial units to the industrial sites/not in the city area • Development of green belts in the cities	• Strengthening of forest departments (infrastructure, capacity building, etc.).			
Mizoram	• Increase renewable energy generation share through promotion of micro hydro power, solar energy, etc. • Detailed reconnaissance study and hydrology data evaluation and approval of micro hydro projects • Survey and investigation to identify appropriate sites for solar energy generation • Installation of grid interactive solar PV applications		• Improved enforcement of vehicular pollution control mechanisms	• Awareness generation • Research and capacity building initiatives on urban management • Formulation of building guidelines with provision for promoting traditional houses in different agro-climatic zones, flood plains and in consideration of the seismic vulnerability of the state • Climate-responsible master plans for selected city/towns (CDP)	• Development of land (levelling, bundling, etc.) for wetland rice cultivation (WRC) on available lands • Developing database on genotypes of local crop varieties (mainly rice), identification of suitable varieties for different agro-climatic zones • Impact assessment of paddy cultivation • Promotion of rain water harvesting and construction of eco-friendly mini-check dams for irrigation	• Improvement of forest quality and density in degraded lands, abandoned jhum lands • Improvement of productivity of bamboo and promotion of local value addition through establishment of market linkages • Study of climate change impacts on NTFP productivity, investment promotion and indigenous harvesting practices	• Awareness generation • Research and capacity building initiatives on advance solid waste management, water management and efficient distribution of supply and delivery • Developing models of urban storm water flows and capacities of existing drainage system • Climate-friendly waste management systems and improvement of aesthetics through landfill	

Sector → / State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
	• Promoting off-grid renewable energy applications like solar water heating systems, etc. • Investment friendly policies to promote solar thermal applications • Penetration of energy efficient devices (lighting, etc.) in domestic sector facilitated by financial, supply chain and market incentives • Strengthening of technology supplier and manufacturer • Energy efficient public lighting facilitated by financing and supply chains • Identification and empanelment of technology partners in the state			• Reformulation of land tenure policy to enable sustainable urban development • Energy efficiency improvement and promotion of renewable energy usage in urban sector, e.g., solar water heating and lighting • Assessment and inventorization of climate change impact on urban sector • Research initiatives to identify change in pattern of diseases by region due to climate change/weather variation • Assessment of ground water availability in usage and conservation plan	• Assessment study and demonstration of systematic rice intensification (SRI) cultivation • Capacity building of farmers in latest rice cropping techniques • Optimization of jhum cultivation through conservation of arable land, water utilization management, parallel cultivation of alternative crops • Construction of hill slopes for conservation of moisture and cultivation of food grain, vegetable, pulses and oilseed crops • Increasing the area under perennial fruit, plantation crops and low value high	• Undertaking study on valuation of forest resources (non-traded) and climate change impacts on vulnerable ecosystems • Eco-tourism promotion for biodiversity protection and sustainable livelihood through pre-investment feasibility study, etc. • Capacity building of communities/ community forest management • New systems to support public awareness building (Envis Centres, etc.) • Prevention and control mechanism for forest invasive species and its utilization strategies	• Gas recovery from closure of landfills, reduction of vector borne diseases, from unmanaged dumping grounds, etc. • Study and documentation of diseases caused by water (water borne) and development of institutional mechanisms to reduce the incidence/ outbreaks of such diseases along with awareness generation	

3.3

Sector → / State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
	• Energy efficiency measures in government buildings • Awareness building of State Energy Departments, officials, etc. • Awareness building of common people on energy efficiency measures, use of star rated devices and use of renewable energy applications • Curriculum development on energy efficiency and renewable energy applications in schools • Empanelment of ESCOs in the state • Multi-purpose hydro projects and integration of drainage with irrigation infrastructure			• Mandating water harvesting and artificial recharge in water stressed areas • Enhancement of recharge of the source and recharge zone of deeper ground water aquifers • Institutional development of ground water board • Community tank management for combating water-borne diseases • Promoting zero energy water purification for domestic water supply • Capacity building of Water Resources Departments/officials • Expansion of hydrometric network and establishment of micro weather station for regular	volume crops to help cope with uncertain weather patterns • Improving post-harvest management such as cold chain for perishable crops • Promotion of organic farming • Integrated pest management for improved crop yield • Research study on livestock disease and establishment of early warning system • Study of impact on the indigenous fauna of the aquatic ecosystem and open waters • Water storage and provision of proper diversion channels to the existing ponds for drainage • Establishment of fishery units in reservoirs and	• Promotion of forest-based industries • Formulation of conservation strategies for orchids and establishment of market linkages • Restructuring land use policy for jhum cultivation and habitation on notified forest lands • Policy formulation on transportation subsidy or development of low-cost transportation for primary forest products • Catchment and command area treatment through riverine afforestation		

Sector → / State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
				monitoring • Renovation and development of traditional water harvesting systems • Formulation of State Water Policy	riverine area • Assessment of climate change impacts on food security due to water stress			
Rajasthan	• GHG inventorization and GHG management plan to assess key areas where the intervention is required, potential policies, spatial and sectoral analysis to identify hotspot areas for effective decision making • Development of future emissions scenarios for identifying technological and policy choices and avoiding the issue of stranded assets			• Urban storm water drainage infrastructure improvement through development of a comprehensive drainage master plan (including background studies, phasing of projects, operation and maintenance arrangement, funding, etc.), construction of roadside and outfall drains in order to carry the storm water, etc.	• Enhancing productivity of crops and livestock through development of climate-hardy cultivars which are tolerant to droughts, thermal extremes, alkalinity and pests, and cultivars that are less water consumptive • Breeding of climate-hardy livestock and development of nutritional strategies to prevent heat stress and productivity loss	• Planting of trees on the banks of rivers/ canals etc., roadside tree plantations • Promotion of farm forestry through distribution of seedlings to farmers, schools, panchayats, urban areas and government institutions for planting • Promotion of sustainable eco-tourism and greater involvement of local people and panchayats in the protection of wildlife		• Groundwater management with focused attention on over-exploited areas after comprehensive assessment of ground water resources and evaluation of ground water recharge potential. • Mass awareness programme by publication and distribution of booklets/pamphlets on ground water situation

3.3

Sector → / State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
	• Integration of GHG management plan with existing plans and policies targeting relevant sectors • Harnessing full renewable energy potential of the state • Detailed biomass assessment study and forecasting for preparing an integrated plan for biomass dealing with production, transportation, distribution, regulation, and monitoring, etc.; demonstration of well-designed prototypes of renewable energy technology systems for various applications, such as SPV domestic lighting system, street lighting system, solar pump sets, solar stills,			• Restricted/ controlled land use in areas prone to flash floods • Development of a preparedness and mitigation plan, hazard risk mapping for areas prone to extreme rainfall and climate modeling analysis, and efforts to incorporate communities residing in the flood prone areas in the disaster preparedness and mitigation plan • Information education communication (IEC) campaign to educate communities about the risks of climate extremes • Development of an inter-departmental coordination strategy for effective implementation of disaster management plan	• Restoration and development of wastelands using crops like khejari which helps stabilize the sandy desert soil and shifting sand dunes and serve as a windbreak; its wood is excellent for firewood and charcoal and is highly suitable as dry fodder. • Research and assessment of specific climatic risks to agriculture by setting up more automated weather stations, collaborating with research institutes, etc. • Promotion and management of multifunctional agroforestry systems which provide fodder, fuel, timber, fruits, seeds, pods, as well as non-timber forest produce such as	• Eco-restoration of degraded forests through closures, tending and silvicultural operation, in situ soil and moisture conservation measures, adopting low cost regeneration options such as direct seeding and cutback operation with supplementary multi-tier plantations of indigenous and site specific species • Providing incentives to informers leading to detection of forest offences • Modernization and outsourcing of survey work, preparation of maps of forest areas including superimposition of revenue maps on forest maps, strengthening of land record keeping system at division		• Setting up research facilities for ground water assessment and flow modelling with respect to changes in the climatic variables • Enhancing preparedness for drought monitoring, drought mitigation and development of early warning system mainstreaming traditional water storage structures/ practices, conducting feasibility studies for in-situ water and soil moisture conservation practices like contour furrowing, contour bunding, vegetative barriers, and percolation ponds/ trenches; developing integrated drought monitoring systems, etc. • Developing a drought management and mitigation policy for the state

Sector → / State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
	biomass gasifiers; detailed technical assessment of potential sites for large-scale wind and solar farms and synergising it with the available land resources, existence of investors, etc. • Creation of solar centre of excellence which would enable applied research and commercialization of nascent technologies in case of solar energy • Creation of Rajasthan Renewable Energy Infrastructure Development Fund for accelerated development of solar and other renewable energy systems • Development of indigenous and cost-effective solar technology in the			• State directive (to urban local bodies) to incorporate water harvesting and waste water treatment and dual water supply for other uses than drinking, in building bylaws • Amendments to existing urban policies in order to incorporate water conservation and harvesting principles • Calculation of water footprint, linking with tax rebates for business owners and individuals • Encouraging large business owners/corporate and individuals to calculate their water footprint • Promoting green buildings using indigenous planning	gum, apart from soil quality enhancement, livelihood support and mitigation co-benefits • Promotion of horticulture through production and export of seed spices, training and demonstrations on the growing of suitable horticultural crops, etc.	level and at range level • Community involvement in afforestation activities • Afforestation of private land holdings • Assessment of shifts in forest types		• Educating famers about matching land-use systems with water availability by adopting water efficient practices, low water requiring crops, etc. • Mass construction of roof top rainwater harvesting structures in urban areas • Conducting pilot studies to explore augmentation of water resources by transferring the surplus flood water into utilizable water from flood prone districts • Promoting waste water recycling and reuse in all sectors and creating a knowledge bank linking level of treatment and waterquality for each reuse category like

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Sector → / State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
	state to enable harnessing full potential and also reach grid parity in the next 6–7 years • Provision of fiscal incentives to promote setting up of manufacturing units in the state • Conducting training programmes to create skilled and semi-skilled man power • Promotion of efficient biomass gasification based cooking systems, solar-based lighting solutions, solar based irrigation pumps; desalination systems could be launched or reinitiated (as in case of biogas and biomass) in the state. • Detailed assessment and			methods, building materials and building technologies to promote green construction and introduce planning practices specific to climatic conditions of area inquestion				domestic usage, industrial usage, etc. • Conducting studies on efficient crop water application and utilization by promoting 'water saving' techniques like pressure irrigation methods, e.g., drip, sprinkler irrigation; 'life saving irrigation' techniques like diggi construction, water storage tanks; farm ponds, etc. • Measurement of UfW (unaccounted for water) and its reduction to an acceptable level • Mandatory water audit for all sectors including domestic, small and large scale industries, etc. • Rationalizing water pricing for domestic, industrial

Sector → State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
	technical study on energy saving potential in the state, demand side measures including energy efficiency • Promotion of waste to energy through secure landfills, composting plants, etc. • Creation of energy conservation fund for energy efficiency and renewable energy measures in the state; the resources shall be generated by a cess on unit energy consumption • Capacity building of municipal bodies and other local bodies for implementation of energy efficiency measures • Reduction of transmission and distribution losses							and irrigation water usage by introducing IBT(increasing block tariff); water tariff should account for full cost of O&M • Developing a comprehensive water database for assessment of impacts of climate change by setting up a real time dynamic, web enabled water resources information system (WRIS) • Review of availability and scale (spatial and temporal scale) of hydrological data like surface/ groundwater resource, irrigation canal flow, etc., and identification of additional data requirement for climate change and water research in collaboration

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Sector → / State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
	by modernizing, automating, and instrumenting all sub stations • Promotion of industrial shivirs to facilitate energy efficiency in the industrial sector							with research organizations
Sikkim	• Large-scale penetration of solar water heating systems with heat exchangers in buildings particularly in winter months • Promotion of solar passive architecture with a couple of pilot models • Large-scale penetration of biogas plants • Renewable energy equipments and appliances in primary health centres, rural and remote areas, schools and educational		• Introduction of vehicle registration policy/taxation to deter artificial demand of vehicles, the tax proceeds to be used for improving the transport infrastructure • Public Transport Policy to guide and regulate the operation of buses and other modes of public transport by introducing fiscal incentives, concessions and obligations for public transport operators	• Capacity building of authorities (GMC, UD&HD, autonomous WS & Sewerage & Drainage Agency, Transport Authority, etc.) • Involvement of NGO, community groups and social organizations for inducing awareness • Mandatory solar water heating in all hotels and home-stays having more than 10 rooms • Upgrading the house building condition up to the standards	• Creation of weather stations with satellite enabled internet facility to provide the much required data and information on weather (and provide farmers and others with the crucial information at the earliest without having to depend on forecasting exercises) • To ensure livelihood security and optimizing productivity with maximum profits • Introduction of new varieties, popularization of	• Afforestation for protecting the soil cover • Development of botanical garden • Development and exhibition of flowering plants, gardens, etc. • Redevelopment of degraded area • Spring recharge and enhancing ground water recharge in forest areas through climate proofing of the existing programmes of IWMP, CAT and MGNREGA through appropriate	• Source segregation of biodegradables from non-biodegradables • Manual handling to be reduced • Separate collection and treatment facility for biomedical and hazardous waste • Storage of waste in mechanized containers • Providing personal protective equipments to sanitary workers • Capacity building and educating workers	• Building local capacity with skills in geo-hydrology, social mobilization and taking up rain water harvesting works • Increasing base flow of critical streams (harnessed for drinking water purposes) by rainwater harvesting: There are a few critical streams • Increasing water storage capacity by building household, community and village level reservoirs

Sector → / State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
	institutions, dairy farms, monasteries and tourist camps and forest department buildings and outposts		• Creation of a nodal agency with the powers to schedule and route services, regulating and monitoring operations with respect to planned routes and schedules • Rescheduling of work/activity timing to address traffic congestions during peak hours, etc. • Establish a Transport Regulatory Authority under JNNURM with the powers to schedule and route services, etc. • Traffic segregation by building of pedestrian grade separators, pedestrian malls, sidewalks, central dividers, footpath and central railings, creation of storage		indigenous varieties, crop diversification, integrated pest management (IPM), organic seed production and certification, water management, soil conservation, rejuvenation programmes for large cardamom, mandarin oranges, etc. • Promotion of drip and sprinkler irrigation, multiple-cropping, macro-irrigation, macro-management of agriculture, etc.	management of water sheds • Enhancing quality of moderately dense forest, open forests, and degraded forests though regulation and monitoring of invasive species and identification of non-native species that can survive climate change and be beneficial to the ecosystem, etc. • Preventing forest fragmentation by conserving contiguous forest patches, eco-restoration of degraded open forests, and restoration of grasslands • Sustainable management of forests to increase soil moisture content of forests, increase	•Awareness of community to be upgraded with the help of NGOs	• Formation of Water Users Associations (WUAs) • Pricing and regulation through metering, etc., to prevent leakage of water • Irrigation Water Tax

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Sector → State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
			lanes at turning points, bus bays, bicycle lanes, off street loading/ unloading facilities, etc. • Demand management through parking restrictions, parking supply reduction, parking pricing, preferential parking and preferential lanes for high-occupancy vehicles, road and bridge tolls, supplementary licensing, area tolls, vehicle ownership taxation, general fare reduction on public transport • Bus priority through creation of priority manoeuvers, bus lanes, bus precincts, bus priority single systems, bus operation management			biomass density, increase the flow of forest goods like NTFPs, fuel wood, hydrological services; improvement in biodiversity and enhancement in C sequestration • Linking of protected areas through connecting fragmented forests with 'canopy corridors' and 'flyways' to assist species migration • Effective fire prevention and fire management through early detection and management extended to higher altitudes, including community participation in management of fire and, planting species in forests, immediately after the area is burnt with		

Sector → / State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
			• Promotion of non-motorized transport systems through a combination of constructing pedestrian pathways and footpaths, steps and stairs, rope ways • Fuel policy for largely government and public transport vehicles and exploring the possibility of extending it to other vehicles as well • Setting up of one-stop kiosks to book air tickets, rail tickets and even bus tickets from even the remotest corner of Sikkim (to reduce transportation needs) • Payment of electricity and other utility bills on line • Mass transport system for commuters in the form of mono rail			trees generated in the nurseries, etc. • Conservation of high altitude wetlands (HAWs) • Promotion of renewable energy technologies through rapid assessment and identification of high fuel wood villages in all eco-regions to identify opportunities of renewable energy technology interventions		

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Sector → / State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
			• Pay and use rental of two and four wheelers for tourists • Development of bus terminals, truck terminals • Development of parking areas for public vehicles, for private vehicles in existing residential areas • Street fixtures for pedestrians					
West Bengal	• Promotion of grid connected renewables—solar PV for large-scale power in areas where wastelands is available • Promotion of solar thermal units for decentralized uses, e.g., water heating • Demand side energy efficiency measures in identified consumer				• Crop diversification in the various agro-climatic zones • Enhanced R&D for developing cultivars that are salinity/flood/ heat tolerant • Research to identify tolerant indigenous cultivars • Resource conservation technologies (RCTs) like 'no tillage'	• Spring recharge, enhancing ground water recharge within the forests • Regulated grazing • Invasive species eradication, management of insects and other pathogens • Reduction in forest fragmentation by conserving contiguous forest patches		• Rain water harvesting along the hill slopes (e.g., use of trenches to recharge aquifers, gully plugging) • Development of reservoirs intercepting rivers across the state • Construction of check dams for harnessing surface water

Sector → State ↓	Power	Industry	Transport	Urban/rural habitat (includes buildings, etc.)	Agriculture (includes livestock, horticulture)	Forestry	Waste management	Water resources/ coastal areas (as applicable to the state conditions)
	categories to reduce peak demand, efficient device penetration facilitated by financial, supply chain and market incentives • State-led adoption for enabling critical volumes of devices and technologies in local market and breaking current cost barriers • Reduced system losses (technical and commercial) • Improved efficiencies in energy production • R&D for improved green energy assessment (solar, wind and biomass), technology and operations				• Modernization of irrigation system using drip, sprinklers systems • Promotion of organic farming • Establishment of seed banks • Setting up of agriculture BPOs in each district through PPP • Real time monitoring for weather forecasting, fish shoals • Promotion of canal fisheries, sewage-fed fisheries, etc. • Breeding of small ruminants for livelihood security • Fast penetration of renewable energy technologies • Rapid assessment and identification of high fuel wood villages	• Eco-restoration of degraded open forests, grassland, scrublands • Connecting fragmented forests with 'corridors' to assist species migration • Planting species in forests, immediately after the area is burnt with trees generated in the nurseries		• Removal of siltation in the reservoirs to increase storage capacity • Resuscitation of derelict channel with provision of sluice gates for storing rainwater • Encouraging surface water schemes, rain water harvesting, etc., to avoid groundwater extraction • Pricing and regulation through metering, etc., to prevent leakage of water

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Issues and Strategies

This book is an output of the collaborative study on low carbon development for China and India is directed towards developing specific strategies for low carbon development in crosscutting areas such as financing, innovation policy, and subnational actions. The intended outcome of the collaborative project on low carbon development for China and India would be supporting policy development by facilitating south-south cooperation, creating relevant knowledge and building capacities through exchange of experiences and ideas. The book discusses dimensions, issues and strategies to further low carbon development in China and India. This publication will be an essential reading for policymakers, development community, practitioners, researchers and the public.

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