The Energy and Resources Institute

SHAKTI SUSTAINABLE ENERGY FOUNDATION

Discussion Paper

Science, Technology and Innovation for Low Carbon Development in India

September 2015

About the Project

The study on low carbon development in India is directed towards developing specific strategies for low carbon development in crosscutting areas such as financing, technology and innovation policy, and subnational initiatives. By engaging with stakeholders, the project seeks to support policy incubation and development at both the national and sub-national level. Targeted policymaker engagement and advocacy will support design and adoption of new policies and programs based on findings from the study. The study is implemented by The Energy and Resources Institute and is supported by Shakti Sustainable Energy Foundation.

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Abstract

The Discussion Paper provides insights on innovation and low carbon development in the Indian context. It seeks to highlight research and development initiatives and innovation in select sectors including the policy and regulatory apparatus that have a bearing on low-carbon innovation. Insights from stakeholder consultations inform the paper's sector-wise analysis in context of low carbon development. Suggestions for incubation of policies and measures for promoting and strengthening innovation for low-carbon development are provided.

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Science, Technology and Innovation for Low Carbon Development: Insights from India

1. Innovation and low carbon development

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 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 and Eurostat 2005).

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 behavior can produce positive outcomes only up to a point or a frontier; beyond which depleting natural capital has negative consequences for overall growth for the economy. According to OECD (2011), innovation can push the frontier outward and help to decouple growth from the natural resource degradation. Innovation is key to developing the 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 larger role has been attributed to scientific research however, regulatory, financial, cultural, institutional, 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.

2. Innovation ecosystem in India

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-government 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 gives 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 contributes to DST's priority setting. The Science and Technology Advisory Committees formulate joint technology development programmes for the 24 socio-economic 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 called '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.

Figure 1: R&D Ecosystem in India

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 Industry • Associated Chambers of Commerce and Industry of India • National Association of Software and Services Companies • Federation of Asian Biotech Association • Association of Biotechnology Led Enterprises	• Universities • Government R&D organizations • Non-for-profit Independent research Institutes • 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

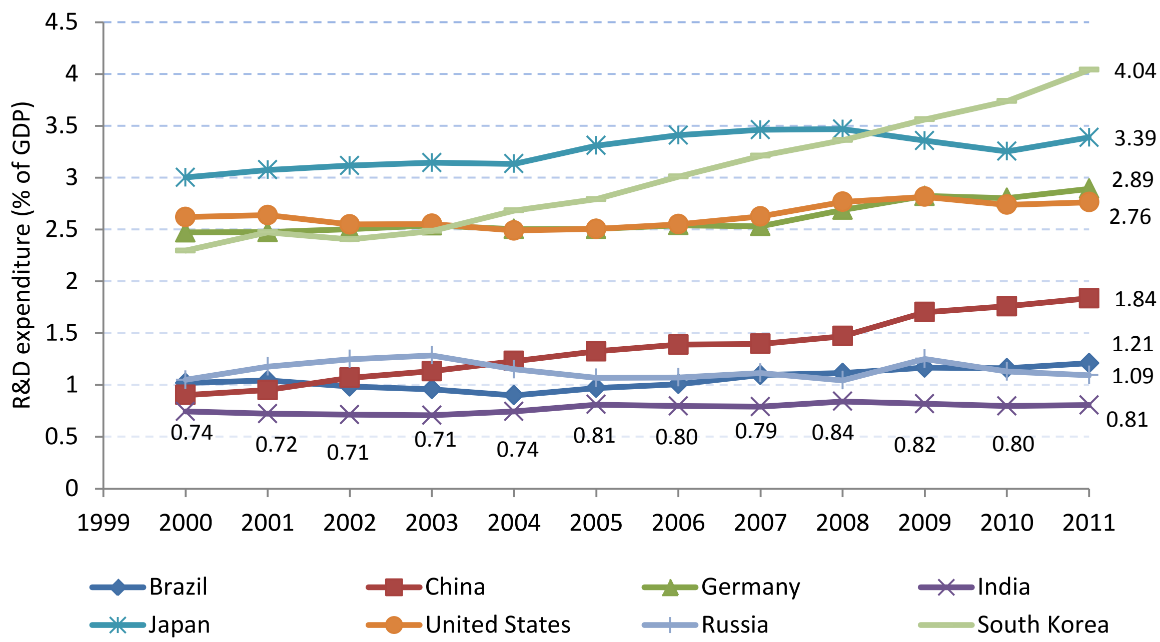
Source: *Adapted from Evalueserve Business Research (2008)*

The total R&D spending in India is about 0.88% 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 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%) 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 2 and 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% in 1980 to around 0.8% in 2011 while for China the increase has been substantial, from 0.1% in 1980 to around 1.84% in 2011.

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

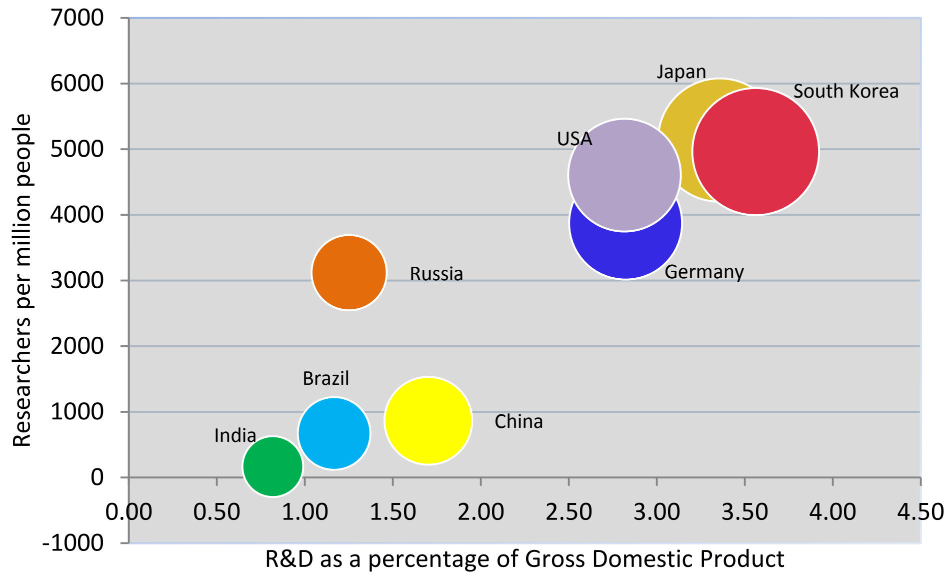
With regard to breakdown of government expenditure on R&D by type of research, the relative share of basic research and applied research to total R&D expenditure declined from around 28% and 38% respectively in 2003 to 26% and 36% respectively in 2010 whereas, the share of experimental development to total R&D expenditure witnessed an increase from 34% in 2003 to 38% 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 programs. 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.

Figure 2: Percentage of GDP spent on R&D in BRICK and other countries, 2000-11



Source: World Development Indicators, World Bank

Figure 3: R&D expenditure (percentage of GDP) and S&T human resources (per million people) of BRICK and other countries, 2009



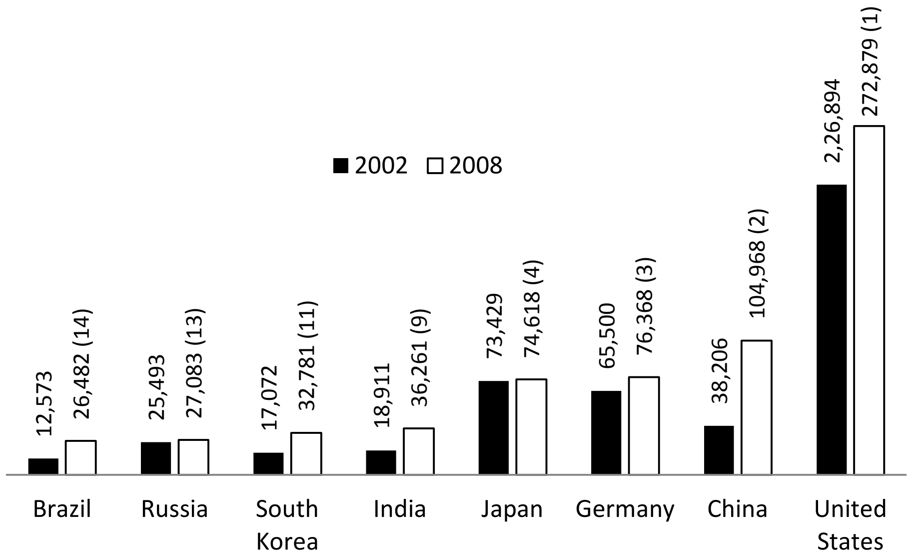
Note: Size of circle reflects the relative amount of annual R&D spending by the country

Source: *R&D expenditure data from World Development Indicators, World Bank; S&T human resources data from UNESCO*

India's global share of scientific publication in the year 2008 is about 3.7% with a global ranking of 9. In comparison, China has achieved spectacular success in increasing its publication standing 2nd in the global ranking with a global share of scientific publication of around 11% (See, Figure 4). Further, China 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 5). Looking at the number of patents granted in the USA, India has increased its patent from 8 in 1980 to 1137 in 2010 whereas China witnessed a rapid increase in the number of patents from 4 in 1980 to 3303 in 2010 (Ramani, 2014)[2].

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

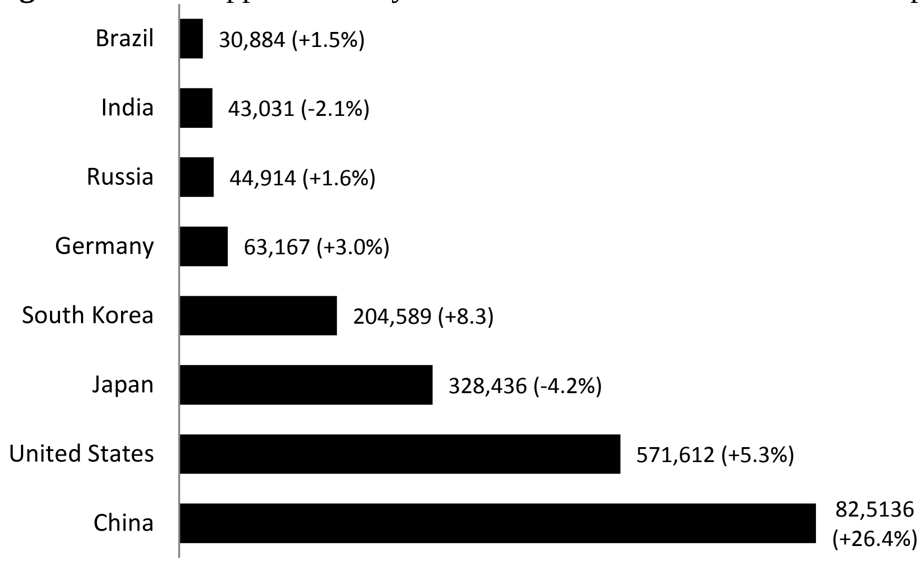
Figure 4: Publications by BRICK and other countries, 2002 and 2008



Note: Figures in parenthesis indicate global ranking in publications of respective countries in 2008

Source: *UNESCO Science Report (2010)*

Figure 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]

[3] World Intellectual Property Organization 2014 WIPO IP Facts and Figures

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

Vision 2020 plan proposed by Dr A.P.J. Abdul Kalam identifies five areas to make India a developed country by the year 2020 viz., agriculture and food processing, infrastructure with reliable electric 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% by 2020 (against 0.8% 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 post-graduate 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 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 form 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, 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% of GDP by the end of the Twelfth Plan, the need for greater private sector R&D expenditure to at least 50% in the Twelfth Plan from the present 25% 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.

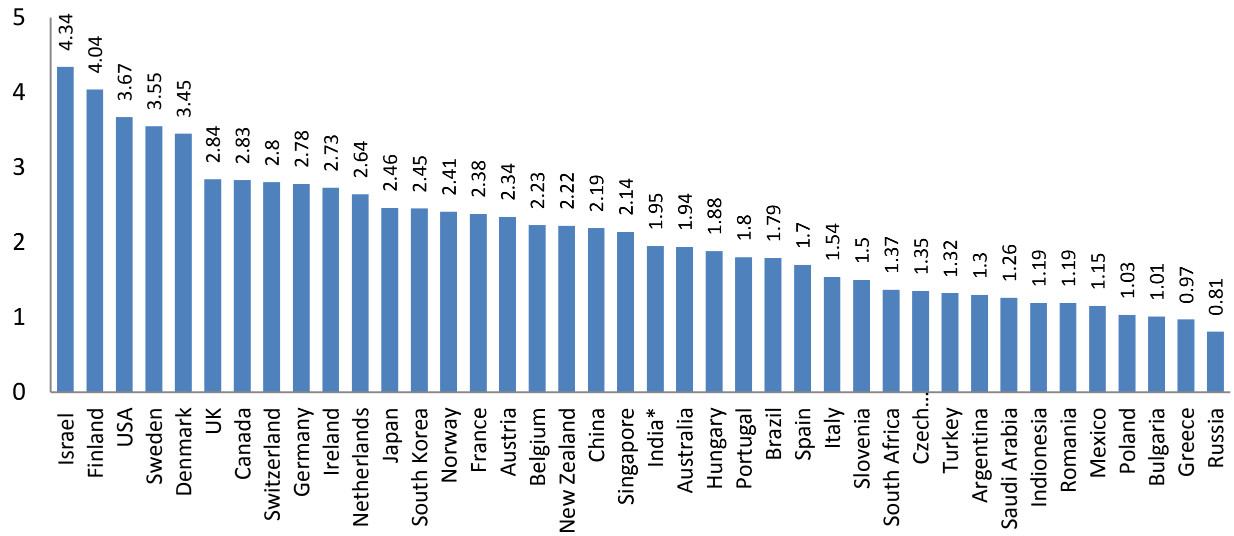
The Science, Technology and Innovation Policy of India, 2013 prepared by the Department of Science & Technology (DST), recognizes the role of the science, technology and innovation (STI) system in the National Action Plan on Climate Change (NAPCC). The document states that the STI system will "serve 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.

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 6). The average score of India on the overall index 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 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 possess a strong climate for growth and development, high levels of pollution, or resource drivers to commercialize clean technology innovation.

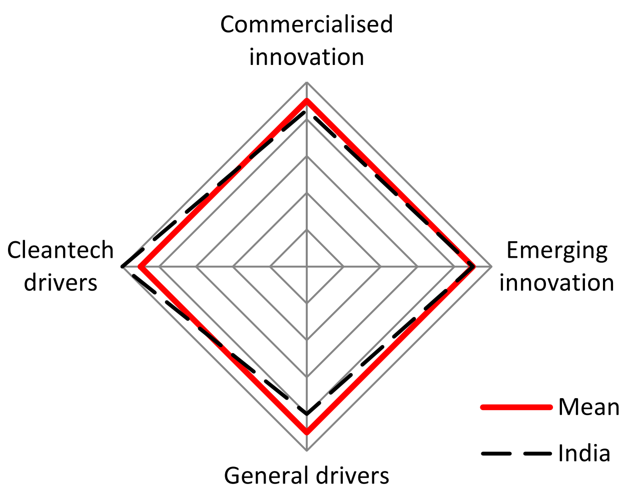
Figure 6: Cleantech Innovation Index for different countries, 2014



A range of initiatives have been initiated towards low carbon development in India. The Technology Development Board (TDB), Department of Science & Technology, Government of India is responsible for aspects related to technological development in the country. With the support of 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 (a) industrial low-grade waste heat recovery; (b) pumping; and (c) 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.

National Clean Energy Fund has been created by the government in 2010 to fund research, innovative projects in clean energy technologies, and environmental remedial programs. Any project/scheme relating to innovative methods to adopt to 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 project 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 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 ~ 3096 million)

Figure 7: India's performance profile in Global Cleantech Innovation, 2014



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 endeavor 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.

4. Stakeholder need assessment

Stakeholder need assessment was carried out under the study in which science, technology and innovation related issues on low carbon development in India were assessed. A survey was conducted to understand and analyze issues on science, technology and innovation for low carbon development in India mainly pertaining to – aspects of technology development and diffusion, sources of technology and technology awareness, type of innovation activity pursued, relevance of different strategies that could be adopted by the government for energy savings technology development, deployment and scaling up, collaborations and issues of intellectual property rights. The targeted group included different stakeholders in the sectors considered in the study. The results of the stakeholder need assessment are provided in the Annexure.

Assessment was undertaken based on the responses elicited from stakeholders on various aspects of technology for low carbon development viz., import and customization of appropriate technology, indigenous R&D and technology development and technology demonstration. The aspect of technology demonstration has been perceived as the most important in the renewable energy, industry and non-renewable energy sector. Adaption of imported technology to suit the local conditions emerged as an important aspect with regard to the transport, building and waste sector. Given the nature and characteristics of these sectors, the imported technology cannot be deployed on a turnkey basis and needs to be adapted to the local conditions. Also indigenous R&D and technology development was considered to be crucial for low carbon development in the agriculture sector.

The sources of technologies are diverse viz., in-house R&D, domestic technologies and international technologies, with the in-house R&D being the major source in the renewable, transport, buildings, waste and non-renewable energy sector. The agriculture and industry sector mainly derived their technologies from an external source such as Indian research institutes.

In the transport sector, a deliberate, holistic plan and long-term commitment for indigenous development of low-carbon technologies was listed as the most important strategy that could be adopted by the government for energy savings technology development, deployment and scaling up. In the buildings and waste sector, direct R&D funding programs to support the launch and scale-up of low-carbon technology innovation was perceived to be important, whereas in the agriculture sector initiatives and investment that improve technological absorptive capacity of businesses by facilitating technology learning, emerged as important strategies. In the waste sector, designing national-level and sector-wide laws, policies, and regulations to scale-up commercialization of low-carbon technology and Tax incentives for technology parks and incubation centres were equally considered to be important. In the industry and non renewable energy sector, the need for the government to facilitate creation of domestic markets for low carbon technology development and deployment emerged as important.

The role of external collaboration in low carbon technology related innovation was considered to be important in almost all the sectors, with majority of them being engaged in any technical collaboration or technology licensing agreement with any international organization/company, especially of the nature of R&D and capacity building.

With regard to the issues associated with intellectual property rights vis-à-vis low carbon technology innovation, a high legal cost in the case of renewable, transport and non renewable sector and a high transaction cost in the buildings sector were perceived as the most important. Lack of clear understanding of IPR related issues emerged as a challenging factor in the agriculture, industry and waste sectors.

5. Understanding Science, Technology and Innovation for LCD Sectors

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

5.1 Renewable Energy

Innovation and R&D

The continuous need to innovate and to pursue Research and Development (R&D) vigorously in direct and translational research has been emphasized upon for promotion of renewable energy in India. The revised target of adding 1,75,000 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 (CEWT), 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 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) is presently around INR 910 crore (approx. USD 152 million) in the 12th Five Year Plan, up from 525 crore (approx. USD 88 million) in the 11th Five Year Plan which funded 169 projects.

Table 1 provides an overview of the R&D projects supported by the MNRE for various years.

Table 1: R&D Projects Supported by MNRE

Year(s)	Total no. of projects sanctioned	Amount (INR crore)	Amount (USD million)	Areas
2014-2015	22	N.A	N.A	Solar thermal, solar photovoltaic, biogas, hydrogen and wind hybrid systems
2013-2014	17	N.A	N.A	Higher efficiency solar cells, Solar thermal, Hydrogen energy storage, Fuel cells, bio-fuel, bio-gas and waste to energy
2012-2013	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 2,73,000 MW.

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 aims primarily 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 RD&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).

Box 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), PIB (2015)

5.2 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) 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 12th Five Year Plan (MoP, 2015).TEDDY 2014-15 informs that reliance on coal will be as high as 50% 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 a 200 MW IGCC demonstration plant in Vijayawada, Andhra Pradesh was begun in 2010 by a consortium of BHEL, Andhra Pradesh Power Generation Corporation Limited (APGENCO) and the Department of Science& Technology.

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), 5 of which will add 20,000 MW capacity this year (MoP, 2015). The minimum capacity for a UMPP is 4000 MW. The projects are awarded to developers through competitive bidding and operated through Plug and play mode thereby reducing investment bottlenecks. In the 12th Plan, a capacity addition of 78 GW of coal-based power is planned along with 100 GW in the 13th 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 before, 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 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 include 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 (TERI, 2013). At 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 CO2 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), PowerGrid, DISCOMs, Bharat Heavy Electronics limited (BHEL), the Council for Scientific and Industrial Research (CSIR), Crompton Greaves, CSIR laboratories, IITs, and 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 12th Plan (2012-2017) is provided in Table 2

Table 2: Research related schemes sanctioned by CPRI under the 12th Plan (2012-2017)

Scheme	Amount (INR crore)	Amount (USD million)	Areas
Plan Research and Development	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
National Perspective Plan R&D	45	8	New Product and Process development leading to field implementation

Source: *CPRI (2015)*

In order to initiate the Smart grids the Government 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 programme 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, Orissa, 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, the National Power Training Institute along has been set up as the apex institution with state of the art training infrastructure and expert faculties to make the power sector competitive. 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.

5.3 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 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 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	

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
Fuel cell vehicles		X	X	X		X	
Improved diesel vehicles	X	X		X			
Flex-fuel vehicles		X		X			
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			

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
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 Research and Development in the Auto 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 8 years.

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 2006–2016 (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 (HEV), plug-in hybrid electric vehicles (PHEV), 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 GHG's with estimated savings of 9500 million litres equivalent of INR 62,000 crores (USD 10333 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 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 12thFive Year Plan (2012–2017).

Table 4: R&D Focus and Proposed Investment in Transportation Technologies for 2012–2022

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)			4 Wheeler	50 (10)
		2 Wheeler	200 (40)			2 Wheeler	50 (10)
		Bus	200 (40)			Bus	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 brackets indicate approximate values in USD million							

Source: *Report of the Working Group on Automotive Sector for the 12th Five Year Plan (2012–2017), 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% 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 4000 watts, having three wheels for carrying goods and passengers have been given legal status under the Central Motor Vehicles (Amendment) Bill, 2015 (PRS, 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.

5.4 Buildings

Innovation and R&D

Smart cities is 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. 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 (IGBC, 2014). The construction sector of which buildings is a part 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 12th Five Year Plan (2012–2017) 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 on 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 (GOI) created the Bureau of Energy Efficiency (BEE) to institutionalize the promotion of energy efficiency and building energy efficiency. BEE focuses 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 5. The table is only an indicative list.

Table 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. Research and development 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
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 Resource 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, bio-fuels, 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 markets 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 6.

Table 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*

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 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. 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:

- Flyash 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/aluminum composite formwork
- Rapidwall Construction System

Research has gone into the brick making industry by Government, bilateral and multilateral agencies. The details are stated below in Table 7.

Table 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 (1970's)
Central Pollution Control Board/Ministry of Environment and Forests	Air emission regulation for brick kilns (1990's)
Swiss Agency for Development and Co-operation	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 will build formal training programmes and systems related to skill assessment and certification of construction workmen.

Policies to promote innovation in the buildings sector

India has a comprehensive regulatory framework aimed at mainstreaming energy efficiency and green buildings in India 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 ≤ 1,50,000 sqm; and for townships and large area development projects with a built up area ≥ 1,50,000 sqm. The Ministry of Environment and Forests 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 Buildings Rating System India) and IGBC (Indian Green

Building Council). A list of policy initiative for the sector under the central government is provided in Table 8.

The following activities are initiatives under the Central Government

Table 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 (BEE)) 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 100kW or a contract demand of 120kVA. 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, 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, section6 as 6.18 titled '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 Departments, 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 make to make the cement production more environmentally sustainable. The permissible limit for stack dust emissions from new cement plants in the country is 50mg/Nm3 (for existing plants, this is 150 mg/Nm3 and 100 mg/Nm3 for critically polluted areas (Minerals Yearbook). The Cabinet Committee on Economic Affairs has recently approved Housing for All by 2022 with 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 (ULB's) 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.

5.5 Demand Side Management (DSM)

Innovation and R&D

Bureau of Energy Efficiency (BEE) under the Ministry of Power (MoP) 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 12th Plan (2012-2017) 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 7489

MW can be achieved. At the end of the 12th Plan the avoided peak capacity is estimated to be 12,350 MW.

The allocations to BEE for the years 2012-14 have increased; however in the current Budget year 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 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 from 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 program includes work on commercialization and market transformation mechanisms. The 12th plan working Group on Power emphasizes on developing State Designated Agencies (SDA) 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 12th plan informs on setting up 10 research centres in collaboration with Department of Science and Technology (DST). 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 (ESCO). It will offer funding for initial setting up, partial running and maintenance cost for the first 5 year period. The 12th 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 (SME's), 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 % 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. 26.86 million SEA fans are expected to be sold during the 12th 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) initiative 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% 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% interest subsidy is given on procurement of energy efficient technologies by designated consumers in 7 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 like 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 12th 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 11th 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.

5.6 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 co-ordinates, 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 641 Krishi Vigyan Kendras (KVKs) spread across the country. The major thrust areas of agricultural research in the country as articulated in 12th Plan (2012-2017) 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 10 below highlights the Institutions established to promote Science and Technology in Agriculture

Table 10: S&T infrastructure in agriculture

Institutions		No.	Activities undertaken
A	**Research and Development**		
1	State Agricultural Universities	42	All
2	Research institutes	47	Region specific (crop, animal, fish, water, soil)
3	National Research Centre (NRC)	26	Various crops, horticulture, fish, poultry, water, soil etc
4	National Bureau	5	Plant, animal, fish, soil and micro-organism
5	Project Directorates	10	Crops, water, animal, poultry etc.
6	International Linkage	16	CGIAR, FAO, WTO etc
B	**Transfer agencies**		
1	Agricultural Technology Management Agency (ATMA)	-	
2	Agriculture extension - KVKs	547	
3	State Agriculture Department	28	-
4	Private 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	13	Region specific
3.	State Seed farm Corporation	2	
4	Seed Companies	400	
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 12th plan emphasizes on the need to increase spending on National Agricultural Research Systems (NARS) to 1% 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%. However, in the current budget there is a boost to Agricultural Research and Education. This can be seen in Table 11.

Table 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 significant impetus given to expanding and strengthening research institutions. Table 12 below highlights the current initiatives and resources allocated for S&T institutions in the agriculture sector.

Table 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
4 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	1600	267

Source: *ICAR (2015)*

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 constrains (soil and water salinity, soil acidity, drought, floods etc).

Table 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: *ICAR (2015)*

In addition, scientists at ICAR in collaboration with other Institutions have succeeded in Sliced the Wheat Genome. The decoded draft sequence of bread wheat genome has revealed more than 1,25,000 genes assigned to individual wheat chromosomes. This path breaking research will assist in DNA finger printing, diversity analysis and marker assisted breading. High protein rice variety 'Heera', which is a short duration early maturing variety useful for both rain fed and irrigated areas has also been discovered. It has 11.5% protein and is used to address malnutrition in Orissa.

Cloning of high ranking progeny tested bull 'Rajat' has been successful. It is cloned from the frozen semen of elite Marah bull (MU4393). Successful cloning of the wild buffalo 'Deepasha' found in Chattisgarh, which has been declared endangered under the Wildlife Conservation Act. Use of Hand Guided cloning technique, by using somatic cells of the Murrah Buffalo's urine. 'Apurva' was created out of this technique. Additionally, two indigenous variety of buffalo's have been cloned. To sustain local livelihoods, Kamrupa, a multi colored poultry bird, a hybrid of the Assamese local ecotype, colored broiler and Dalhem red population was released for backyard poultry in the North Eastern region.

The Government has also introduced 'Mridaparikshak' (related to the Soil Health Card Scheme), is 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 like 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 12th 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 sanction INR 4500 crore (USD 750 million) towards a National Supercomputing Mission in building the capabilities in India (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 50 km radius of IMD monitoring stations. This is under the National e-Governance Plan-Agriculture for disaster risk reduction.

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 (PHT&M). Between 2011-2012, 2012-2013, 7947 and 4808 technology demonstration had been made for PHT&M, 1221 and 1128 units have been established and 1770 and 3450 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% of their funds for training women. MoA has reformed the National Mission on Agricultural Extension which includes 4 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 focuses 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 12th 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 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 by this project is listed in Table 14.

Table 14: Major agricultural research projects in India

Name	Implemented by	Key achievements
National Agriculture Innovation Project (NAIP)	ICAR with support from 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 co-operating centres. NPOF has the objective to address issues of comparing inorganic and organic agriculture, integrated nutrient management practices, method 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 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 5300 crore (USD 833 million) has been sanctioned under the current budget.

Box 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. MoA, Government of India (GoI) 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, through a 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 USSD for accessing e-kisan portals has 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.

5.7 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

[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

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 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 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-government organizations. Moreover, technologies developed for industries in other countries may have to be adapted to Indian conditions.

Table 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 from http://indiabudget.nic.in*

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 16.

Table 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

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.

<table>
<tr><td></td><td>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 the11th 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 12th 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)</td></tr>
<tr><td>Cement</td><td>▪ The NCCBM is responsible for R&D activities in the sector. Current research include initiatives such as
o Adaptation of technology to reduce Nox and Sox and formulation of emission norms
o Productivity Improvement in Kiln through Optimization of Precalciner Operation and Thermal Loading of Kiln as well as Computer Based Simulation Techniques
o Development and Adaptation of Technologies for Utilization of Wastes in Cement Manufacture
o Studies to reduce CO2 emissions from cement plants through absorption of CO2 by algal farms
o Enhancing the use of fly ash in cement and concrete
o 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, NCCBM, 2015)</td></tr>
<tr><td>Chlor-Alkali</td><td>▪ 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)</td></tr>
<tr><td>Fertilizers</td><td>▪ 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 coal bed methane (CBM) which can be used as a feedback in the manufacture of urea
Source: (DoF, undated)</td></tr>
<tr><td>Pulp and paper</td><td>▪ 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</td></tr>
</table>

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 2010-2015 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 Source: MoT, 2015 Scheme for Integrated Textile Parks and Integrated Skill Development Scheme have also been initiated

Significant energy-efficiency gains have been identified in the micro, small and medium enterprises (MSME) 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 focused 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 (2009–2011) with a goal to obtain energy savings of 20–30% 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 MSME's 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, incentive 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 food park 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 by dedicated Industrial corridors are being developed.

DIPP's Discussion paper highlights that India share of global trade in high technology products is only 8% 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.

5.8 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). 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 17 gives an indicative list of some institutions which have actively taken up forestry research in the country.

Table 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 eco-systems), 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 sanctuaries are some of the clear national research priorities in the forestry sector (Forestry Policy, 1988).

Table 18 shows the budget allocation made to forestry research in the Union Budget of India. In 2014-15, the amount allocated to research has increased by INR 22.55 crore (USD 4 million)

Table 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 Ministry of Environment and Forests**
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: *IIFL (2013, 2014)*

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 agrisilviculture, silvipasture, silvi horticulture, social sciences, watershed development and human resource development (CAFRI, 2015). In addition, to promote 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 (ENVIS, 2015).

There has also been significant advancements in the remote sensing technology to map forest cover. Table 19 below highlights the advancements in these technologies.

Table 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
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 forest, moderately dense forest and open forests than the dual classification used until 2001. The LISS III sensors along with Resourcesat have increased the resolution uptil

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 indicator (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, 2015).

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 (m ha) 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 (TOI, 2015). 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 prorgammes. 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 (MOEF, 2014).

The National Forest Policy advocates the use of research and development for the conservation and sustainable development of forests. MOEF 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 14th Finance Commission recommendation to give 7.5% 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 (MFP's) produce 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 Co-operative Marketing Development Federation of India Ltd. (TRIFED) is acting as the nodal agency to commercialize MFP's. 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 (Trifed, 2015). The larger framework of the Van Bandhu Kalyan Yojana (Forestdwllers Benefit Scheme) will bring greater development for forest dwellers. State level interventions such as Madhya Pradesh's Vindhya Herbals is also seen as 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

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 support to SME's in the sector (NMBA, 2015).

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 MOEF 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 needs in the context of low carbon development needs to be directed to understand linkages with existing as well as new initiatives.

5.9 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 help of waste to energy plants are gaining importance now a days due to their capacity to reduce waste volumes by more than 90 percent. 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 is actively promoting all technology options available for energy recovery from urban and industrial wastes. 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 & Technology under the Technology System Programme on Waste Management focuses on electronic waste, biomedical waste, and plastic waste. DST has started new programmes on waste recycling and rehabilitation of scavengers, 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 20 gives an overview of the status, issues and technology interventions relevant to waste management in India.

Table 20: Waste Management: Status, Issues and Technology Interventions

Category of waste management	Status	Issue	Technology intervention
Municipal solid waste (MSW) management	144165 TPD MSW is generated out of which about 80.28% is reported to be collected and only 32871 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+-, 41Biogas plants-+, 13power plants-)(out of these 30 plants are set up and 46 under construction /planned, 94 sanitary landfill facilities (SLF) have been constructed in th

			e 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, 6289 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 3500 organized and 4000 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
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	1.7 MT 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: *Author compilation from various government documents*

The recently launched Swachh Bharat programme of the Government has emphasized on solid waste management and has the following technological interventions to be scaled up (See, Table 21).

Table 21: Technological interventions in solid waste management under the Swachh Bharat programme

Organization	Sector	Intervention	Use
EcomanEnviro 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: *Swachh Bharat Urban (2015)*

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 4 centers 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 22.

Table 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.

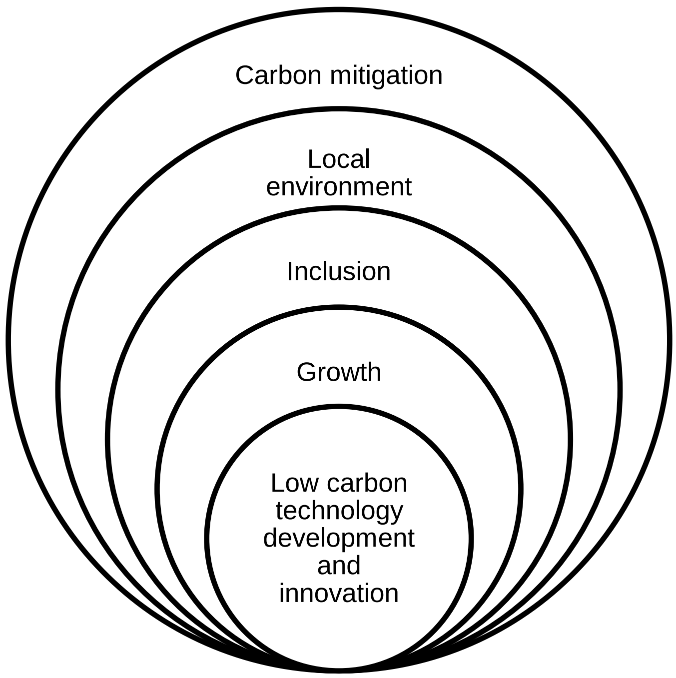
The regulatory framework in this sector encompasses the Municipal Solid Wastes (Management and Handling) Rules, 2000; the Bio-Medical Waste (Management and Handling) Rules, 1998; the Plastic Waste (Management and Handling) Rules, 2011; E-waste (Management and Handling) Rules 2011 etc. The Government 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 pelletisation 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.

6. Discussion and ways forward

Focusing 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 development and innovation in the developing country context (see Figure 8).

Figure 8: Co-benefits Framework for Technology Innovation

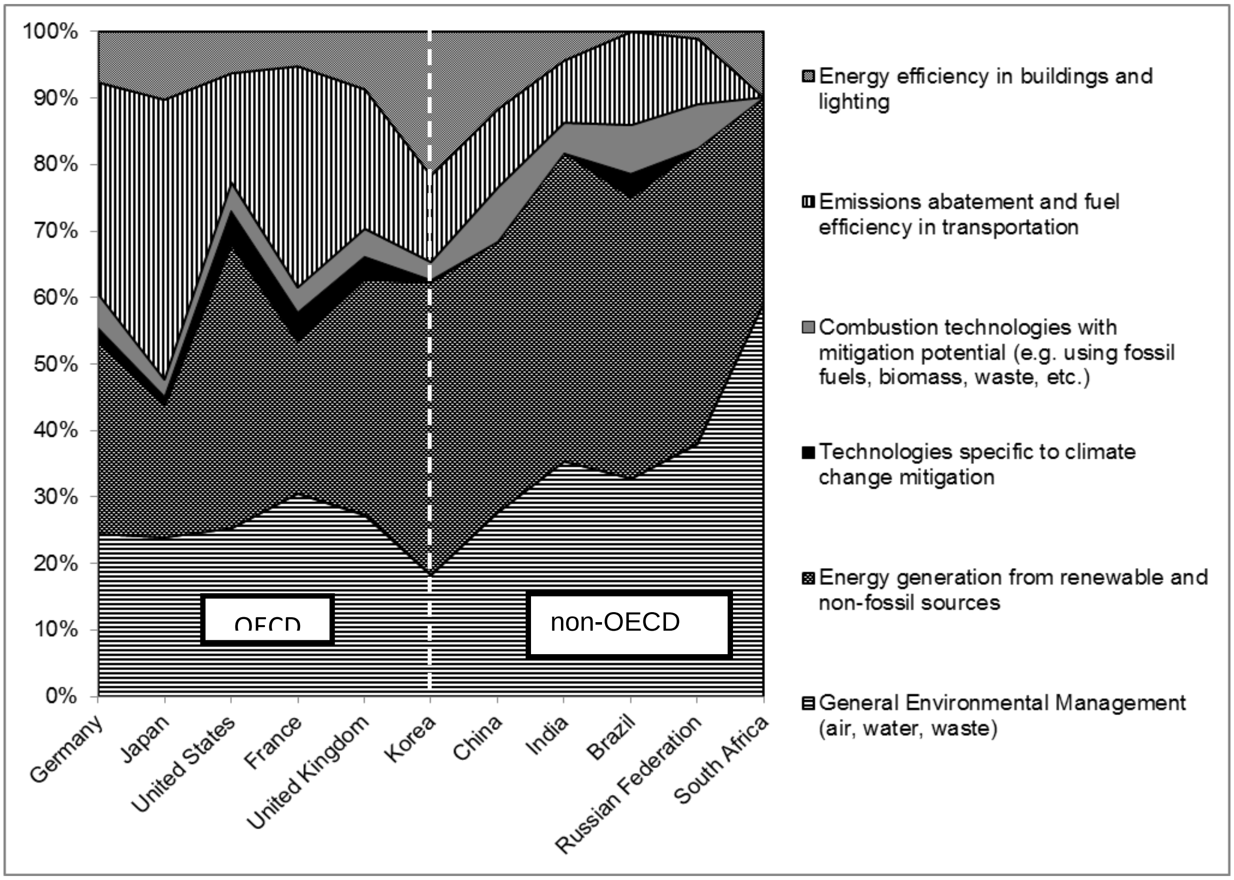


Source: *Author compilation*

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 to be a priority of developing countries, competitiveness of domestic industries would continue to be relevant.

Figure 9 plots the data on patent applications to the EPO in environment-related technologies collected for six 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.

Figure 9: Trends for Patents in OECD and Non-OECD Countries (2008)



	Name	General Environmental Management (air, water, waste)	Energy generation from renewable and non-fossil sources	Technologies specific to climate change mitigation	Combustion technologies with mitigation potential (e.g. using fossil fuels, biomass, waste, etc.)	Emissions abatement and fuel efficiency in transportation	Energy efficiency in buildings and lighting	TOTAL
OECD countries	Germany	467.28	558.02	36.02	96.04	607.17	147.17	1911.70
	Japan	389.00	323.30	22.50	41.50	683.54	166.83	1626.67
	United States	361.41	608.30	72.14	58.89	235.24	89.42	1425.39
	France	176.27	131.73	26.00	20.89	192.14	30.39	577.41
	United Kingdom	88.63	114.49	11.39	13.26	68.44	27.83	324.06
	Korea	35.12	83.94	1.00	5.00	25.00	41.45	191.51
non-OECD countries	China	23.87	35.04	0.00	7.00	10.20	9.97	86.08
	India	11.13	14.58	0.00	1.42	2.95	1.38	31.45
	Brazil	9.00	11.60	1.00	2.00	3.86	0.00	27.46
	Russian Federation	9.58	11.17	0.00	1.67	2.50	0.25	25.17
	South Africa	6.00	3.14	0.00	0.00	0.00	1.00	10.14

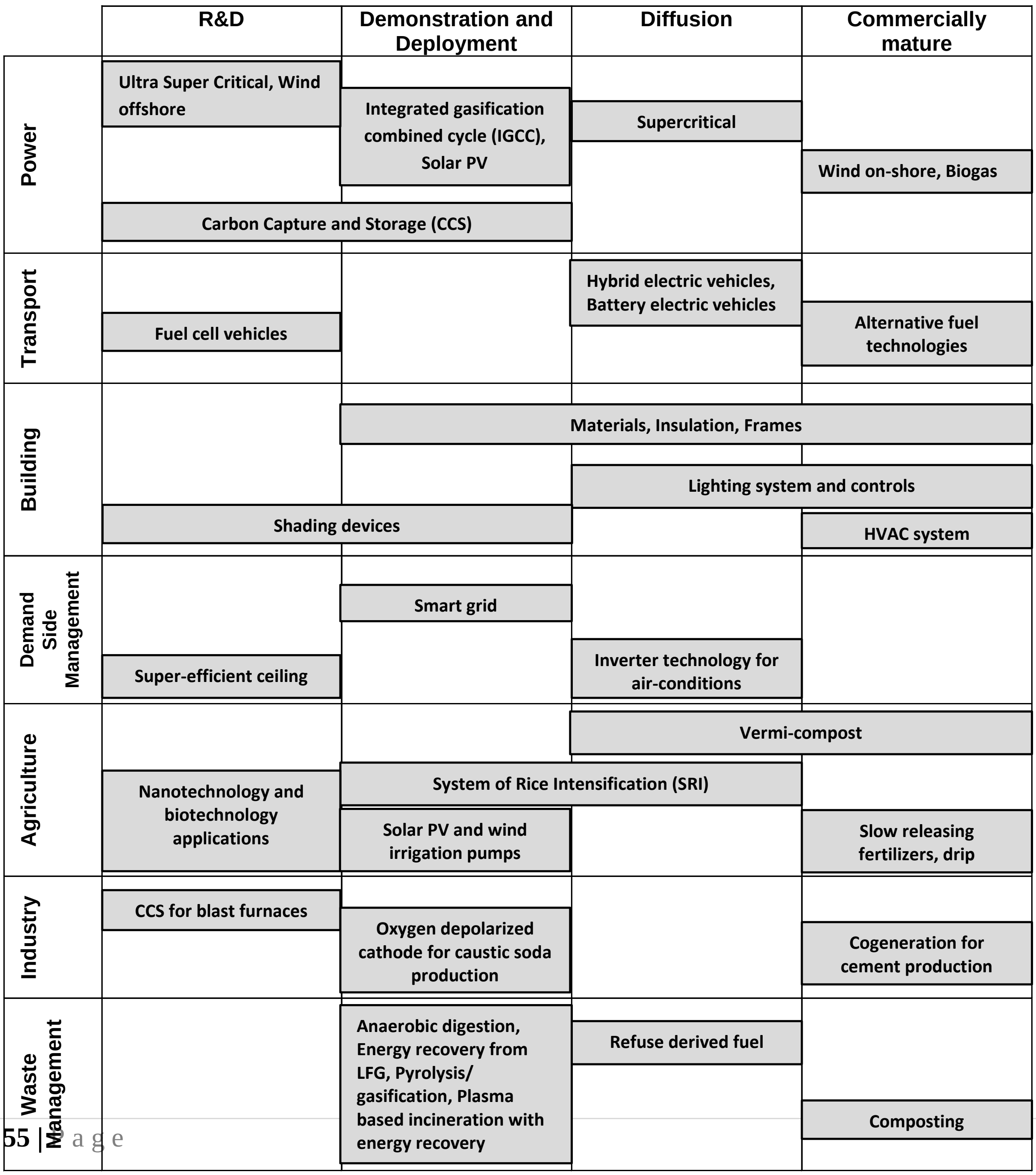
Note: Patent applications to the EPO in environment related technologies in 2008

Source: *TERI (2012)*

This could also 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 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 on-going in all of these technology areas.

Figure 10: Status of Maturity of Different Low-Carbon Technologies in Key Sectors



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 on-going technological activities and their respective maturity stage 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 has 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 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 some 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 happening 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. 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 need to be determined through structured analysis. This could be facilitated by using the tools of technology foresight, technology roadmapping, 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 addressthose challenges

- Measures supporting R&D in micro, small and medium enterprises needs 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

Annexures

Annexure A: Technologies and innovation stages for sectors

Table A.1: Technologies and innovation stage: 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: 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: 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			
	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
	Lighting system and controls				
	Luminaries			X	X

	Controls		X		X
	HVAC system				
	High COP Chillers			X	X
	Heat Pumps	X	X		X
	Economisers				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: Demand side management

Sector	Technologies	R&D	Demonstration and Deployment	Diffusion	Commercially mature
Demand Side Management	Smart grid		X		
	Inverter technology for air-conditions			X	
	Super-efficient ceiling fans	X			

Table A.5: Technologies and innovation stage: 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: Industry

Sector	Technologies	R&D	Demonstration and Deployment	Diffusion	Commercially mature
Industry	CCS for blast furnaces	X			
	Oxygen Depolarised Cathode for caustic soda production		X		
	Cogeneration for cement production				X

Table A.7: Technologies and innovation stage: 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					

Annexure B: Results of stakeholder need assessment

Sector	No. of stakeholder interviewed
Renewable	49
Waste	21
Non-Renewable	24
Building	67
Transport	22
Agriculture	37
Industry	67
Total	**287**

How important are following aspects of technology for achieving low carbon development in your sector? (Rate from 1 to 5)

Aspects	RE	Transport	Buildings	Agriculture	Industry	Waste	Non-RE
Import of appropriate technology	3.77	4.36	4.27	3.95	3.96	4.43	3.54
Customization of imported technology	3.96	4.59	4.42	3.72	3.97	4.62	3.79
Indigenous R&D and technology development	3.89	4.32	4.21	4.22	3.99	4.14	4.00
Technology demonstration	4.15	4.55	4.18	4.09	4.01	4.43	4.08

Note: Highlighted Boxes indicate the most important aspect as perceived by stakeholders

For low carbon technology development/upgrading in your sector, what, in your knowledge, is/ are the source/s of technologies? (in %)

Source of technology	RE	Transport	Buildings	Agriculture	Industry	Waste	Non-RE
In-house R&D	56	68	58	49	30	67	75
Domestic technologies	31	45	55	62	36	33	25
International technologies	46	41	10	32	19	14	21

Note: Highlighted Boxes indicate the most important aspect as perceived by stakeholders

Elucidate the type of innovation activity undertaken

Type of innovation activity	RE	Transport	Buildings	Agriculture	Industry	Waste	Non-RE
Product innovation (e.g.; new product)	25	14	29	43	52	29	46
Process innovation (e.g.; energy efficient process)	50	32	53	57	57	48	67
Organization innovation (e.g.; environment and energy monitoring cell)	64	64	56	46	39	67	38
Marketing Innovations		23		27	42		
Business models	6	27	31	24	28	43	25

Note: Highlighted Boxes indicate the most important aspect as perceived by stakeholders

How relevant are the list of strategies that could be adopted by the government for energy savings technology development, deployment and scaling up. (Rate from 1 to 5)

Strategies	RE	Transport	Buildings	Agriculture	Industry	Waste	Non-RE
Deliberate, holistic plan and long-term commitment for indigenous development of low-carbon technologies	3.91	4.50	4.18	3.95	4.16	4.48	3.63
Direct R&D funding programs to support the launch and scale-up of low-carbon technology innovation	4.04	4.32	4.43	4.05	3.91	4.52	3.79
Initiatives and investment that improve technological absorptive capacity of businesses by facilitating technology learning	3.85	3.91	4.10	4.18	3.84	4.19	3.46
Capitalizing on public-private and industry-academia synergies	4.34	4.05	4.12	3.64	4.09	4.24	3.92
Designing national-level and sector-wide laws, policies, and regulations to scale-up commercialization of low-carbon technology	4.19	4.14	4.24	3.89	4.1	4.52	3.88
Creation of domestic markets	4.28	4.09	4.18	3.89	4.22	4.43	4.08
Strengthen international cooperation to pursue new-to-market technology and knowledge	4.40	4.18	4.04	3.86	3.94	4.38	3.92
Strengthen Intellectual Property Rights (IPR) regime	4.23	4.14	4.01	3.91	3.93	4.19	3.92
Tax incentives for technology parks and incubation centres	4.28	4.23	4.07	4.05	3.64	4.52	4.00

Note: Highlighted Boxes indicate the most important aspect as perceived by stakeholders

What is/are the source(s) of awareness for low carbon technologies? (%)

Sources of awareness	RE	Transport	Buildings	Agriculture	Industry	Waste	Non-RE
Trade fair and conferences	56	91	56	38	51	71	67
Through industry associations	65	77	53	57	42	48	58
Networks (including peer learning)	65	86	55	32	33	57	17
Direct contact between technology provider and your sector/industry	79	91	55	68	27	67	46
Government promotions	48	82	49	43	51	62	58
Trade and industry media (journal, newsletters, other print media etc.)	48	82	47	40	21	57	25
Specialized information portals	50	86	34	24	19	43	42

Note: Highlighted Boxes indicate the most important aspect as perceived by stakeholders

Is your department/company/ industry presently into any technical collaboration or technology licensing agreement with any international organization/company?

	RE	Transport	Buildings	Agriculture	Industry	Waste	Non-RE
Yes	79	86	69	88	48	89	96
No	21	14	31	12	52	11	4

If yes, what type of collaboration have you engaged in?

Type of collaboration	RE	Transport	Buildings	Agriculture	Industry	Waste	Non-RE
Bilateral	45	14	10	30	38	24	17
Multilateral	84	14	6	14	34	12	46
Private collaboration	58	23	37	16	19	53	54
Public-private collaboration	42	55	31	32	22	59	25

Note: Highlighted Boxes indicate the most important aspect as perceived by stakeholders

What is the nature of collaboration?

Nature of collaboration	RE	Transport	Buildings	Agriculture	Industry	Waste	Non-RE
Research and development	64	68	38	27	59	94	63
Capacity building	80	27	37	35	41	47	54
Transfer of technology	29	64	20	22	31	71	38
Business and markets	52	32	26	22	25	35	50
Technical advisory services	52	73	19	30	28	88	29

Note: Highlighted Boxes indicate the most important aspect as perceived by stakeholders

What are the key issues associated with Intellectual Property Rights?

Issues	RE	Transport	Buildings	Agriculture	Industry	Waste	Non-RE
High transaction costs	50	36	65	41	39	52	67
High legal costs	63	64	56	41	37	57	75
Lack of clear understanding	48	50	34	65	49	62	13
Perceived lack of proper enforcement (in the particular context of developing countries)	27	45	37	27	45	71	29
Refusal to license or licensing with onerous conditions (on the part of firms in the developed world)	33	45	31	54	37	52	50
Insufficient information	52	50	37	35	36	62	29
Ambiguous ownership and contractual arrangements between domestic and foreign firms	23	23	29	32	28	38	33
Lengthy process	33	36	29	32	13	43	25

Note: Highlighted cell indicates top three items

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