‘Innovation Hot Spots’ in India

27th July, 2011

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1. EXECUTIVE SUMMARY

The report on ‘Innovation Hotspots’ was commissioned by TAFTIE to study the present R&D landscape in India and highlight thematic areas that may emerge significantly based on future demand. The study also aimed at mapping spatial agglomerations that offer ecosystems conducive for propagation of innovation activities for these thematic areas. These findings are expected to provide directions, which acted upon concertedly, will open up a plethora of opportunities for TAFTIE member agency’s internationalization program.

To begin with, it is important to understand the historical perspective. Therefore, the report starts with the evolution of economy and socio-political development. India has come a long way from its socialist principles and economic liberalization ushered by Dr. Manmohan Singh in 1991. Since independence, then there has been a drastic shift in the composition of GDP with agriculture falling below 20% and the services sector reaching an overwhelming proportion of 60%. Over the years, political developments too have been quite significant. Today, India is the largest democracy in the world with the most diverse coalition government. The days of single party rule is over and with coalition governments there is a new set of challenges in terms of reforms pace and decision making. Society too has undergone enormous changes. From being a poor agrarian population, there has been a steady rise of the educated middle class which has had profound impact on the country’s economy. This section of the population has become the prime mover for value added products and services.

Further, the report analyses present science and technology system with various government agencies involved in IP development and propagation. The current contour of R&D is studied in terms of patent filings and research paper publishing. The scientific community has made great strides in this aspect and has put India firmly in the global map. Since 2004-05, the number of patent filings has gone up from 17,466 to 36,812 and concurrently, patents granted have risen from 1,911 to an impressive 16,061. However, most of the output (84% in 2008-09) has come from foreign organizations through their R&D centers in the country. Paper publishing too has tripled since 1996, though it still remains a lowly 10% and 30% of USA and China respectively.

Based on IP activity and patents granted, the report then tracks major sectors and technologies that are being developed therein. These sectors are also looked at from the standpoint of future demand potential. The thematic areas studied in detail are:

1. Healthcare (Pharmaceuticals and Bio-Pharma)
2. Information Technology
3. Telecommunications
4. Automotive
5. Energy (Renewable)
6. Nanotechnology
7. Defence
8. Space

While India has held pre eminent position in some sectors like space, others have emerged in recent years like IT and Pharmaceuticals due to the cost benefits and availability of skilled manpower. Nanotechnology is at its nascent stage but is one of the thrust areas of the government. Automotive, Telecom and Energy are driven by demand from a burgeoning population while focus in Defence is due to India's near obsolete hardware and dependency on foreign suppliers. Each sector is presented as separate chapters in the report. The areas covered under each sector include:

a) Market assessment
b) R&D spend
c) Major participants
d) Type of Innovation activities
e) Geographic clusters (infrastructure and ecosystem)
f) Government initiatives and policies
g) Future outlook

Analyses of innovation activities by sectors reveal interesting findings. Predominantly, most of the research conducted in India is basic research done for processes and applications rather than for product development. In certain sectors the focus in on the local market while for others it is targeted at developing markets. Indigenous research is still dominated by Government institutions and agencies that provide bulk of the funding. Spending on R&D/innovation is comparatively low but this trend seems to slowly changing. Most Indian companies now harbor global ambitions and are active in M&A's resulting in acquisition of R&D capabilities. Companies that have acquired R&D skills are steadily moving up the value chain to remain competitive. Some organisations are using innovative business models for driving innovations e.g. hiving off of R&D unit in to a separate entity by Pharma companies.

Innovation needs to be firmly established in the business and academic environment covering the complete spectrum from pure science to business processes to product development. This phenomenon is starting to emerge in India, particularly in the pharmaceutical, biotechnology and IT industries. However, an all encompassing innovation culture is still in its early stages in the country.

The present Innovation (R&D) ecosystem in India can be best described as unstructured. Over the decades, the government has promoted innovation and scientific knowledge accumulation in pockets like space research, defense, pure sciences etc. but never has this been institutionalized with a proper framework and ecosystem for its propagation and development. In the earlier days, it was only government sponsored research in its laboratories and universities that had the scientific community involved. Only since economic liberalization, has the private sector gotten involved with its fair share of R&D activities in order to develop and market newer products and services brought about by market pressures.

Innovation in the private sector is dominated by foreign companies. Many now have their own captive R&D centers involved in high level innovations, while others often collaborate with Indian partners. However, apart from a few companies, it will take considerable time for truly global innovative companies to emerge from India.

Major innovation hubs are concentrated in three regions of the country; NCR in the North, Mumbai-Pune in the West and Bangalore-Chennai-Hyderabad in the South. Favorable Government policies and incentives, presence of academic and research institutes and development of allied industries have made these regions hot spots for innovation.

The huge domestic market and availability of skilled manpower at lower costs have made India an attractive R&D destination however; significant challenges still remain, to make the country a global innovation center.

The extent of industry academia partnership is limited. Availability of funds remains an issue. There is lack of angel investors supporting innovation due to poor risk taking ability. There is also lack of coordination between several agencies and organizations involved in innovation especially in the public sector. Currently, the contribution of academic institutes to innovation is lower compared to developed countries. There are only few institutes deemed ‘Institutes of National Importance’ like the IIT’s, IISc, CCMB, etc. that are involved in high level innovation. Active steps need to be taken to build more institutes and attract more students towards research activities. India also does not have enough number of expert advisors and the necessary social acceptability for risks associated with innovations.

Finally, the report concludes with the potential areas of opportunity and ways to engage Indian organisations. For European innovation agencies, there exists excellent opportunities at various levels in the present innovation ecosystem. Possible areas of engagement include project financing, knowledge creation and exchanges, managerial expertise, manpower training, course curriculum and pedagogy and joint development programs. These agencies need to create better visibility and establish a compelling value proposition amongst Indian counterparts. As a first step, promotions can be done through bilateral interactions, ministerial delegations, industry events and conferences. For government laboratories and universities approach can be made via respective ministerial departments of the central and state governments while private industries can be approached through industry bodies like CII, FICCI, ASSOCHAM or Chambers of commerce in different states. To tap into private universities, trust foundations or management boards can be independently contacted.

The appendix at the end provides contact details of major industry bodies, trade associations and some important collaboration. It also lists key sectoral events which can be a useful starting point for outside observers looking at entering this vibrant market.

2. SCOPE OF THE REPORT

This report makes an attempt to objectively analyze existing Innovation landscape in India from the perspective of technology/product R&D activities, focusing on the most active and demand generating thematic areas along with the underlying ecosystem. For the purpose of this report, 'Innovation Hotspots' refer to a combination of thematic areas and geographic clusters. The European Association of Innovation Agencies (TAFTIE) is currently looking into how its member agencies can promote internationalization and this report will form the starting point to devise a systematic approach for international innovation cooperation with India. Therefore, the report will assess;

− Regions or spatial agglomerations that is interesting for European innovative firms. And thematic areas, industries that might be interesting for European firms

− Likely future development of the relevant innovation hot spots (which could be both spatial and thematic)

- Factors those are likely to affect the demand and supply for/of innovative products and services in India in the future (e.g. economic, social, political, regulatory, technological, demographic developments)

− Key players/bodies and decision makers in Indian innovation

− Possible research and innovation collaboration opportunities for European companies/countries at different levels like:

I. Governmental Level

II. Educational Institutions

III. Industrial Bodies and Chambers of Commerce

IV. Private Initiatives

V. Industry Level

VI. European Program

Innovation as defined by OECD comprises of 4 types;

I. Product innovation - This involves a good or service that is new or significantly improved. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics. In the education sector, a product innovation can be a new or significantly improved curriculum, a new educational software, etc.

II. Process innovation - Process innovation involves a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software. In education, this can for example be a new or significantly improved pedagogy

III. Marketing innovation - Marketing innovation involves a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing. In education, this can for example be a new way of pricing the education service or a new admission strategy

IV. Organizational innovation - Organizational innovation involves introducing a new organizational method in the firm's business practices, workplace organization or external relations. In education, this can for example be a new way organization of work between teachers, or organizational changes in the administrative area

Innovation as defined by the National Innovation Council (NIC) India is a much wider spectrum. It states; 'Innovation involves thinking differently, creatively and insightfully to enable solutions/ inventions that has social and economic impact. Innovation should fulfill unmet needs not met by conventional products/processes and institutional forms. It is moving beyond R&D to mean new application of old technologies, new processes, structures, organizational creativity and more.

For the purpose of this report, Netscribes restricts the boundary of innovation to technology advancement largely for products and processes and attempts to map knowledge/IP creation in the recent past within the most active thematic areas with the brightest potential of future demand, arising because of economic, social, political, regulatory, technological, demographic developments.

3. METHODOLOGY

The report has been prepared keeping in mind the future evolution of Innovation landscape in India. Hence, the methodology adopted is a combination of desk research (literature analysis) and primary interactions with experts from government agencies, private industries and independent consultants involved with R&D activities. Insights into future developments and validations of our findings from existing literature has been put forth on the basis of these interactions with different stakeholders involved in the innovation propagation in the country.

Desk Research (Literature Analysis)

Extensive research and evaluation has been conducted of published literature from sources including, government portals, company websites, proprietary databases, trade journals, consulting firms, industry bodies, research papers and blogs etc.

Primary Research

Semi structured, open ended interviews have been conducted with senior officials of government agencies, public and private companies, universities and independent consultants to understand the current innovation spectrum in the country. The interviews also intended to gain insights on major focus areas and R&D activities being conducted in each field, challenges facing the nation and future directions that might emerge from the demand side. The interviews were conducted based on a questionnaire, designed specifically to derive relevant responses and opinions. In order to obtain a rounded view of the subject, respondents contacted were from different spheres of work. Total number of experts contacted was 32 as per the following composition;

Government Agencies	Academia	Private Industries	Consultants
10	8	12	2

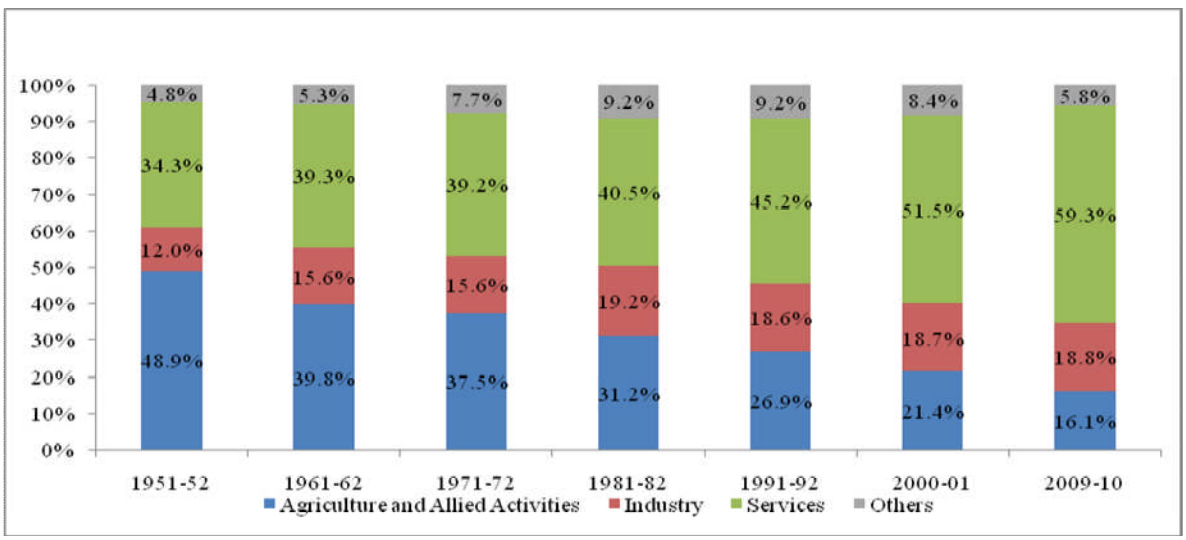
4. INDIA – AT THE CROSSROADS

ECONOMIC DEVELOPMENT

Indian civilization dates back 5000 years and was amongst the most eminent in its time. Trade, culture, and knowledge all intertwined made it a vibrant region then. However, the story of modern India, which embarked on its journey as an independent nation in 1947 after achieving freedom from the imperial rule of the British, is quite different. Post industrial revolution, India had lost its pre-eminence in practically all aspects of economics. With centuries of neglect under colonial subjugation, the country had been reduced to a poor stagnant nation reminiscing of its old glory. The economy then was largely agrarian with little pockets of industrial clusters in and around large port cities like Kolkata, Mumbai and Chennai. Social indicators were equally poor; illiteracy was as high as 84%; public health services were inadequate and mortality rate remained high at around 27 per thousand.

Post independence, under successive governments the country began to emerge steadily. Economic activity gained momentum with state sponsored industries mainly in the primary sectors. Private enterprises emerged slowly to compliment growth and propagate development in the country. The figure below illustrates the development of the Indian economy since independence.

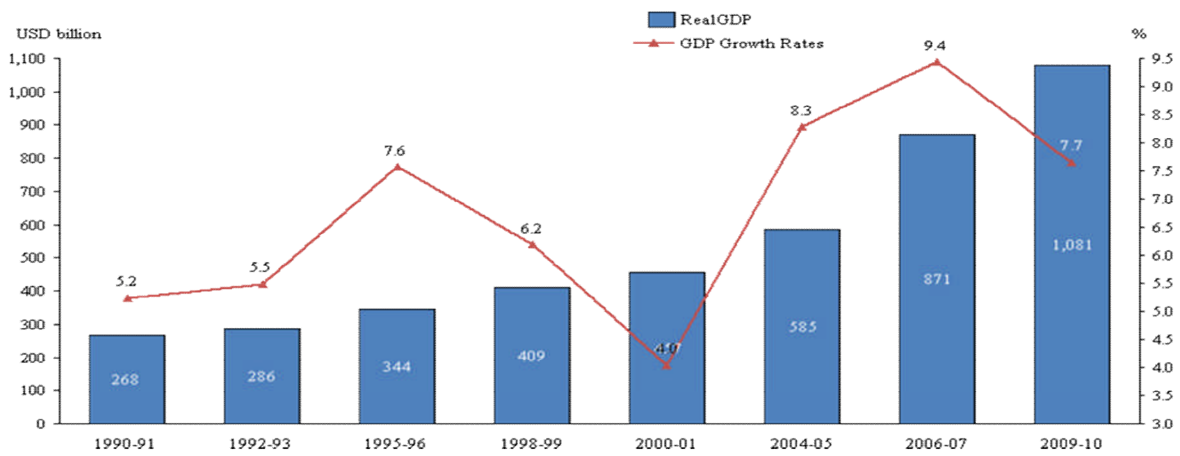
Chart 1: Share of key sectors in Indian economy



Source: Reserve Bank of India

However, amidst this development, through several decades, India remained a closed economy with marginal foreign trade. The policy of self reliance professed by nationalist governments, attempted to protect state owned businesses from competition both internal and international which in effect hindered economic growth and rendered industries inefficient. Products and services were of basic qualities and not easily available to most people. In contrast, today, India has a dynamic economy ranked 12th largest in the world by nominal GDP and 4th by PPP growing at an average of 7% since 1997.

Chart 2: Growth of the Indian economy



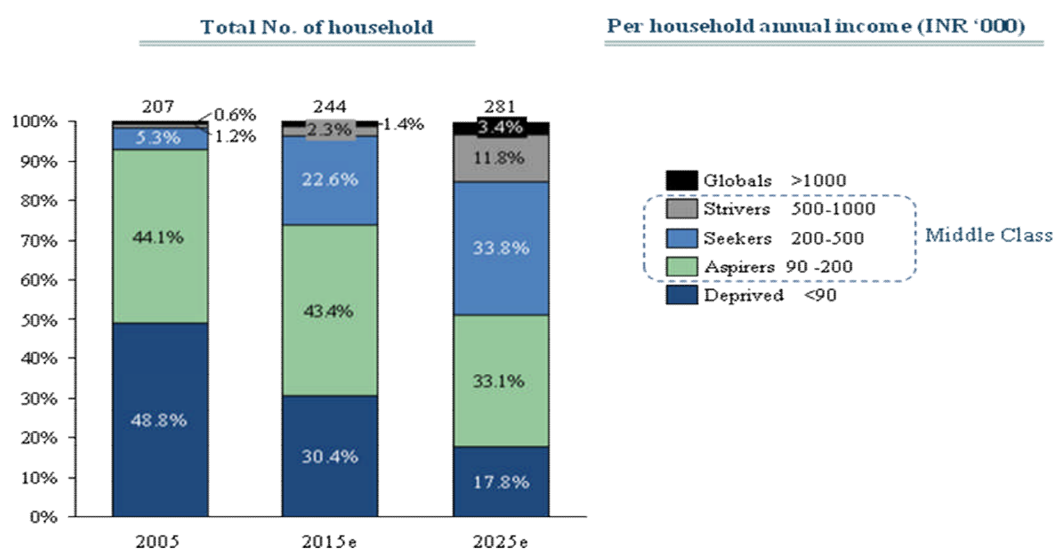
Source: Reserve Bank of India

Post liberalization in 1991, cautious steps have brought noticeable changes to the economy. Most sectors were unshackled in order to make industries more competitive, productive and efficient. Many more cities emerged like Bengaluru, Hyderabad and Ahmedabad. Today, the country has numerous companies coexisting with global powerhouses, operating and vying for the domestic market and competing for exports which have grown multifold. The thriving services sector too have experienced meteoric rise since the time of the 'License Raj'. Today, the services sector constitutes 59% of the country's GDP and has been growing at over 10% annually over the past few years. Nevertheless, with this continuum of evolution from an agrarian economy to an industrialized one, there have been some disruptive developments. One amongst those that needs serious attention is the economic disparity, which has widened further. On one hand around 50% of the population still lives below USD1 per day while on the other, the 'upwardly mobile' class holidays abroad twice a year. In this new realm, India stands at a crucial juncture; it needs to balance both industrial ambition with social obligation of bringing its deprived population into the ambit of growth and prosperity.

SOCIO-POLITICAL DEVELOPMENT

There have been significant changes in the social and political environment in India. From the days of the bullock carts, unpaved mud roads and almost no electricity, today India has Formula1 track, Volvo buses, Mercedes cars, 3G wireless handsets etc. The cycle of development has been quite astounding considering that just 60 years ago the country was a wreck of its glorious past. However, as no development can happen in isolation, the economic growth was backed by socio-political changes across all levels. From feudal landlords and the Maharajas, from caste based communities practicing sati and untouchability there has been a constant transformation and a steady rise of the middle class devoid of the emotional baggage of the by gone era, focused on self development and progress. This section of the population estimated to be around 350 million or 30% is the prime mover for consumption that has more or less driven growth for most industrial and service sectors. In the near future, the growth of the middle class will further boost consumption of all products and services with a more discerning zest.

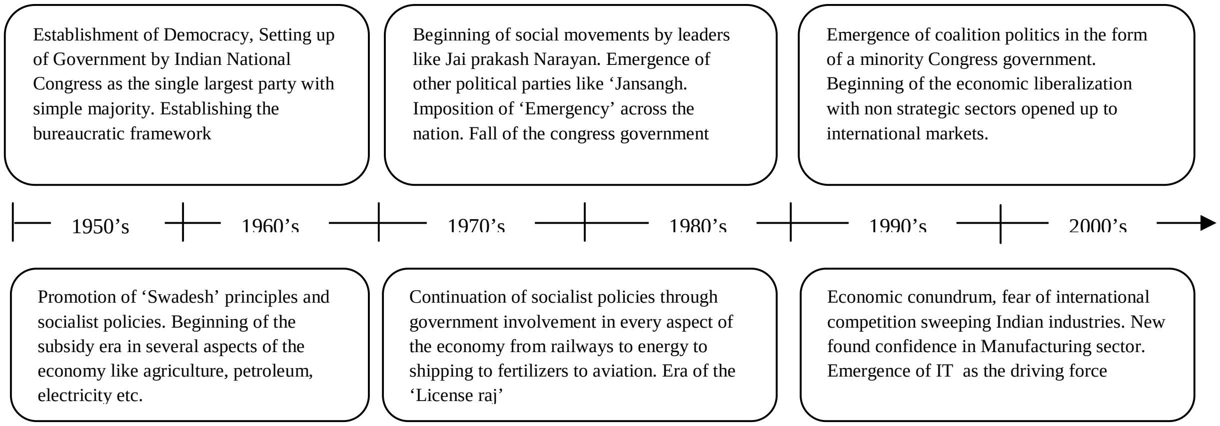
Chart 3: Forecast of demographic profile



Source: Mckinsey Institute report (2007, 2010)

Along with the societal transformations, India has undergone waves of notable political changes. Politics has defined and influenced the rocky course the country has traversed to reach where it is today. From nationalist doctrines of self reliance 'Swadesh' to globalization and making a statement to the world that India has arrived and is going to play an important role in the future.

Figure 1: Political developments since independence



Over the course of 60 years, single party governments have given way to coalition politics where multiple parties with varied agenda join hands. Different forces act on the government to accommodate and include different sections of the society in policy making bodies. Amidst this new reality, however, successive governments have tried maintaining a balance between growth ambitions and sustenance. Unfortunately, in order to please the polity, policies regarding the latter have always taken strong precedence. In effect, the country has failed to successfully implement either. Since the dawn of the new millennium, the focus of the governments has been more practical and pragmatic, due to which there have been definite improvements in growth objectives and sustenance initiatives to bring about inclusive development.

EVOLUTION OF THE INDIAN INNOVATION SYSTEM [1]

India as a country has a long and distinguished history of learning, knowledge development and innovation. The tradition of science in India extends back millennia when India was the world's largest economy in the first millennium, producing a third of global GDP. Aryabhatta, Bhaskara, Brahmagupta and others from that era are still celebrated for their foundational contributions to the fields of mathematics, astronomy, and chemistry. Ayurveda, the science of longevity, has its roots in scholarly writings as far back as 800 BC and still plays an important role in modern medicine in India. Indian mathematicians can also stake strong claims to being the inventors of the mathematical concept of zero in

[1] Ministry of Commerce and Industry, Cygnus Research

around 600 AD as well as the decimal system. Even Pythagoras is said to have learnt his basic geometry from the Sulva Sutras.

The next major stage in India's innovation journey was the introduction of modern science by the British. During this period, the structures, foundations and guidelines for science were laid down. The British established the first universities in India in the late 19th century and imposed English education to the country. The English system of education was rapidly adopted and propagated by the Indian elite. Indians started receiving more and more training not just locally but also in Europe, Britain in particular, and were directed into scientific lines of enquiry laid down by the West in institutions that followed Western design.

But it wasn't until independence was achieved in 1947 that the nation began pursuing what could be called an innovation system. The development of the national innovation system in India can be divided into three phases, starting with the period between independence and the first steps of modernization and concluding with the last two decades of economic reforms and rapid growth.

Phase I: Focus on self reliance, post independence

India's economic policies were strongly based on achieving self sufficiency post independence, probably a result of the colonial past. The Government's focus was higher on self sufficiency than growth. This resulted in a "License Raj" characterized by development of protectionist policies that adversely affected the country's innovation capability. Under import substitution, local manufacturing was encouraged to reduce dependence on foreign production. Government approval and permit was necessary for technology import, setting up a new plant or increasing capacity.

These policies significantly limited internal competition but did not deter growth completely. Indian companies resorted to reverse engineering and replicating foreign technologies. The patent law during this period made it easier for companies to domestically produce foreign inventions. However, reverse engineering and manufacturing did require significant creativity and expertise. To develop these skills, a network of Indian Institute of Technologies was established in the 1950s. These network of nation wide engineering institutes provided excellent education creating a technically skilled talent pool. India also started building a scientific R&D system to complement the industrial base.

A resolution in 1958 on Scientific Policy declaring that "technology can only grow out of the study of science and its applications" established a political resolve with respect to technological development. In 1974, the Government came up with a Science and Technology Plan that reformed import substitution for enhancing indigenization of technology but continued with the centrally designed R&D program. The plan outlined development of technology in 24 sectors and several subsectors. Although the plan was comprehensive, its implementation was hampered because of changes in budget, inadequate political support from different government bodies and administrative reorganizations. Although the plan fell short of achieving the declared objectives, it did represent a systematically developed Science & Technology (S&T) policy than the one prevalent in many developing countries. The Council of Scientific and Industrial Research (CSIR), established in 1942 to assist industrial development was and still is the major source of government sponsored R&D. The body in charge of the 1974 S&T Plan was dissolved by 1977 and then reconstituted. The S&T policy regained focus in the VI Five Year plan developed in 1980 and ushered in the next important phase in the advancement of the innovation system in India.

Phase II: Move towards change

Self sufficiency in technology continued to be the top priority in the VI Five Year Plan. Formation of the Scientific Advisory Committee to the Cabinet confirmed the importance of developing S&T capability. This body allocated specific objectives to existing institutions and also started implementing certain stalled measures outlined in the 1974 plan.

A major policy change emerged with the Technology Policy Statement of 1983 which explicitly supported creation of R&D entities in the private sector. It also incentivized setting up of research labs and partnerships with national research entities. The policy statement was amazingly forward-looking compared to earlier policies with respect to technological change. The result of this was the creation of the Technology Information and Forecasting Assessment Council (TIFAC). In 1985, Texas Instruments became the first multinational to establish a foreign R&D center in Bengaluru creating a milestone.

1985 also witnessed initial economic reforms by means of trade liberalization that reduced number of products requiring import licenses. Even though the growth rate increased, industrial output continued to be influenced by controls on the industry and imports. Technology self reliance continued to be the dominant theme during this period and was confirmed by the Research and Development Cess Act of 1986. The Act levied a tax of 5% on technology import by industry. Although the old industrial license regime nominally still existed, the government was keen on encouraging entrepreneurs to pursue new industries and technologies.

Phase III: Liberalization of the Indian economy and Internationalization

The 1990s marked the turning point for India. Burdened with high inflation, high deficits, exchange rate problem and an escalating balance of payments crisis, the government had to seek support from the International Monetary Fund (IMF) to bail it out. The IMF offered conditional help forcing the government to liberalize the economy by instituting reforms. The “License Raj” was dismantled to a large extent except for few select industries. There was automatic approval for 51% FDI. Technology imports and engaging foreign professionals were approved more freely. Underperforming public sector organizations would be restructured or even privatized.

In spite of these reforms, the idea of self sufficiency remained and change in the old policy on S&T was slow. The reforms opened up India for domestic as well as foreign competition forcing a relook at the S&T plan. The S&T policy of 2003 laid the perspective for a national innovation system. The idea of self reliance had also evolved in to a thought of prosperity based on India’s terms. The 2003 S&T policy does not mention concrete actions but outlines national innovation objectives, some of which include:

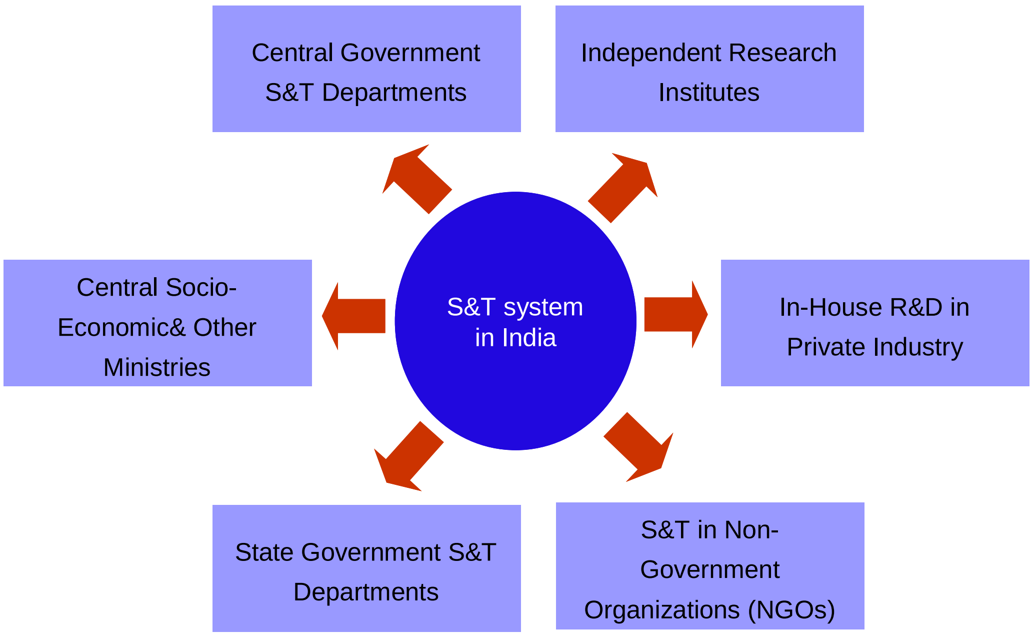
- Increasing share of R&D investments to reach 2% of the GDP
- Commitment to IP reform
- Increasing autonomy and bringing professionalism in national science entities
- Providing financial incentives to industry for in-house or outsourced R&D
- Enabling national labs & universities to set up offices for technology transfer that are independent of the government

India is now transitioning to an era of scientific interdependence. There has been a significant change in thinking regarding internationalism. Earlier, science was considered predominantly a national activity for self reliance, now it is viewed as an international activity which depends on global network of discovery ad knowledge sharing. There is a commonly held ambition among scientists as well as a drive from the government to become a hub for global science through increasing international linkages.

INNOVATION SYSTEM IN INDIA

The Government has played a key role in developing the innovation system in India. The Government’s Department of Science & Technology (DST) describes the S&T system in India as follows:

Figure 2: India's science and technology system



Source: Department of Science & Technology, Government of India

The Indian Government has six departments that deal exclusively on S&T matters. These include:

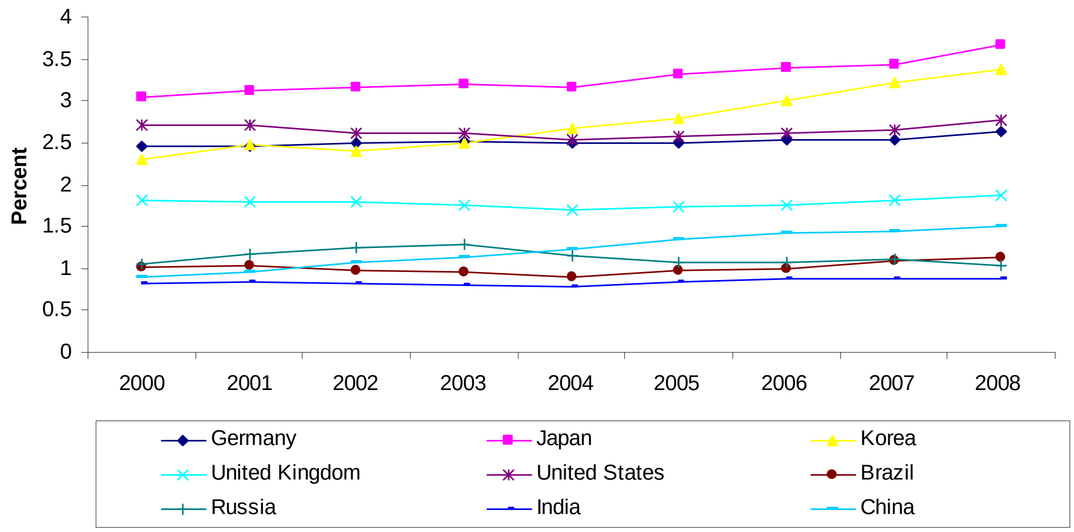
1. Department of Atomic Energy
2. Department of Biotechnology
3. Department of Earth Science
4. Department of Science and Technology
5. Department of Scientific and Industrial Research
6. Department of Space

In addition, other Government departments having significant R&D operations include

1. The Ministry of Defence
2. Department of Agriculture and Cooperation
3. Department of Chemicals and Petrochemicals

The aggregate domestic spending on R&D in India has never surpassed 1% of the GDP. Over the past 20 years, domestic R&D spending in India as a share of GDP has fluctuated between 0.71% and 0.91%. India has the lowest spending on R&D as percent of GDP of the BRIC countries who spend over 1% of their GDP on R&D activities.

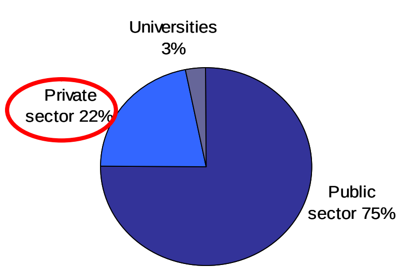
Chart 4: R&D spending as percent of GDP

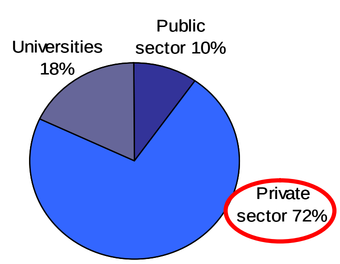


Source: OECD

The Government through public sector organizations and institutes is the dominant contributor to spending on domestic R&D. With respect to the distribution of domestic R&D spending, India is at a typical initial innovation stage. For instance the public sector in India contributes to around 75% of the spending on domestic R&D compared to only 10% in OECD countries.

Chart 5: Domestic R&D spending in India and OECD countries





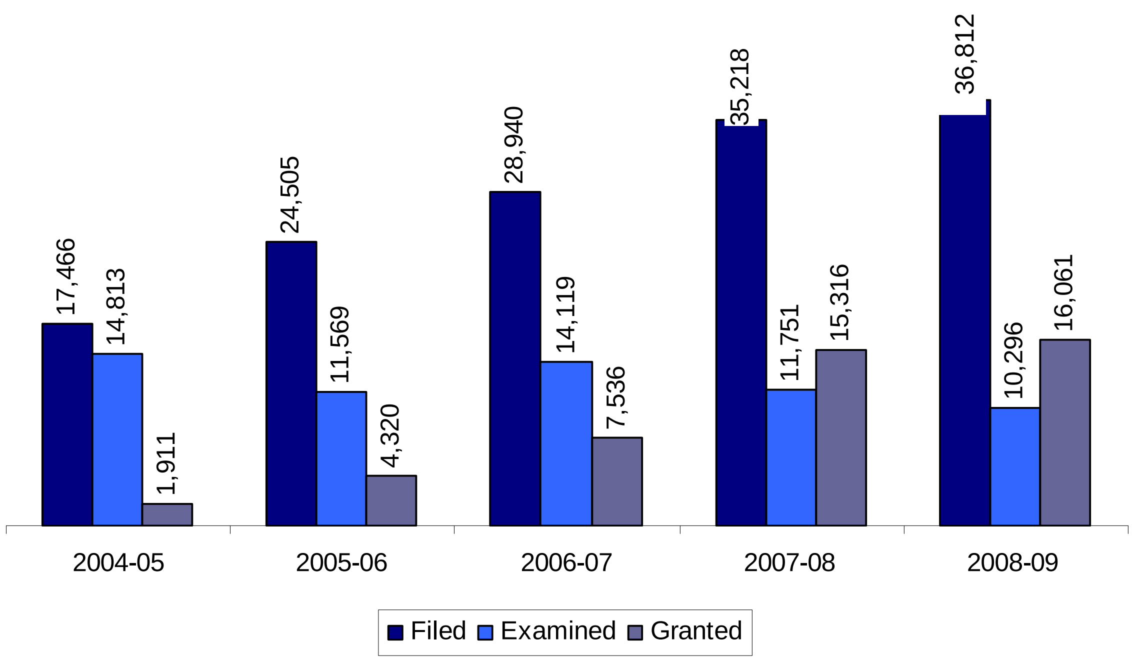
Source: OECD

A major component of the private sector R&D is through offshore R&D undertaken by foreign companies. There are about 600 foreign R&D centers in India. Initially the offshore R&D centers were confined to testing and repetitive routine tasks and were thus secondary entities. As these centers matured, they developed local partnerships and networks and started influencing the research direction. Some of these centers are gaining significant autonomy and have even been able to innovate to an extent that they have built products catering to the global markets. Foreign companies with their offshore R&D centers are thus contributing to the widening, deepening and maturing of the innovation ecosystem in India. However the number of such centers with the necessary authority to pursue collaborative R&D in the country needs to increase considerably.

INNOVATION OUTPUT

Patent filings and published science papers serve as common measures to assess innovation in a country. There has been a considerable increase in patent filing trend from India in the last few years.

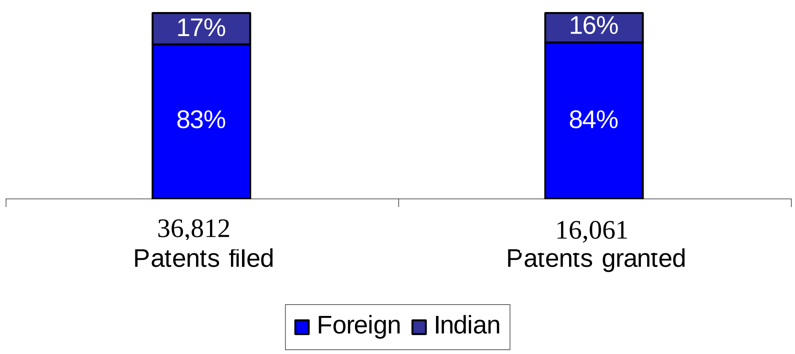
Chart 6: Number of patents filed, examined and granted in India



Source: Controller General of Patents, Designs & Trade Marks, Government of India

The number of patents examined and granted show significant variation because of the shortage of qualified patent examiners in India. Foreign applicants are more active in the Indian patent landscape. The number of patents filed and granted for foreign applicants has been increasing rapidly over the last few years and reached almost five times that of Indian applicants in 2008-09.

Chart 7: Number of patents filed and granted, Foreign and Indian applicants (2008-09)

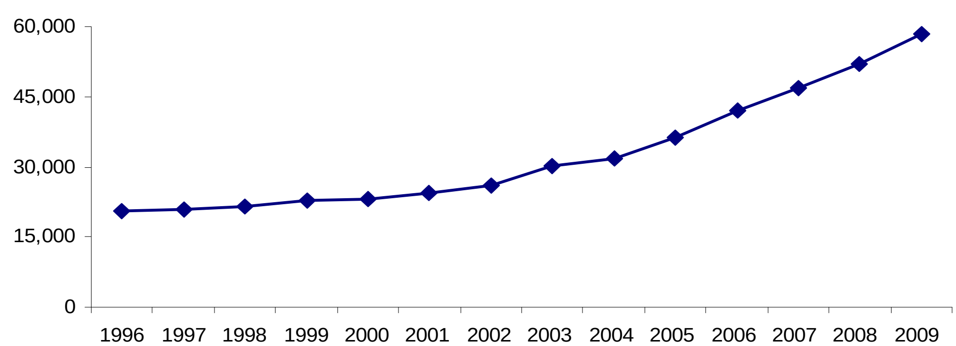


Source: Controller General of Patents, Designs & Trade Marks, Government of India

The above trend is a clear indication that foreign entities are increasing their R&D activities in India and ensuring that their intellectual property is protected in a developing and attractive Indian market.

The other most common measure of innovation is the publication and citation of articles in scientific journals. According to the Scopus International database, India has improved its global position in the area of scientific research, measured by number of research papers published, from 13th in 1996 to 10th in 2009.

Chart 8: Number of publications from India



Source: Scopus International database

India's output of total publications has nearly tripled from 1996 to 2009. However, the total number of publications during this period was only 10% and 30% of that of United States and China respectively. Although the number of publications has increased over the years, a more important measure to evaluate impact of publications is the H-index. During the period from 1996 to 2009, India's position is 25th on the H-index. This implies that India's quality of research is low or the scientific community has overlooked publications from the country.

FULFILLING PROMISED POTENTIAL

India's rapid increase in innovation ability in the past several years is often praised, but it had the potential to be far ahead compared to its present state. During the first two phases of India's innovation evolution, many important parts necessary for a successful innovation system such as established industries, good quality education and national funding for R&D did exist. However, linkages between these components necessary to foster and sustain pure as well as applied scientific research were absent. Industries focused on imitation to meet demands of the import substitution regime. Professionals trained from the IITs had no incentive to work on new technologies and had to work in an environment where their skills could not be challenged. As a result majority of the bright professionals moved abroad resulting in costly 'brain drain' for India. Also, the national funding for R&D programs was not aligned to the needs of the industry

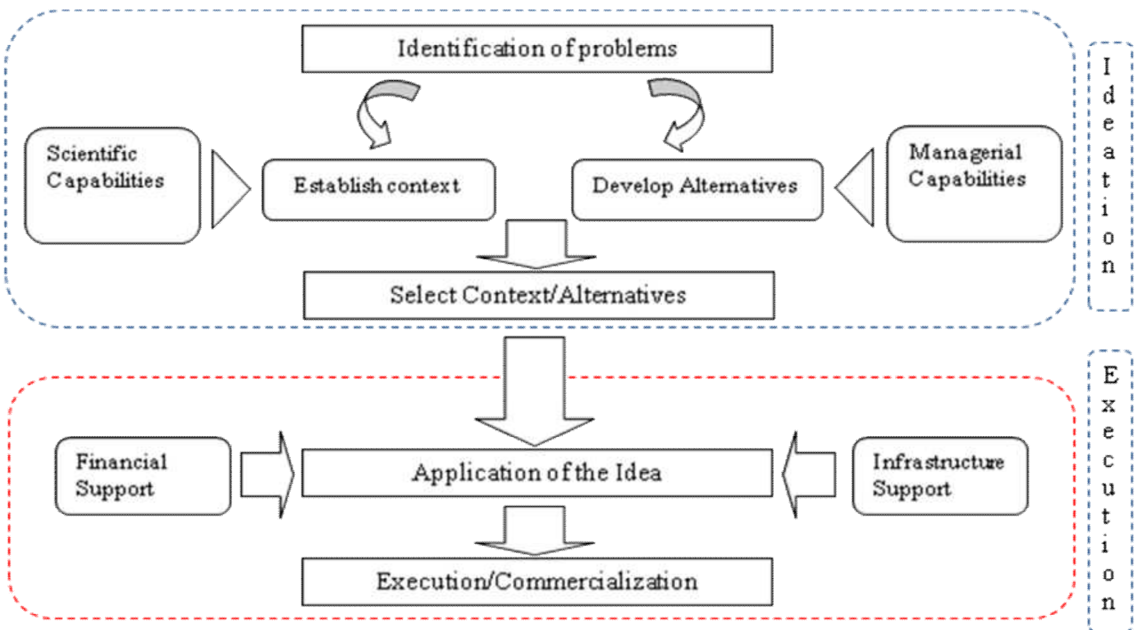
Although the systems for innovation were not in place, India had recognized the importance of S&T during its early development. By the end of the first phase and commencement of the second phase, India had built a core of educated engineers and scientists prepared to take advantage of the modifications in the national innovation system.

Innovation needs to be firmly established in the business environment and education covering a complete range from pure science to business processes. This phenomenon is starting to emerge in India, particularly in the pharmaceutical and biotechnology industries. However, an all encompassing innovation culture is still in its early stages. The trends though are encouraging and if India is able to capitalize on the knowledge from local and global sources and adapt it to Indian circumstances, it may succeed in its ambition to be a global leader.

PRESENT STATE OF INNOVATION

The present Innovation (R&D) ecosystem in India can be best described as unstructured. Over the decades, the government has promoted innovation and scientific knowledge accumulation in pockets like space research, defense, pure sciences etc. but never has this been institutionalized with a proper framework and ecosystem for its propagation and development. In the earlier days, it was only government sponsored research in its laboratories and universities that had the scientific community involved. While others who did not have the opportunity within the country went abroad for their scientific pursuits. In fact, only since the liberalization, has the private sector gotten involved with its fair share of R&D activities in order to develop and market newer products and services which have been brought about by market pressures.

Figure 3: Innovation ecosystem



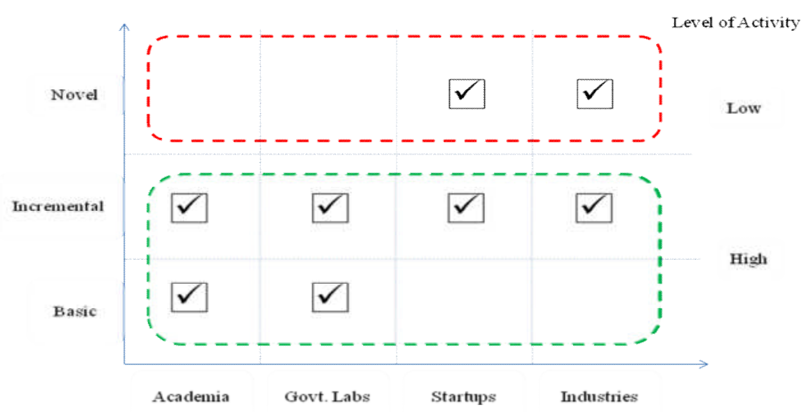
Source: Adopted from Venture Intelligence report 2009

In developed economies Intellectual capital always triumphs financial capital but the situation is quite different in India. In the advanced economies realization of innovation and the rewards is structured and transparent providing a strong incentive to the scientific community. Other than the monetary rewards, a well respected and long running non-monetary reward system exists which provides stature and credentials within the scientific community. Further, right from the idea generation stage, there is enough managerial capabilities who can provide the appropriate context increasing the chances of success of these ideas.

In India, many of the pieces in the execution stage are missing or are not present in a critical mass. The system of recognition of reward, both monetary and non-monetary is by and large political, faction ridden and not cognizant of merit due to which good ideas are not recognised most of the time. India also does not have enough number of expert advisors and the necessary social capability to accept the risks associated with innovations. Lastly, the ideas available for further dissemination and development also get adversely impacted by leadership and discipline issues.

The figure below depicts the current footprint of innovation activities conducted by Indian organisations. Most of it is concentrated around incremental innovation which is driven by market conditions. The government mandate to make goods and services affordable to the mass restricts its sponsored R&D activities primarily at the basic level though there are some instances of novel innovations happening both within the academia and government laboratories but are few and far between. Since the opening up of the markets and the inflow of international companies to these shores there has been a significant rise in the competitive intensity in almost all sectors of the economy. The expanding consumer base has forced organisations to be more efficient and quality driven. These factors have played a major role in bringing the private sector and entrepreneurs to gear up their R&D activities and remain relevant in the market. Infact, most of the market facing innovations in recent years has come out of private enterprises. While the level of activity still remains considerably low as compared to advanced nations, it is still a noteworthy development. Other than technology developments, there have been innovations in business and distribution models, organizational structures, packaging and pricing models etc as well.

Figure 4: Footprint of Innovation activities in India



Source: Adopted from NASCOMM- BCG innovation report 2007

Recognizing the challenges facing the country and the need to bring about a positive change to the existing innovation landscape, the Indian government has initiated major steps to institutionalize innovation ecosystem (scientific – industrial) through the formation of the 'National Innovation Council'. The question is, is it enough? The consensus amongst experts is, it is atleast a good beginning.

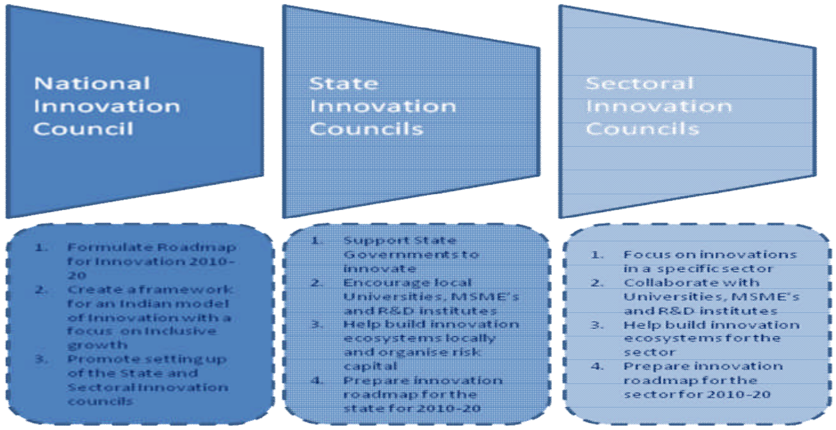
GOVERNMENT INITIATIVES

The government has embarked on a challenging mission to create a knowledge based economy for the country within the next couple of decades. With internationalization of the country's economy it has become imperative for India to differentiate from other emerging economies and to achieve that there is no better way than to innovate. The president has declared the 2010 as the beginning of the 'Decade of Innovation'. To take this plan forward, the Office of Adviser to the Prime Minister on Public Information Infrastructure and Innovations (PIII), Mr. Sam Pitroda, has started working on framing a national strategy, roadmap for innovation 2010-20 with a focus on inclusive growth. The idea is to create an indigenous model for development suited to Indian needs while recognizing domestic challenges.

The government has approved setting up of a National Innovation Council (NIC) which would be the first step in creating a crosscutting system that will provide reinforcing policies, recommendations and methodologies to implement and boost innovation performance within the country.

India has a strong pool of qualified people, both in the country and outside, engaged in innovation centric activities. This talent pool has to be engaged and leveraged upon to promote the innovation agenda. Further, the Government realizes, there is a need to capture the various innovations happening in different domains such as, R&D labs, universities, and across sectors, to give a boost to the innovation process. NIC role will be to act as a platform in order to facilitate this engagement and collaboration with domain experts, stakeholders and key participants to create a vibrant innovation movement in India. The aim is to herald a mindset change so as to bring more stakeholders, particularly from the grass roots level, in its fold to be a part of the shaping of national innovation strategy.

Figure 5: Proposed structure and role of Innovation councils



Source: NIC, 'Decade of Innovation': 2010 – 20 Road map

The broad guidelines of the innovation roadmap as proposed by NIC also points towards;

- Identify 20 innovation clusters across India based on sectoral ecosystems. These will enable interconnections between intellectual, financial, human and creative capital as well as unearth latent potential
- Create innovation centers in universities to strengthen industry- academia linkages. The idea is to go beyond IITs and established institutions and enable young innovators in the country
- Build a platform for international collaborations. These collaborations will be in the form of inter-ministerial exchanges, bilateral exchange forums or through linkages at the grassroots level. These cross-cultural exchanges will stimulate and add value to India's views on innovation
- Inclusive innovation fund, establish an autonomous fund of USD 1 billion. To be structured as a 'Fund of Funds' with seed capital from Government and built up by investment from private/public sector enterprises, banks, FIIs, HNIs and overseas investors. This will be based on a PPP model, to achieve a 10 to 20 fold multiplier on government investment

The different sectors/thematic areas which have strong underlying demand and also patronage from the government and private enterprises has been described subsequently under each chapter. These areas were narrowed down based on literature and patent analysis together with expert opinions. For the report we have considered the following areas;

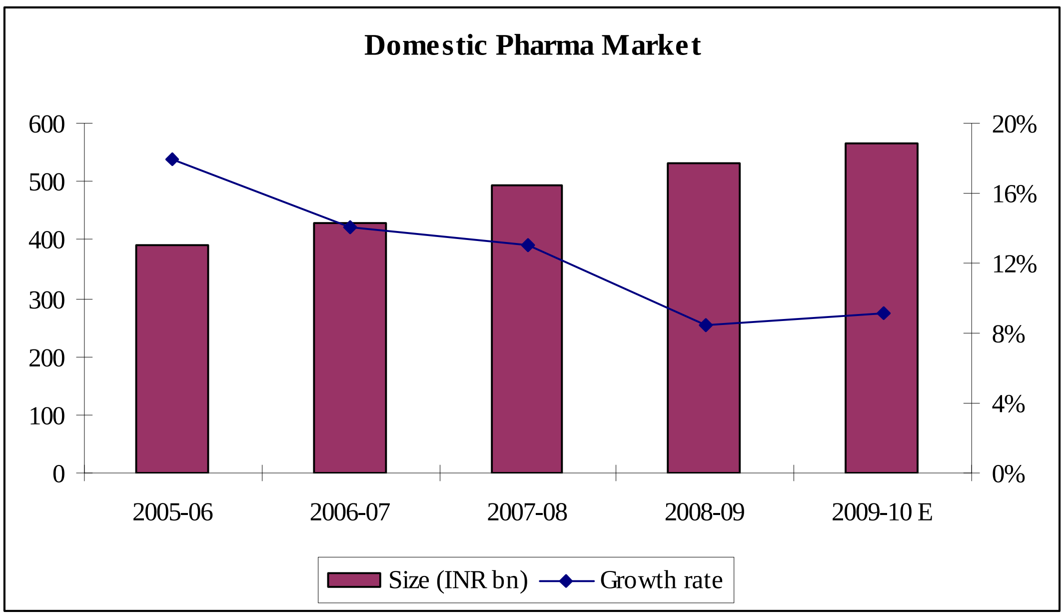
1. Pharma & Bio-Pharma
2. Information Technology
3. Telecommunication
4. Automotive engineering
5. Energy
6. Nanotechnology
7. Strategic areas (space & defence)

5. HEALTHCARE

PHARMACEUTICAL[2]

The Indian pharma industry has been witnessing a lot of change over the last few years, much of which has been driven by the introduction of product patents in 2005. The industry has also been growing at a rapid pace, led by both rising domestic consumption and a strong increase in export values. The industry ranks third globally in terms of volume and fourteenth in value. The primary reason for the lower share in value terms is because drugs in India are priced 5-50% lower as compared to those in developed countries. However by the year 2020 the industry is expected to be worth INR 1,354 billion. By this India is set to rise from fourteenth in the global market to among the top ten markets by 2020.

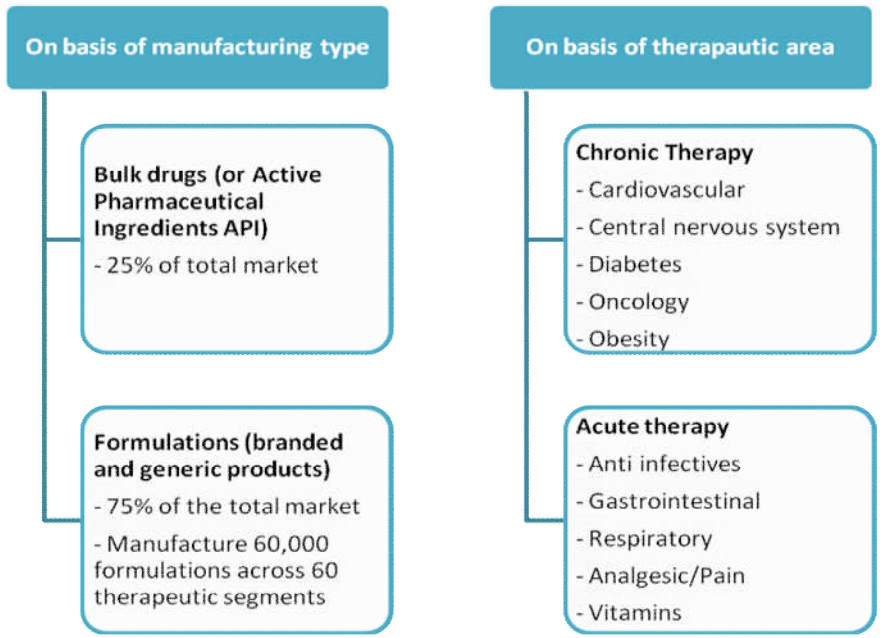
Chart 9: Domestic Pharmaceutical Market



The structure of the industry is highly fragmented and comprises of around 250 large and 80,000 small scale units involved in manufacturing, R&D, marketing and distribution. Out of these the top five companies comprise only 22% of the market share, while the top 20 companies make up 57% of the market. This number is low when compared to the global industry where the top 10 companies comprise 40% of the market.

[2] Ministry of Commerce and Industry, Cygnus Research

Figure 6: Market segmentation



- **Manufacturing type:** India has well developed capabilities in bulk drugs and has developed cost-effective technologies for manufacturing of bulk drugs. Over the next few years the share of bulk drugs is expected to increase with increasing dependence of international companies on the Indian market. At the same time, the Indian market is self sufficient in meeting the domestic demand for formulations; which are also being exported to the developing nations in CIS, South East Asia, Africa and Latin America.

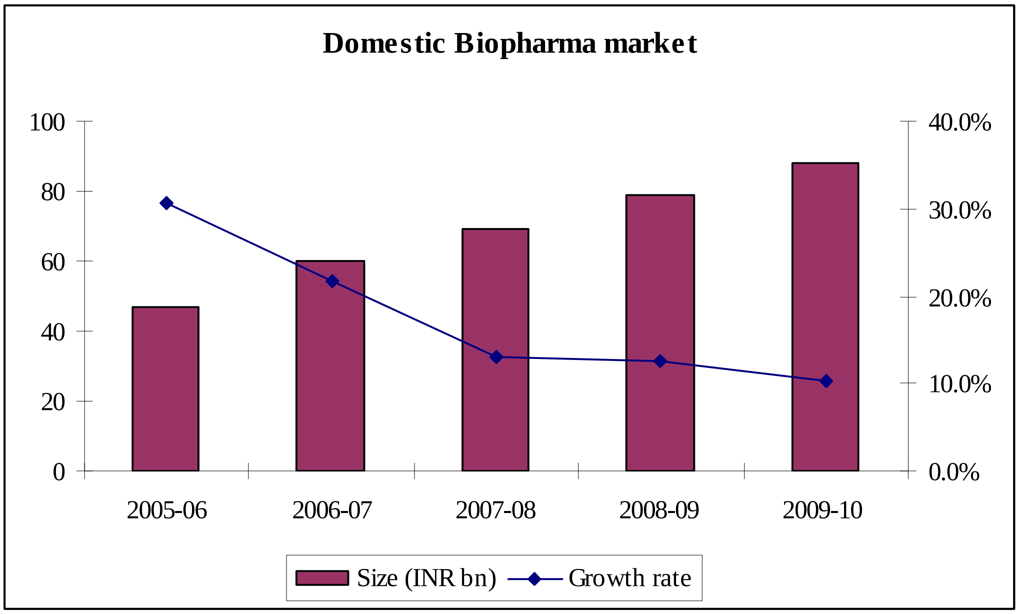
- **Therapeutic area:** There are two main therapy segments namely chronic and acute therapy areas. Chronic diseases are long term diseases which are mainly caused due to changes in lifestyle, stress and eating habits. Though chronic diseases constitute only 28% of the market; their share has been rising over the past few years. On the other hand, acute diseases are short term illness, the drugs for which are low value and for mass consumption.

BIOPHARMA[3]

The biotech sector comprises of five major segments namely bio pharma, bio agriculture, bio informatics, bio services and bio industry. Biopharma products are therapeutic or preventative medicines that are derived from materials present in living organisms using recombinant DNA technology. These may include recombinant proteins, short sequences of DNA, Therapeutic Monoclonal Antibodies and antigen and genetic vaccines.

The Indian biotech sector recorded revenues of INR 135 billion for the year 2009-10, a growth of 17% over the previous year. Out of this, the biopharma segment comprising of vaccines, therapeutic drugs, insulin, animal biologicals, statins and diagnostics accounted for 65% of the market share.

Chart 10: Bio-Pharma Market



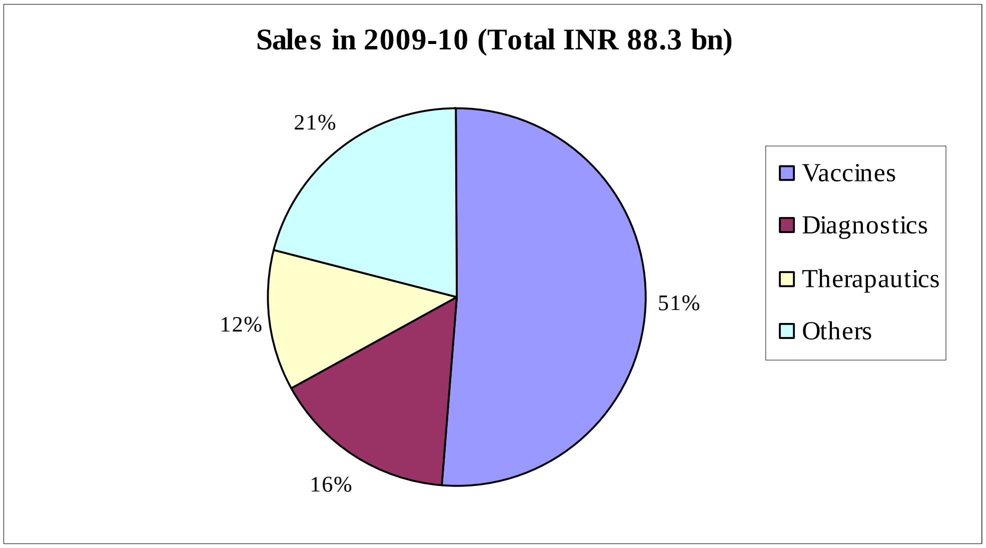
The biotech market comprised of 340 registered companies, with the top 20 companies contributing around 20% of the total revenue. Exports form a major part of the revenue and comprised of 53% of the total revenues for the industry

[3] BioSpectrum—ABLE Biotech Industry Survey 2010
Cygnus, Industry Insight – Indian Bio-Pharmaceuticals

MARKET SEGMENTS

Biopharma comprises of three main segments namely Vaccines, Diagnostics and Therapeutics. The chart below shows the percentage share of each of these segments for the year 2009-10.

Chart 11: Bio-Pharma segments



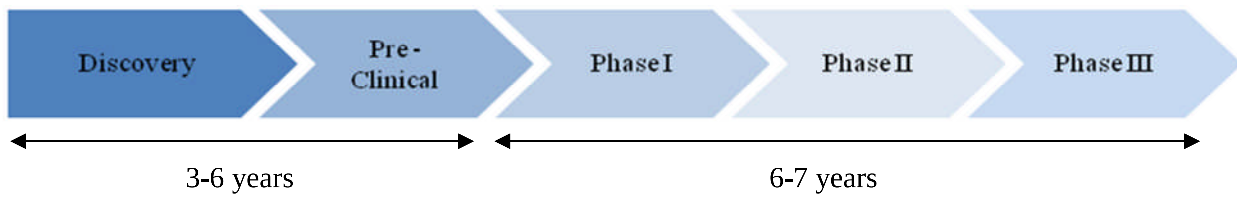
- **Vaccines**: Vaccines comprised more than half of the total revenues of biopharma sales in 2009-10. India has a huge market for both conventional vacancies and combination vaccines. There is a high demand for vaccines like DPT with Hepatitis B, Hepatitis A and injectable polio vaccine among others. Apart from these new rDNA and nucleic vaccines are also getting approval.
- **Diagnostics**: Diagnostics is also a large segment in biopharma. For the year 2009-10, the segment saw a growth of 12% over the previous year. Some of the major companies in this area are Bharat Biotech, Qualigens Diagnostics, Span Diagnostics, J. Mitra and xCyton Diagnostics
- **Therapeutic**: The therapeutic segment also saw a growth of 12% in the year 2009-10. The major therapeutic areas are tuberculosis, HIV, malaria, cholera, dengue, and cancer, typhoid and cardiovascular for which companies are developing biopharma products. Biocon, Eli Lily and Wockhardt are the major players manufacturing therapeutics.

INNOVATION IN INDIA

OVERVIEW[4]

India has always been a major hub of research & development activities in the pharmaceutical and biotech sector. A typical drug discovery and development process involves the following stages:

Figure 7: Drug – development process



The drug discovery process starts with the pre discovery stage which involves identifying and understanding the disease to be treated and the underlying causes of it. The next step is the identification and validation of the target to be treated i.e. selecting a single molecule such as gene or protein.

Subsequently, the drug discovery stage starts, which entails searching for a compound or molecule which acts on the target. Initial tests are performed on the molecule to test its safety. Further, the molecules are screened and their structure may be altered in order to make them more effective. After the discovery, the molecule goes for preclinical testing. In this tests are conducted in test tubes and also in living cells and animal models. Once a molecule passes the preclinical tests, it moves to the clinical trials stage.

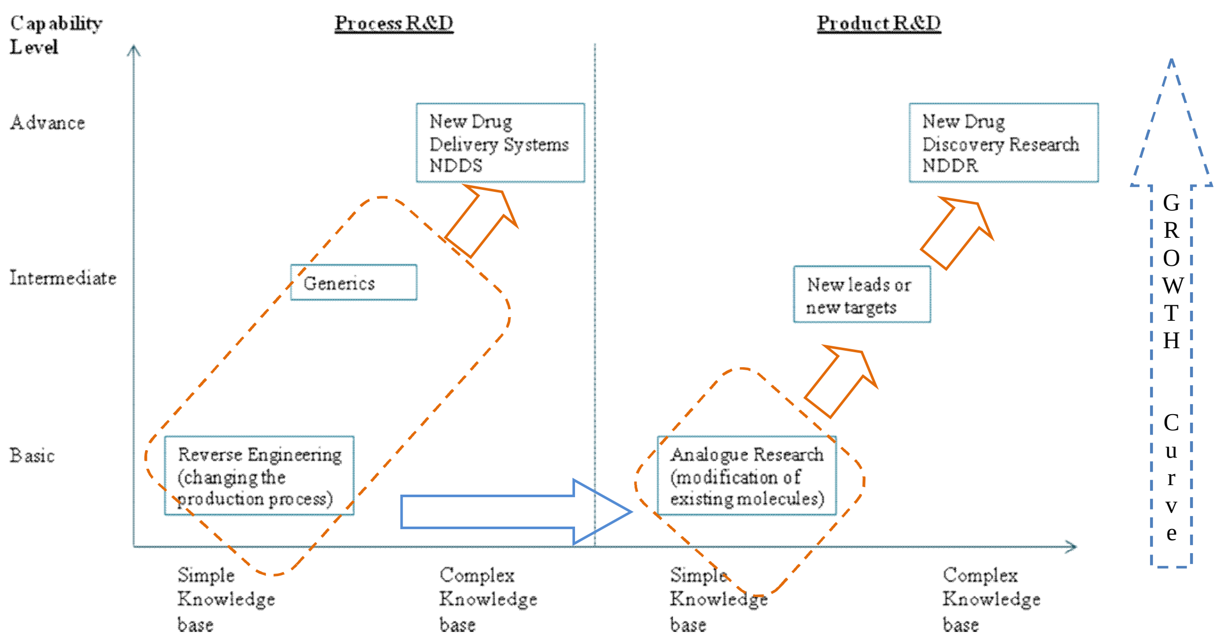
Clinical trials involve three phases of tests. These phases aim to identify if the drug is safe for humans, the possible side effects and associated risks, and finally its effectiveness. The number of patients on whom the tests are performed keeps increasing with each phase. A drug which succeeds phase III clinical trial is submitted for approval. Once approved, large scale manufacturing can begin. Though the process may appear simple it involves a lot of resources both in terms of time and money. The average costs for discovery and development are estimated between INR 36 billion to INR 45 billion.

Research and development activities carried on by pharmaceutical companies, can be in two main areas; process R&D and product R&D. In both of these the activities can be classified on the basis of the

[4] Innovation.org, Drug discovery and development process
DRUID Academy, Learning to innovate: The Indian pharmaceutical industry response to emerging TRIPs regime

capability levels. The movement of activities from basic to advance capabilities directly relates to the evolution of Indian pharma R&D activities over a period of time.

Figure 8: Pharmaceutical – Capability growth curve



Initially the large private Indian pharmaceutical firms focused their efforts on reverse engineering oriented process and development of generics. Along with them a few public laboratories under the Council of Scientific and Industrial Research (CSIR) also operated in pharmaceutical R&D, specifically imitative process R&D. Over the years India has become one of the major hubs for reverse engineering activities. This can be measured by the fact that the number of Abbreviated New Drug Applications filed by Indian companies has increased from 3 in the year 1998 to 181 in the year 2009. With sixty one blockbuster drugs worth INR 3.6 billion going off patent between 2011 and 2013, this segment is expected see rapid growth and most pharmaceutical majors are investing heavily to capture this opportunity.

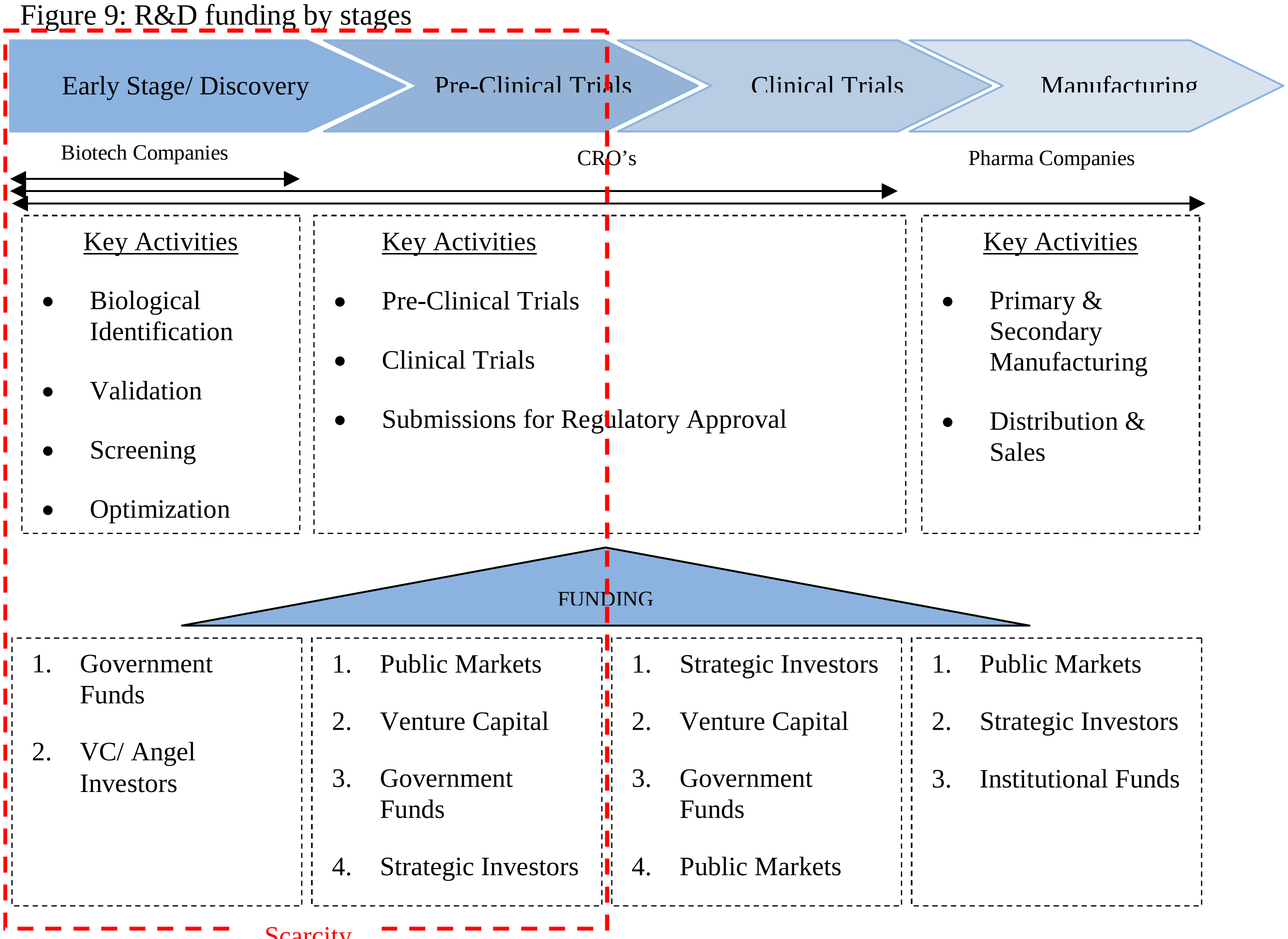
With development of a large number of generics, India established its capabilities in research and manufacturing activities. This in turn attracted a lot of MNCs to forge tie-ups with Indian companies for research, manufacturing and clinical trials activities. As a result; India has become a major hub for contract research outsourcing (CRO) activities. However, most of the research being outsourced has been related to basic research activities and clinical trials. This scenario is now seeing a change. There is a shift from a one way relationship to a mutually beneficial relation between the Indian company and its foreign counterpart. Most of the Indian CROs are now ready to invest in drug discovery and share the risks and rewards.

Indian companies have now started focusing on development of new drug delivery systems and development of new drugs. A shift is being observed from process R&D to product R&D activities. Even companies who are strong players in the generics market have started emphasizing on product R&D activities. Companies have realized that to compete internationally in the long term, they will have to develop their in-house research capabilities. In order to tap the patented products market companies are making changes to their business models. **Several companies have hived off their R&D unit into a separate division or a subsidiary. This in turn is expected to attract more investments and would enable scaling up at a rapid pace.**

Indian pharmaceutical sector is trying to develop its capabilities in preclinical and complex research in order to move up the value chain. Many companies have already forged alliances with a number of international companies and research institutes for various stages of drug discovery. In the future, a lot of strategic alliances are expected to be established between Indian and foreign firms and between the industry and academia. Initially this will be in the stage of development of new leads or targets. However, eventually the activities will move towards NDDR activities.

FUNDING FOR RESEARCH & DEVELOPMENT ACTIVITIES

Figure 9: R&D funding by stages



Expenditure on R&D activities in the Pharma and biotech industry is done both by the public and private institutions at varying levels depending on the stage of research. All major government institutes like Department of Science & Technology (DST), Council of Scientific and Industrial Research (CSIR), Indian Council of Medical Research (ICMR), Department of Biotechnology (DBT), Central Drug Research Institute (CDRI) have allocated funds for promotion of research activities specific to the industry. As of 2008-09, India was amongst the top 5 public funders worldwide for research on neglected diseases with investments of around USD 33[5] million.

Table 1: Funding through Government agencies

Government Agencies	Funding Amount (USD million)	Percentage
Indian Council of Medical Research (ICMR)	19.5	60%
Department of Biotechnology (DBT)	5.1	15%
Department of Science & Technology (DST)	4.0	13%
Council of Scientific and Industrial Research (CSIR)	3.8	12%

A large portion of this investment was expended on following 5 major endemic diseases showing the concern of the government because of continued presence of these diseases in the semi urban and rural parts of India where most people do not have access to quality health care;

Table 2: Funding for diseases

Diseases	Funding Amount (USD million)	Percentage
Malaria	12.5	39%
Diarrhoeal diseases	4.2	12.9%

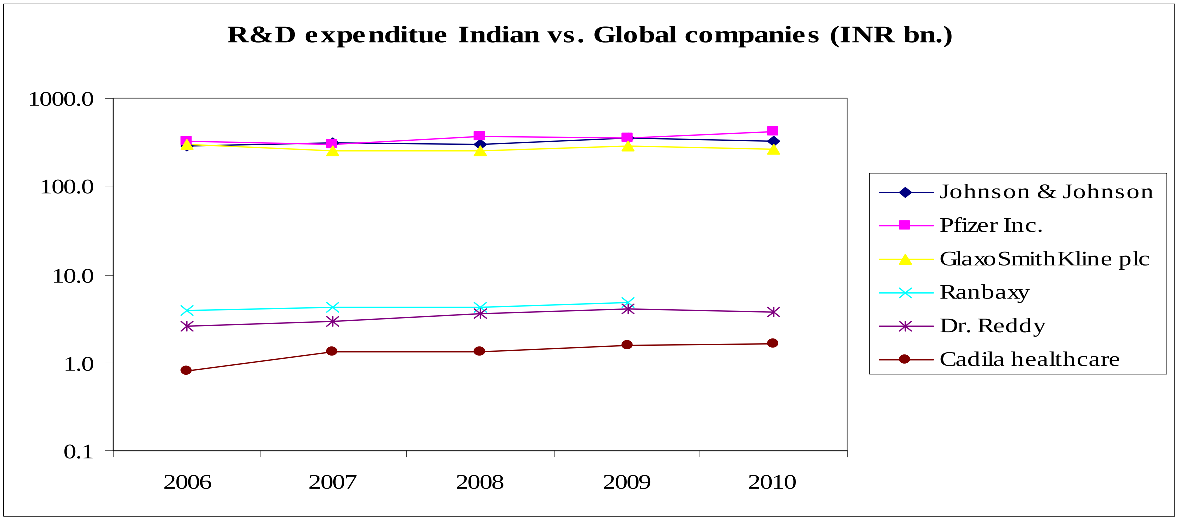
[5] Global Funding of Innovation for Neglected Diseases (G-FINDER) survey

TB	4.0	12.4%
Leishmaniasis	3.1	9.6%
Leprosy	2.7	8.3%

The industry is the also the focus of most other central institutes. For instance, the Science and Engineering Research Council (SERC) under DST had allocated 26% of its funds for life sciences projects in 2009-10. However, many experts feel that government and the associated institutes need to do a stronger evaluation of projects before funding it. The success factors and the market potential of the product should be evaluated properly to ensure that the funds are channeled in the right direction. Secondly, the industry also needs to be more proactive in utilization of the allocated funds. **As per experts, a related concern in this area is when the benefits of public funded research get transferred to a foreign company**. **The main purpose of public funding through direct and indirect measures is to meet the local healthcare needs and develop domestic capabilities. However, with a number of mergers & acquisitions taking place, the benefits of such funds get transferred to a foreign entity. The government bodies are considering formulating policies for this, which may impact the transfer of research assets or intellectual property rights.**

Along with the public institutes, the private sector has also stepped up its investments particularly for drug discovery and development in the past few years. However, the research budgets of top pharmaceutical companies in India are still low when expressed as a percentage of sales. On an average the R&D spends of India's leading pharmaceutical companies is around 5-7% of their total turnover. On the other hand, for some of the large western companies it is almost 20% of the turnover. Though domestic companies have significantly increased their expenditure on R&D, it will take a long time to come even close to the level of their global peers.

Chart 12: R&D expenditure – comparison with global peers



Apart from the big companies a lot of research and innovation related activities are being carried out by small and medium enterprises (SMEs). In most cases the research investment for such companies comes through a mix of government funding and Angel investors or Venture capital (VC) firms. With the focus on Pharma research rising in the country and a number of successful innovations coming from the SMEs, PE and VC firms have started adding Pharma companies in their portfolio. However, securing funds from PE or VC firms is no way easy for these companies. Many experts voiced their concern on the lack of angel investors in the country and the network of VC and PE firms focused on this sector. Another aspect that drives domestic VC firms is that they are always in the lookout for high revenue flow targets and seek to exit their portfolio companies within 3-5 years. Whereas, Pharma research activities take anywhere between 7-12 years to reap results. On the other hand developed regions like America and Europe have a very strong investor community that proactively invests in drug discovery and development.

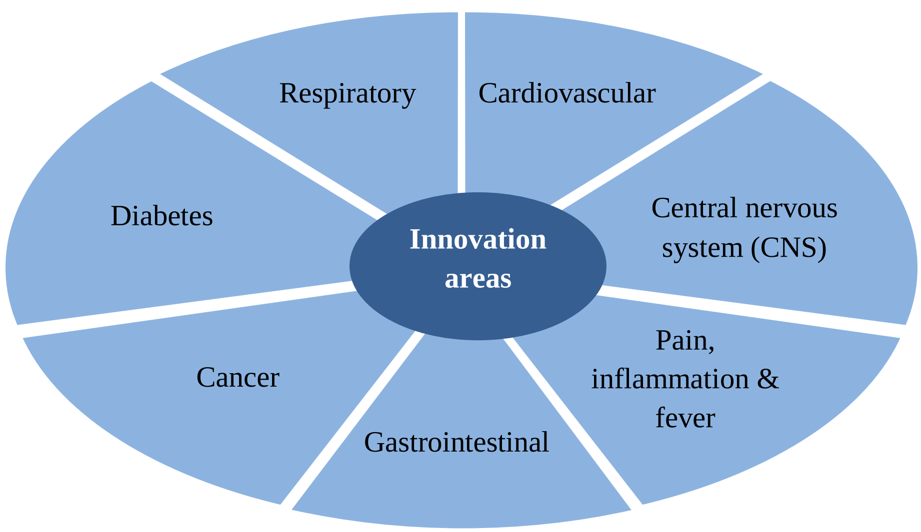
With a number of small firms undertaking Pharma research activities, the need for funding SMEs will rise rapidly as most of these firms do not have sufficient financial resources to sustain. Hence, they will look at both domestic and international partners who can fund their research activities. **European agencies focused on this industry can come in and fill the void. Apart from funds, the agencies can also provide management and administrative support to these companies to bring their efforts to fruition.**

KEY INNOVATION AREAS[6]

In emerging countries like India, two major issues drive innovation. First, more than 50% of the population does not have access to Pharma products and second is the rising price pressure from the government. Given this, reengineering and adaptation of technology from developed countries is not seen as the solution. Companies need to start basic research and develop cost effective yet world class technologies and products for emerging markets. Most Pharma and Bio-Pharma companies are concertedly undertaking innovation activities spread across different areas;

Therapeutic segments: Innovation in Pharma and Bio-Pharma can mainly be classified by the therapeutic segments. The demand for drugs in the Indian pharmaceutical market is beginning to mirror the demand in the global market with an increasing prevalence and demand for chronic diseases. According to the estimates of World Health Organization (WHO), India's mortality due to chronic disease will increase 18% by 2015. There are seven therapeutic areas where Indian companies are actively working on.

Figure 10: Active therapeutic areas



- Diabetes and hypertension are becoming rampant in India. This in turn, is also giving rise to other diseases like coronary heart disease (CHD). As such, companies are investing in new molecules for both cardiovascular disorders (CVD), diabetes and other lifestyle diseases.

[6]Netscribes Analysis
Deloitte, The Right Spice, Pharmaceutical Market Entry in India
Express Pharma, Regenerating stem cell guidelines

- Apart from coronary heart diseases, diabetes related mortality rates are rising rapidly. New therapies and innovations in delivery and disease management are expected to bridge treatment gaps

- Cancer is another therapeutic segment which is seeing increasing prevalence mainly due to high tobacco consumption. The high cost of cancer therapy currently is also expected to drive innovation in this segment to make treatment affordable

- The Central Nervous system (CNS) is also seeing a lot of attention mainly with diseases like Alzheimer's and other dementias, epilepsy, Parkinson's etc

- Apart from these therapeutic areas, HIV/AIDs and Hepatitis are also active areas for innovation amongst the Indian companies. India has been one of the leaders for innovative Bio-pharma drugs for Hepatitis.

Another reason for innovation in chronic diseases is that drugs for chronic diseases are likely to be used repeatedly over a long period of time. Further, in the Indian market, chronic therapies are newer molecules and have relatively less brand clutter and better patent protection. Driven by these factors, many Pharma majors are focusing on development of drugs for chronic diseases. However, with the market evolving fast MNCs will come in soon and would compete with local players to garner bigger share in these therapeutic areas.

Along with drugs for different therapeutic areas there are a number of other areas where innovation is happening in the country.

- **Vaccines:** Vaccine is a key focus area because it helps in increasing immunity towards a disease. Vaccines are being developed at a large scale both by Pharma and Bio-Pharma companies and research organizations. Especially in Bio-Pharma, vaccines occupy the major share of the market. A number of technologies are being used for development of vaccines like Recombinant vaccine, tissue culture based vaccine, genetically modified microbe, DNA candidate vaccines. Several companies like Serum Institute of India, Shantha Biotech, Biocon have already developed and commercialized a number of vaccines across different therapeutic areas. Many of these companies also have a robust pipeline for vaccines in their current portfolio. S**ome experts feel, vaccine development will see a lot of traction in the years to come and a combination of vaccines will be one of the thrust areas.**

- **Stem cell research:** Though India is one of the few countries pursuing stem cell research; regenerative medicines are still at it infancy. Stem cell research is being used to treat a variety of diseases like diabetes, cardiovascular disorders, neurological disorders, burns and wounds, osteoarthritis, osteoporosis, degenerative and traumatic disorders of bone and cartilage, and liver disorders among others. According to estimates approximately 164.4 million patients in India are expected to benefit from stem cell by 2011. Stem cell is also being explored to treat some diseases for which no cure is available presently with traditional medicines. Some of the key examples for this are hematological disorders, leukemia, metabolic disorders, bone and cartilage defects, corneal blindness, neurodegenerative disorders etc.

- **Drug delivery systems:** Apart from the therapeutic areas, companies are also innovating in the dosage forms and the delivery systems. Research is being carried out in different delivery systems like capsules, tablets and injections. The focus here is to reduce the frequency and number of drugs to be administered to the patient. For instance, Sun Pharma Advanced Research Company has developed its proprietary Depot technology for hormone dependant tumors which uses the conventional needle; offers long term drug delivery and lesser pain to the patient. Technologies like Depot have helped to reduce the frequency of injections drastically. Apart from this, many of these innovations are also being done to address the challenges in the domestic pharma market. For example, Emcure launched heat stable Emletra for HIV patients to address the absence of cold chain distribution in wide part of the country. Such innovations in delivery systems, address the issues with the current systems and the needs of the emerging markets like India.

- **Diagnostics and devices**: As preventive care is gaining prominence, demand for diagnostic kits will increase significantly. For e.g.: GE Healthcare designed and developed two ultrasound systems, GE MAC 600 ECG and GE VIVID P3 in India, which has now got FDA approval to take to USA. Devices will continue to be major area of focus for many companies.

Each of the above mentioned areas hold good opportunities of collaboration for European firms and agencies. Concerted effort to reach out to Indian counterparts through Trade associations/ Government forums and individual contacts can yield positive results.

NATURE OF INNOVATION

Innovation for cost effective products: One of the major thrust for research within the Indian Pharma and Bio-Pharma industry is the development of low cost drugs which can be benefit a larger section of the population. Earlier the industry had a major reliance on imported products which were not affordable by many. To bridge this gap, Indian companies and research institutes have endeavored and developed a number of drugs and vaccines which are available at prices way below the imported products. For instance, Biocon's flagship brand Insugen for diabetes is priced 40% lower as compared to its competing alternatives and so was Shantha's hepatitis vaccine. Such innovations have increased the accessibility and affordability of the drugs multifold for a larger patient population across nations.

Focus on both global and domestic market: The R&D activities being carried out in the country are focused both on the global as well as the domestic pharma market. Most of the domestic pharma companies undertake only a part of the drug discovery and development process. In most cases, the molecules discovered are licensed to global companies during the preclinical or clinical stage. As a result, the main focus of these companies is to discover drugs for the global market which has good licensing opportunities to the global MNCs. Few companies like Cadila, Panacea, Biocon have developed low cost drugs and vaccines for the Indian consumers, but now most of these products have a global market.

Along with the private companies a number of government research institutes have also invested and developed drugs and vaccines focusing on the neglected and the prominent diseases for the domestic market. Institutes like CSIR, CDRI and ICMR have focused their research activities especially for the Indian market. However these institutes also license out the drugs to private companies for commercialization in both domestic and foreign market. An important factor for this is that most of the drugs which are developed to meet local needs also have wide spread demand in other developing markets like Latin America, South Africa, Middle East etc. This acts as an attractive force for foreign companies to come to India. The investments made by them for research activities in India, can reap results at a global level.

DRIVERS FOR INNOVATION[7]

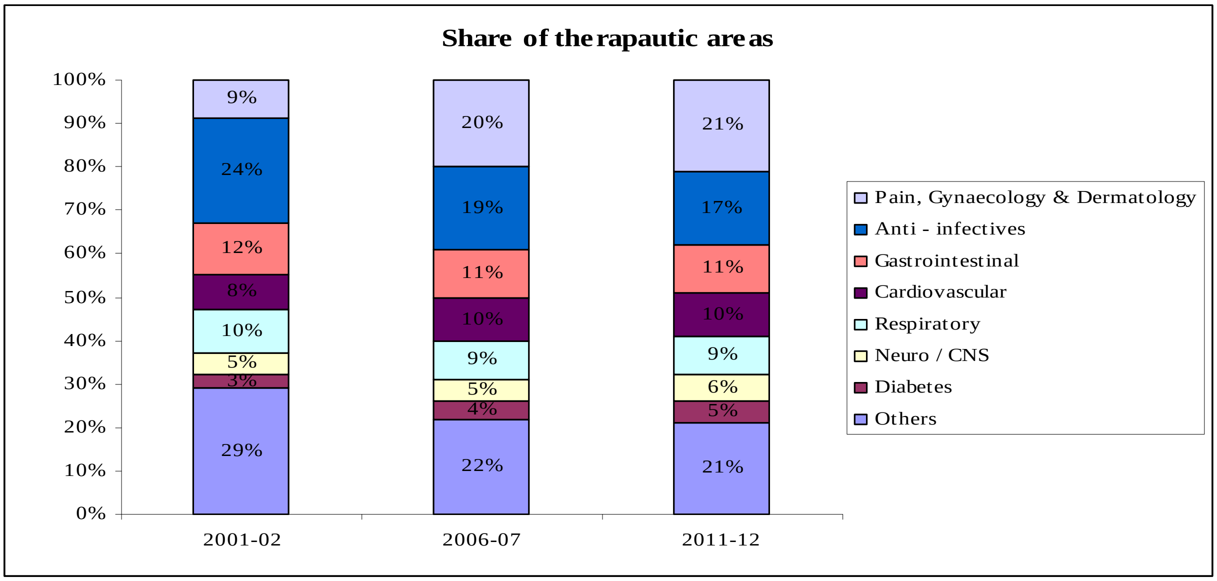
CHANGING EPIDEMIOLOGICAL PROFILE

With rise in the number of lifestyle diseases, India is becoming a large market for chronic drugs. Within this, the metabolic disorders are the most notable. This is turn is changing the epidemiological profile of

[7] McKinsey & Co., India Pharma 2015, Unlocking the potential of the Indian Pharmaceuticals Market
PriceWaterhouseCoopers, Global Pharma Looks to India: Prospects for growth

the country. As can be seen in the graph below, the share of various therapeutic areas has undergone a lot of change in the last decade.

Chart 13: Share of therapeutic areas



While the share of anti-infective and gastrointestinal diseases has decreased, demand for drugs for chronic diseases like cardiovascular and diabetes is set to rise. The demand for chronic drugs and the resultant shift in the therapeutic profile will directly impact the focus of both the domestic and foreign players. Most companies are likely to focus their efforts on developing new drugs for chronic diseases. Within this cardiovascular and diabetes will have the main focus in the chronic segment. However, along with chronic diseases the other mass therapies will also have a lot of emphasis. Demand for treatment of diseases like anti-infective, pain management, gastro intestinal, and respiratory will remain prevalent. There are two main reasons for this. First, in the current scenario only a fraction of the population receives treatment for the mass diseases. With a high gap between the prevalence and treatment numbers, the demand for drugs is likely to remain high. Second, with the increasing purchasing power of the lower strata, more people will be able to afford drugs for treatment.

DEVELOPING FOCUS ON PATENTED PRODUCTS

Historically, Indian market had a strong base of generic products. The implementation of the process patent law in 1972 made India a global hub in reverse engineering of novel drugs. India produces more than 20% of the world's generics and this is set to increase in the coming years. Further Indian companies constitute 35% of the Abbreviated New Drug Application (ANDA) approvals granted by the US Food and Drug Administration (FDA). Domestic companies are also entering into partnerships with large MNCs for development and marketing of their generic drugs.

However, with the implementation of the product patent laws this is set to change. Domestic companies are now focusing their activities on development of novel patented products. According to a report by Mckinsey & Co. the share of patented products is expected to reach 10% by 2015. Within this, the products are expected to be in five major segments including nervous system, oncology, anti-infective, gastro intestinal, and cardiovascular.

PATENT LAWS

The introduction of the product patent regime in 2005 has been one of the main drivers for innovation in the country. Prior to this only the manufacturing process was granted patent for a period of seven years. This had also led to a lot of legal disputes with western companies especially those of US. However, with signing of the TRIPS agreement (Agreement on Trade-Related Aspects of Intellectual Property Rights), the Indian pharmaceutical industry is undergoing a revamp. The industry is now subject to product and process patents which will be valid for twenty years. Companies can no longer use alternative manufacturing process. This in turn has encouraged companies to invest heavily in R&D activities for development of new chemical entities. Companies are now investing in innovation, development of new drugs independently and applying for product patents, rather than jus process patents. According to ASSOCHAM product patent regime will force domestic players to focus on R&D, which in turn will have long-term beneficial effects. As a consequence of these major changes to India’s drug patent legislation, the country’s pharmaceutical industry is undergoing a process of re-orientation. The industry’s new focus is on self development of drugs and contract research and/or manufacturing for western drug companies.

LOWER COSTS IN INDIA

The cost of conducting research in India is almost 50% less as compared to its counterparts in the developed countries. Further, India's long-established position as a preferred manufacturing location for multinational drug manufacturers is also making it a target location of outsourcing activities. Soaring costs of R&D and administration in the developed countries is persuading drug manufacturers to move more and more of their discovery research and clinical trials activities to the subcontinent or to establish administrative centers there, capitalizing on India's high levels of scientific expertise as well as low wages. Now, MNCs and domestic companies are starting to work together, utilizing each other's strengths for their mutual benefit. For the foreign firms, this includes not only the Indian companies' research and manufacturing capabilities and their much lower operational cost levels, but also comprehensive marketing and distribution networks operating throughout India's vast territories. Several MNCs are establishing their research base in India and also shifting their clinical tests. For e.g. Eli Lilly (US) has several projects ongoing in India and Pfizer (US) is carrying out clinical tests for malaria drugs.

HIGH LEVEL OF EDUCATION

Along with lower labor costs, India also provides a skilled workforce for the pharmaceutical sector. Every year, roughly 115,000 chemists graduate from Indian universities with a master's degree and roughly 12,000 graduates with a PhD. This is comparatively higher when compared to countries like Germany where the corresponding figures are under 3,000 and 1,500 respectively. This is turn has enabled the country to offer quality products at competitive prices. With the industry growing at a rapid pace, fewer students are now migrating abroad for employment. This also provides a boost to the sector.

CHALLENGES FOR INNOVATION

INADEQUATE REGULATORY SUPPORT

Even with government and regulatory bodies encouraging R&D, several challenges still remain. **One of the major initiatives was the compliance with TRIPS agreement in 2005, however all norms required for it have not been fully implemented. For instance, unless there is a significant improvement in efficacy, the Indian regulations do not recognize patents on incremental innovation.** This has major impacts, firstly, significant improvement is very subjective and becomes a point of contention and secondly this discounts several significant innovations because of ambiguity. The patent linkage mechanism is also not very strong in the country. As a result authorities grant marketing approval for some products without considering its patent status.

Apart from patents, the industry also expects more tax incentives and better SEZ policies for encouraging R&D activities. Further, there is also a need to reduce paper work required for and regulatory approvals. E-filing of all documents needs to be put in place to speed up all regulatory processes and improve transparency.

ACADEMIA

India has a good base of academic institutes but this is not as strong as that in developed countries. These institutes need to step up their R&D activities from basic research to applied research while taking steps to retain the best brains in the country. There is a need to invest more in training of students and encourage them to undertake research activities. Currently, the contribution of academic institutes in innovation spectrum is comparatively lower as compared to that in many other countries. There are only few institutes deemed 'Institutes of National Importance' like the IIT's, IISc, CCMB, etc. involved in innovation related work. Active steps need to be taken to build more institutes and attract more students towards research activities. A stronger skilled resource base would help in elevating innovation activities within the country.

INFRASTRUCTURE

One of the major challenges with the infrastructure is the absence of cold chain facilities across the country. Cold chain infrastructure is almost absent in the semi urban and rural areas. Investments in these facilities need to come from the public and private enterprises. Though India has good overall infrastructure base, but to make it a global hub for innovation activities, the existing facilities need significant improvements and additions.

FUNDING

Availability of funds, especially for smaller companies is a major challenge. Since small companies do not have enough resources they depend on government institutes and financial institutes like PE and VC firms for funds. However, getting adequate funds for the entire drug discovery process becomes tough and a long drawn process which slows down the innovation momentum. Since a lot of innovation is coming from the smaller firms, adequate channels for funding need to be provide to them. *According to Dr. Rustom Mody, CSO - Intas Biopharmaceuticals Ltd; "There is a need to improve the funding scenario in the industry. Currently, risk bearing for drug discovery is only being undertaken by the larger organizations. Since a lot of cutting edge research is being done by the SME's, their efforts need to be promoted through proper funding facilities. We need to have a strong base of financial institutions like PE and VC firm, and government loans or grant-in-aid to fund the R&D activities of smaller companies."*

LEADING INDIAN ORGANIZATIONS INVOLVED IN INNOVATION

The private sector is one of the key participants in innovation activities in the pharmaceutical industry. Most of the top pharmaceutical companies have been focusing and investing heavily in research & development activities. All of these companies have filed a number of patents across different therapeutic segments. The table below shows the key private companies researching in the major therapeutic segments and the number of patents filed by them from the year 2000 onwards.

Table 3: Top 5 Patent filers by therapeutic area

Cardiovascular	**CNS and muscular**	**Pain, inflammation & fever**	**Gastro intestinal**	**Cancer**	**Diabetes**	**Respiratory**
Ranbaxy-103	Ranbaxy-111	Ranbaxy-83	Ranbaxy-77	CSIR-70	Ranbaxy-56	Ranbaxy-64
Dr. Reddy-62	Dr. Reddy-44	Panacea-31	CSIR-36	Ranbaxy-41	Dr. Reddy-30	Panacea-18
Cadila-57	Cadila-39	Wockhardt-30	Dr. Reddy-32	Dr. Reddy-31	CSIR-24	Cipla-15
CSIR-46	Alembic-31	CSIR-30	Cadila-27	Cadila-26	Cadila-23	Glenmark-15
Glenmark-31	Lupin-28	Cadila-27	Panacea-23	Panacea-19	Panacea-17	CSIR-15

As is evident from the above table some of the key companies researching in India are Ranbaxy, Dr. Reddy's Laboratories, Cadila Healthcare, Wockhardt, Panacea Biotec, Glenmark Pharmaceutical and Lupin Pharmaceutical among others. Along with these companies CSIR – Council of Scientific and Industrial Research, is one of the key patent filers in the pharmaceutical industry. CSIR is one of the top patent filers across most of the therapeutic segments.

INNOVATION SUCCESSES

Shantha Biotech

Incorporated: 1993

Founder and Managing Director: Dr. K I Varaprasad Reddy

Headquarters: Hyderabad, Andhra Pradesh

Shantha Biotech is a pioneer in Biotech in India and has been developing cost effective, break-through products for critical therapeutic areas. In July 2009, the company became a part of the Sanofi Aventis group, a global pharmaceutical company.

Shantha has to its credit a number of innovative products which have proved a boon both for the Indian and global market. It was the first Indian company to develop Hepatitis B vaccine in 1997. At that point of time, the Hepatitis B market was ruled by MNCs in the country. Further, the drugs were very high priced and hence were accessible only to a limited number of people. Shantha's Shanvac B was a break through product, which was affordable and hence available for the masses. The vaccine is also pre-qualified by WHO, Geneva for supplying to UN agencies.

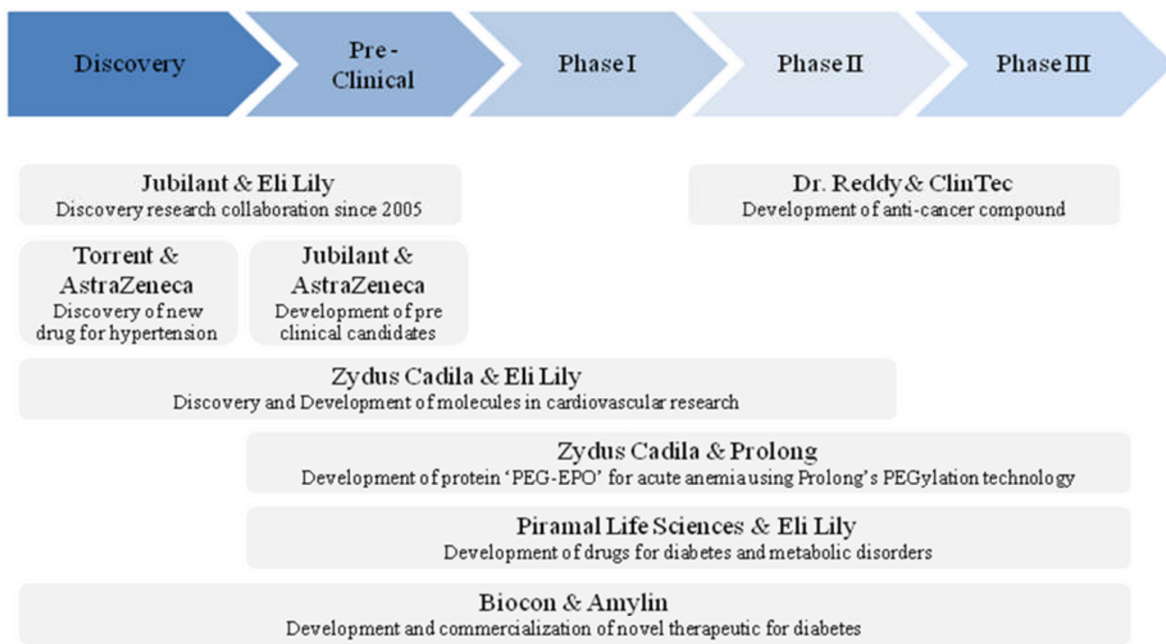
Similarly, Shantha also has to its credit an oral cholera vaccine, which was licensed in 2009. Prior to this, the only WHO pre-qualified oral cholera vaccine was the double dose Swedish vaccine called Dukoral, which is priced at D60. As opposed to this, Shantha's cholera vaccine Shanchol is priced at around D 1.85. Along with the affordable price, the drug incorporates all the important genes required to make it very selective and more effective without much side effects.

Shantha biotech has been a pioneer in India for developing several innovative drugs for major diseases.

GLOBAL PARTNERSHIPS

Indian – foreign company collaboration: Most of the R&D for new chemical entities by Indian companies has been carried out through collaborations with foreign partners. **In the past 20 years, not a single drug has been discovered, developed and submitted for approval abroad entirely by any Indian company due to lack of resources**. **With this background, over the last few years, a number of global companies and research institutes have entered into alliance with Indian companies to work and share the risk burden mutually.** The major driving factor for this being India's lower cost for relatively higher skill base of scientists and research personnel. Further, a growing domestic market for pharmaceutical drugs also provides lucrative opportunities. As a result, many foreign Pharma and Bio-Pharma companies are collaborating with Indian firms across different stages of research activities for drug discovery and development.

Figure 11: International collaborations by stages



Indian – Foreign institute collaboration: Along with the collaborations between Indian and foreign companies, a lot of international institutes and government bodies are also looking towards Indian companies for their research activities. Partnerships are also taking place between Indian industry associations and international associations. Most of these partnerships aim towards development of a new drug, molecule or technology which will be beneficial for both the countries and for the global market as well. For example Association of Biotechnology Led Enterprises (ABLE) has collaborations with BIOTECanada, AusBiotec and Irish Bio Industry Association (IBIA).

The collaboration with international companies and institutes is not restricted to any geographic region. Domestic companies and research institutes are collaborating with organizations across US, Europe and other regions. During collaboration the decision is not dependant on the region, rather it is a match between the requirements and the capabilities. Though Indian companies are seeking to developing indigenous capabilities, the drug discovery process will be conducted mainly through collaboration with a foreign counterpart. Technical know-how and funding are some of the major drivers, which will promote the presence of foreign companies in the country.

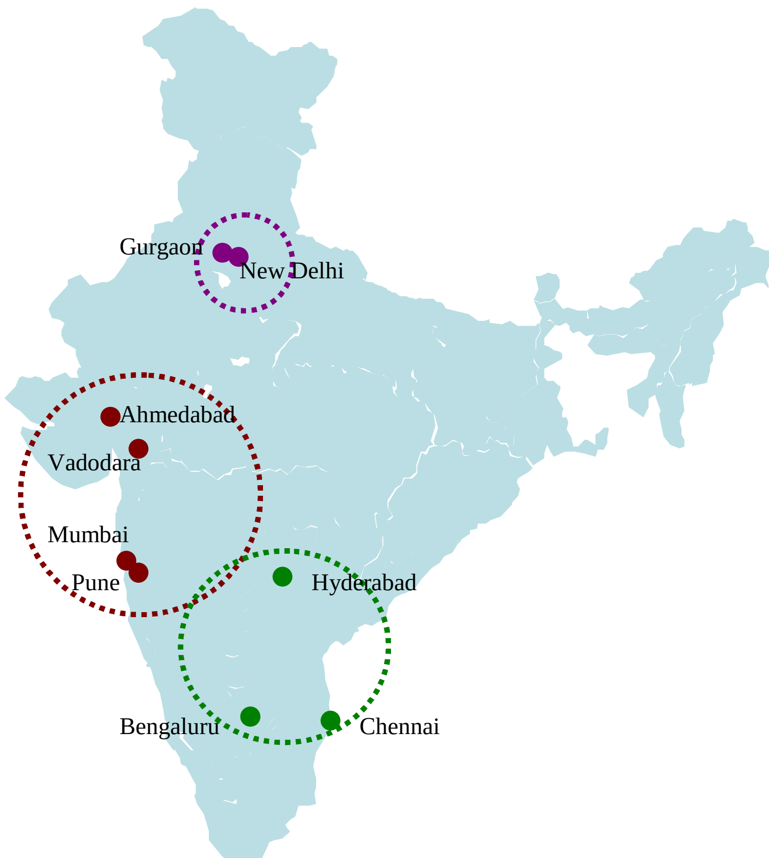
Industry – Academia collaboration: Collaborations are also taking place between academia and industry within the country. Though this is not very widespread, the need for it is increasingly being recognized in the country because both the industry and academia need to align themselves in order to address challenges jointly. Several leading institutes like IISc Bengaluru, IICT Hyderabad, CCMB Hyderabad, IITs, AIIMS etc. are joining hands with the industry to develop products ranging from malaria vaccines to oncology drugs. The people in the industry also feel that academia should become more market oriented and for that to happen there has to be a culture shift. The academia needs to understand that industry cannot support open ended academic research while at the same time industry needs to step up its funding for academic research. With this approach and continuous efforts from these two key stake holders, there is a likely hood of increased collaboration for innovation activities. The list of major collaborations can be seen in Appendix.

INNOVATION HUBS

INNOVATION CLUSTERS

The major pharmaceutical and biotech innovation hubs in India can be divided into three main clusters: western, southern and northern cluster. Out of these the western cluster accounts for the loins share the industry, followed by the southern cluster. The northern cluster comprising of NCR (Delhi, Gurgaon and Noida), Himachal Pradesh is also an emerging location for pharmaceutical companies.

Figure 12: Innovation clusters



Western Cluster ●	
Ahmedabad	Zydus Cadila, Torrent Pharmaceutical, INTAS
Vadodara	Alembic, Sun Pharmaceutical
Mumbai	Glenmark Pharmaceuticals, Piramal Life Sciences, Rubicon, Serum Institute of

	India, Bharat Serums, Reliance Life Sciences
Pune	Lupin
Southern Cluster	
Hyderabad	Shantha Biotech, Dr. Reddy, Aurobindo Pharmaceutical, Natco, Bharat Biotech
Bengaluru	Biocon, Cipla, Novo Nordisk, Astra Zenca
Chennai	Orchid Pharmaceutical
Northern Cluster	
Delhi	Dabur, Panacea Biotech
Gurgaon	Ranbaxy Laboratories, Eli Lily

WESTERN CLUSTER

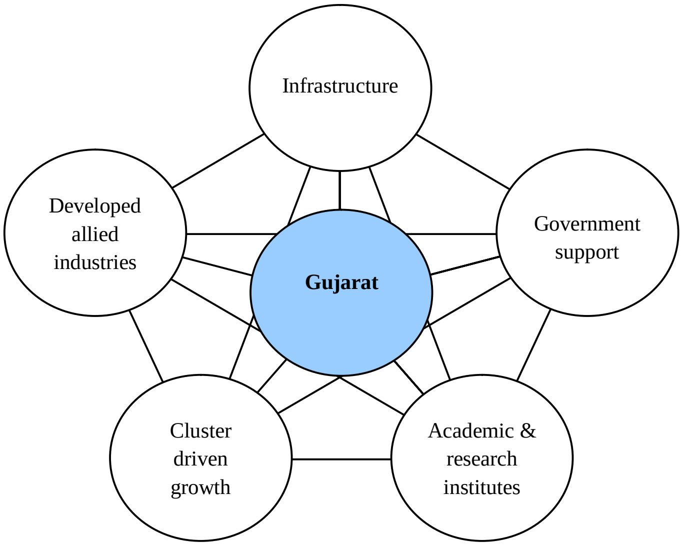
The western cluster with states of Gujarat and Maharashtra is the major hub for Pharmaceutical and Bio-Pharma activities in the country. The western cluster accounted for 46% of the total revenues for the biotech industry in the FY 2009-10. Some of the major reasons for western regions high share are the government incentives and support, infrastructure and resource availability.

GUJARAT[8]

Gujarat accounts for approximately 42% of the pharmaceutical market and 8% of the biotech market in India. Gujarat has an established base of pharmaceutical industry with Alembic Chemical Works setting its base in 1907. Over the years the state has developed as the pharmaceutical hotspot with established manufacturing and R&D centers of a number of companies like Sun Pharmaceutical, Zydus Cadila, and Torrent Pharmaceutical among others. Currently the state has over 3,500 drug manufacturing units and around 127 biotech companies.

Figure 13: Innovation ecosystem - Gujarat

[8] Vibrant Gujarat, detailed sector profile, pharmaceuticals
KPMG, Gujarat Pharma industry Striding into the future



- **Infrastructure:** Gujarat has one of the most well developed infrastructure facilities in the country. The state has a well developed network of roads, ports, and also power and logistic facilities.

- **Government Policies:** The government of Gujarat has formulated a number of policies to boost the Pharma and biotech industry in the state. Some of the key policies include;

    - Development of Biotech clusters in the form of Zones / estates, development of specific parks / SEZ, specific strategic actions for development of sub sectors like Agriculture, Animal husbandry, Health, marine environment
    - Introduction of Pharmaceutical Technology Up gradation Fund scheme of 51% interest subsidy for implementation of schedule M of drugs and cosmetic rules for good manufacturing practices
    - A special package of incentive will be offered for mega project, on case to case basis. A project making investment of Rs.100 crore or more would be considered as mega project. This apart, Projects making investment in setting up of institutes of high end Biotechnology education and research and incurring a minimum of 50% investment on land, building, would also be treated as mega project.

    - State government has established Gujarat Biotechnology Venture Fund (GBVF) to support entrepreneurs with an initial corpus of INR 500 million, of which INR 100 million as government's share and remaining INR 400 million to be mobilized from financial institutions.

- **Government initiatives:** Several initiatives have been taken in order to maintain the state's leading status in the Pharma and Bio-Pharma industry like;

- Genetic Diagnostic Centre [GenDiCe] - The problem of genetic disorders in Gujarat is enormous. Millions of suffer from inherited diseases like Thalassemia, Muscular dystrophy, Diabetes mellitus, Coronary heart diseases etc. GenDiCe will concentrate on addressing the above issues.
- Shivrath Center of Excellence in Clinical Research - A research institute in JV with Gujarat State Biotechnology Mission (Govt. of Gujarat) and Gujarat University providing research based learning modules as per the need of industry.

- **Academic and research institutes:** It has a wide presence of recognized academic and research institutes, some of the prominent ones being L.M. College of Pharmacy, B.V. Patel PERD Center, and National Institute of Pharmaceutical Education and Research (NIPER). The presence of these institutes acts as a simulator for innovation development.
- **Cluster driven growth:** The growth of pharmaceutical industry in the state has been concentrated in several clusters of Ahmedabad, Vadodara being major ones. Further the state also has a number of SEZs and with more proposed SEZs in line like Ahmedabad – Surendranagar Bio-Pharma zone.
- **Developed allied industries:** The pharmaceutical industry has developed strong linkages with allied sectors like chemicals, healthcare and medical equipment, IT etc.

MAHARASTHRA[9]

Maharashtra is the next big hub for the Pharma industry in the western region, accounting for 18% of the Pharma output by value. Within Maharashtra Mumbai, Pune and Aurangabad are the major hubs for Pharma activities. Six of the top ten Pharma companies have their base in Mumbai, these are Glenmark Pharmaceuticals, Sun Pharmaceuticals, Wockhardt, Lupin, Cipla, and Piramal Healthcare. In Biotech, Maharashtra has the largest revenue share of 35%, with Mumbai and Pune being the major hubs. There are two major reasons for the strong Pharma and Bio-Pharma industry in the state:

- **Academic infrastructure:** The state has a strong academic infrastructure with a number of technical institutes providing education on pharma. This in turn provides the state with a strong skilled labor base.
- **Government policies:** The state government has framed several policies to enhance the industry like;

[9] Express Pharma, Mumbai emerging as preferred destination for pharma multinationals
MIDC, Destination ahead- Maharashtra Pharmaceutical sector

- The Government will encourage setting up world class "100% foreign direct investment (FDI) is allowed under the automatic route in the drugs and pharmaceuticals sector including those involving use of recombinant technology.
- Budget 2009–2010 reduced the customs duty from 10% to 5% on imports of select life saving drugs and their bulk drugs for treating ailments such as breast cancer, hepatitis, Rheumatic arthritis, etc
- Customs duty has been reduced from 7.5% to 5% on two specified life saving devices used in the treatment of heart conditions. These devices are now fully exempt from excise duty and countervailing duty (CVD)
- New Biotechnology units, and expansions of existing units, will be exempted from payment of Stamp Duty and Registration fees in C, D, D+ and No Industry Zones in terms of Package Scheme of Incentives, 2001 of the State Centres of Excellence", which will cover all aspects of cutting edge research and development in emerging areas of life sciences and technology. To facilitate this, the Government will offer land at concessional rates to Centres of Excellence in the area of Biotechnology.

- **Government initiatives: Some key inititiatives include;**
  - With a public-private partnership, the Government will set up a special Biotechnology Development Fund with an initial corpus of INR 500 million. This Fund will receive annually a specially earmarked contribution of 1% from the annual Plan funds from different departments of the State Government, who are likely to be the beneficiaries of the Biotechnology Revolution.
  - Biotechnology Park will be set up at Pune (Pharma Biotechnology)
  - Two apex institutions will be created. The first will be the Maharashtra Biotechnology Board, and the second will be the Maharashtra Biotechnology Commission. These will be backed up by a Biotechnology Development Fund.
  - The State Government will promote setting up of R&D centres and pilot plant facilities for undertaking contract research by putting equity stakes in such projects. The Government equity would be in kind, such as in the form of land allotted for the projects.

SOUTHERN CLUSTER[10]

The southern cluster is the next important zone for Pharma and biotech activities in the country. Within the southern cluster Hyderabad, Bengaluru, Chennai are some of the important cities where a lot of Pharma activity takes place. The southern region has 172 biotech companies, the largest in the country. This region is host to a large number of biotech parks set up by the respective state governments like Shapoorji Pallonji Biotech Park, Hyderabad; ICICI Knowledge Park, Hyderabad. These biotech parks act as bioclusters - where companies, universities and R&D institutes are all located in one place. Bengaluru is the biotech cluster of India and is the leading destination in the country. Hyderabad is the next major destination in this area; with the Genome valley having operations of 53 biotech companies.

The Karnataka government has proposed to set up five new biotech parks and has invested INR 11000 million towards new initiatives in 2009-10. The government plans to set up an INR 1000 million fund for manufacturing companies and INR 500 million corpus for R&D. It has also relaxed FAR for all Biotech projects set up outside the limits of the municipal corporations in the state. Along with Karnataka, governments of Andhra Pradesh and Tamil Nadu are also making a lot of effort to promote the Pharma and biotech industries. MedTech Valley, a world-class cluster for manufacturing medical devices and equipment is being set up in Hyderabad, Andhra Pradesh. This will be set up on 1,200 acres of land to be provided by the state government. Further, there are also plans of setting up two biotech SEZs and three biotech parks in Hyderabad. The government will offer special one-time grants for setting up R and D facilities in the Universities in the area of biotechnology and special incentives will be offered, on a case by case basis, to mega projects with an investment of more than INR 500 million in a new company, or in the expansion of an existing company. The Tamil Nadu government plans to set up a Bio-Pharma SEZ Special Economic Zone for an estimated project cost of INR 730 million. The government will create a Life science Venture Capital Fund with a corpus fund of INR 500 million through TIDCO and IL & FS to attract and facilitate more Bio-Pharma projects.

Along with biotech parks and SEZs, the southern region also has many world-class scientific institutions. The prominent ones are the National Centre for Biological Sciences (NCBS), Indian Institute of Science (IISc), Indian Institute of Chemical Science (IICT) in Hyderabad and Center for Cellular and Molecular Biology (CCMB). The presence of these institutes is also acts as a major attraction.

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[10] Royal Danish Embassy, The Biopharma Sector in India
BioSpectrum—ABLE Biotech Industry Survey 2010

NORTHERN CLUSTER[11]

The northern cluster is an emerging location for the Pharma and Bio-Pharma industries, mainly concentrated in NCR (Delhi, Noida and Gurgaon) and Baddi. The region has the presence of a number of domestic and international players like Ranbaxy, Eli Lily, and Valiant among others. Further, it also has the key ministerial departments and many research centers like UN founded International Center for Genetic Engineering and Biology, Institute of Genetics and Integrative Biology, and The National Center for Immunology.

A number of biotech parks are in the process of development in this region. The Health Biotech Science Cluster (HBSC) at Faridabad is expected to be a major biotech cluster comprising of Translational Health Science & Technology Institute (THSTI), Regional Center for Biotechnology (RCB), Center for Vaccinology, Molecular Medicine Center, Center for Diagnostics, Center for Health Science Technology, Center for Platform Technologies, UNESCO Center, and a Center for Animal Model for Clinical Advances. Lucknow also hosts a biotech park providing a platform for research and collaboration. Other states are also developing biotech parks to expand the industry like three parks have been initiated by Rajasthan State industrial Development & Investment Corporation (RIICO), Biocluster at Mohali (Punjab), another at Chandigarh (Punjab) and at Nalagarh in Himachal Pradesh. Such initiatives are likely to make the northern region a promising hub in the near future.

CENTRAL GOVERNMENT REGULATIONS AND INCENTIVES[12]

The Department of Pharmaceuticals is the regulatory body responsible for formulating and implementing policies and programs in the pharmaceutical industry. The department is taking a lot of initiatives with a vision to make India a leading innovation hub by 2020.

- **Tax incentives**: Government offers a number of tax incentives both for manufacturing and research activities of pharmaceutical companies. For instance, a weighted tax reduction of 200% is given to pharmaceutical units for expenses incurred on research. Along with this, there are incentives for research associations, colleges and universities with a deduction from 125% to 175%, exempting incomes of all approved associations. It also has made an encouraging choice by providing uniform

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[11] BioSpectrum—ABLE Biotech Industry Survey 2010

[12] Panorama, November 2010

Economic times, SPV with cover for drug R&D soon, 15 June 2009 concessional reduction from 5 percent to 4 percent on medical equipments, appliances and state-of-the-art facilities with full exemption from special additional duty on all medical equipment. Medical equipments are subject to complex rate structures that result in disputes and at times prevent the latest equipment from availing the benefit of exemption. However, the rise in minimum alternate tax (MAT) from 15% to 18% negates part of the accruable benefits.

- **R&D programs**: In order to promote R&D, the government has launched some programs. Prominent among these are New Millennium Indian Technology Leadership Initiative and the Drugs and Pharmaceuticals Research Program. The objective of these schemes is to
    - Enhance infrastructure facilities
    - Synergize public R&D institute
    - Promote collaborative research program between industry, academia and government
    - Provide financing facilities in form of grants and loans
- **Providing funds and facilities**: The government and the department of pharmaceuticals are evaluating proposals to provide funds and research facilities to private companies. The first step for this is the creation of a SPV (special purpose vehicle) along with insurance cover. The purpose will be used to fund new drug research. The second proposal aims to create a center for drug research. Private companies can use these centers for drug research on a pay and use basis.

  The government has also proposed to set up a venture capital fund amounting to INR 30000 million which will be used to promote drug discovery and also strengthen the Pharmaceutical infrastructure in the country.
- **Promoting specialized pharmaceutical education**: The government is taking steps to develop excellence in pharmaceutical sciences and technologies, education and training. To achieve this it has set up seven National Institutes of Pharmaceutical Education and Research (NIPERs). These have been set up as ‘Institutes of National Importance’

The key policies for promotion of R&D in the pharma and Bio-Pharma industry are given in Appendix.

OUTLOOK

The Indian pharma industry is witnessing a shift from being a reverse engineering hub to contract research and manufacturing services (CRAMS) center to a center for drug discovery and development activities. Over the next few years, the industry is likely to step up investments for research and development projects in a big way. The focus will be in three main areas mainly vaccines, new molecules and new drug delivery systems. However in biopharma, development of vaccines has been and will be the main focus of most of the organizations. In terms of therapeutic areas most of the innovation activities will be for two sets of diseases namely lifestyle diseases like cancer, diabetes, hypertension and cardiovascular; and infectious diseases like malaria, tuberculosis and HIV among others.

The research activities are carried out both by the private sector and the public funded research institutes. Among these some of the prominent organizations carrying out research activities are Dr. Reddy's Laboratories, Ranbaxy, Cadila Healthcare, Glenmark, Biocon, Panacea Biotech, Shantha Biotech, Serum Institute of India among others. In the public sector CSIR, CDRI, ICMR, DBT, OPPI, ABLE are some of the main institutes conducting and promoting research activities. Both the public and private sector enterprises are increasing their focus on R&D activities and are likely to continue doing so.

Most of the R&D activities, especially the drug discovery process would be carried out through collaborations, especially with international organizations. These collaborations would be with and between private companies, research institutes and government bodies. *According to Dr. Satya Prakash Dash, COO – Association of Biotechnology Led Enterprises (ABLE); "The Indian CRO sector is witnessing a change from a linear relationship to a mutually beneficial arrangement. Earlier only routine research activities were transferred to the Indian companies, but now the Indian CROs are ready to share the risks and rewards of drug discovery activities. Several companies are investing in drug discovery and are partnering with foreign companies for the same. This presents a lot of opportunities for European companies to collaborate with the domestic industry"*. One of the key reasons for these international collaborations is the technical know-how and expertise which the foreign partner brings in along with the financial support. The industry has been collaborating with companies across different geographic regions with US and European organization being the main partners. The determinant factor is the match between individual requirements and capabilities on offer. As the Indian pharma and biopharma industry moves towards conducting high end research projects, the need for such collaborations will keep increasing and open up huge opportunities for European agencies and companies.

6. INFORMATION TECHNOLOGY

India is today synonymous with the word Information Technology and over the past decade and a half has established itself as a leading provider of software services around the world. The industry is broadly classified into two categories; Software and Hardware.

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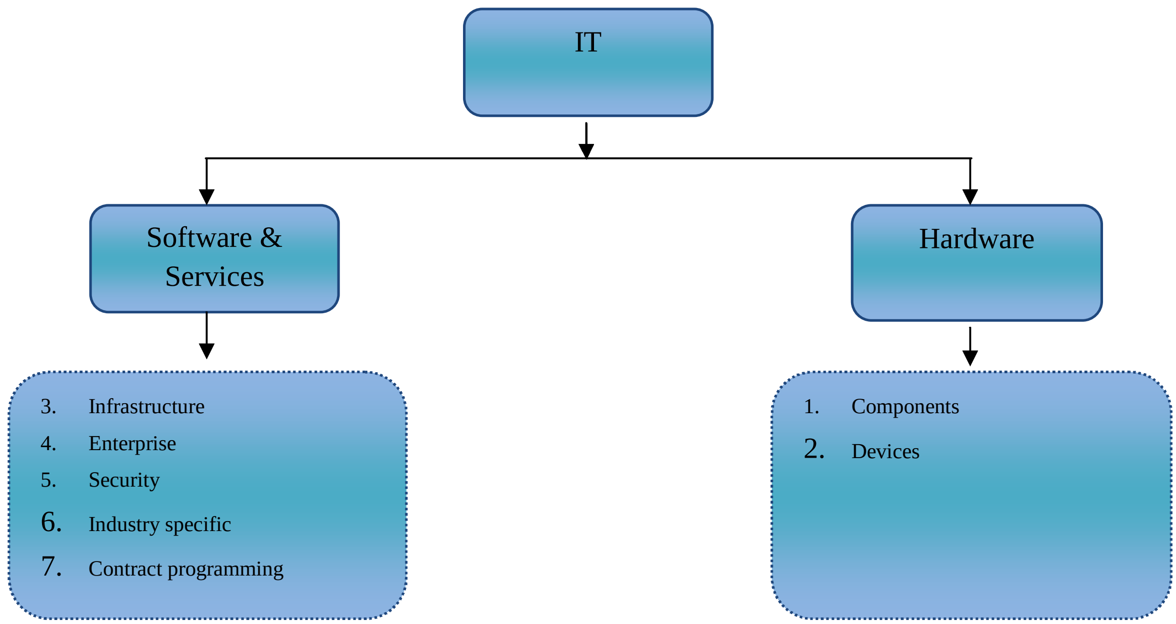
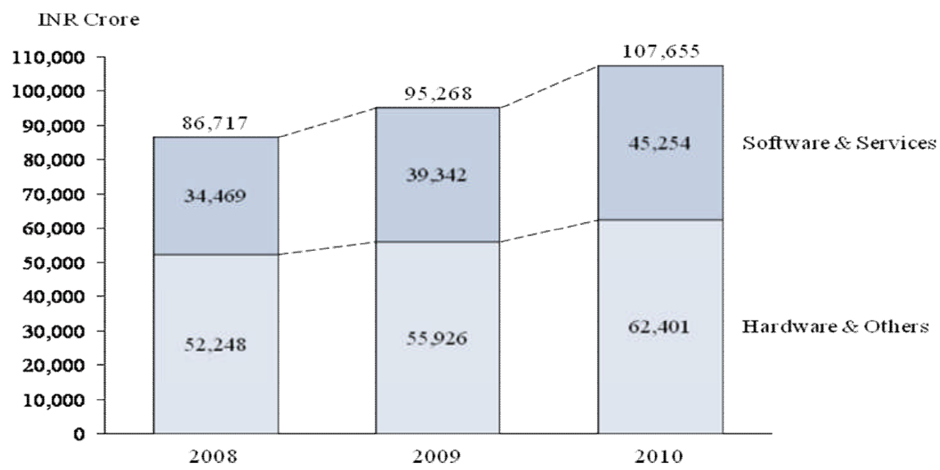


SIZE AND GROWTH

Indian IT industry has registered 50% growth over the past 2 decades. Even during the economic slowdown, the industry has maintained it momentum although IT spending globally had been reduced considerably. According to a recent report by IDC, the IT industry in India is reaching for the next level in its evolution termed as ‘Growth phase 2.0’ which would enable the industry leverage and consolidate its infrastructure built during the earlier phase. The domestic market size had tripled in the 2003-08 phase from INR 31,000 crore to INR 86,717 crore with a CAGR of 22%. However, growth in till 2010 will taper down to 11% CAGR albeit on a much larger base.

Chart 14: Market size IT

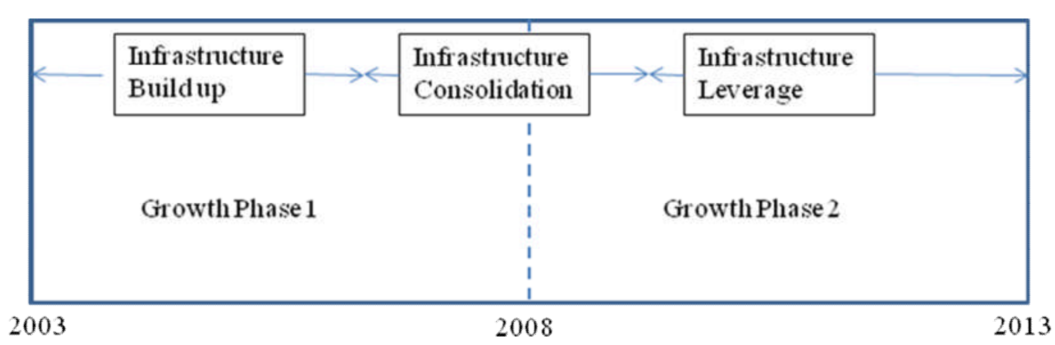


Source: IDC estimates, Netscribes analysis

According to IDC the four major trends in 2010 are:

- Evolution of consumer IT space: the transformation from ‘Consumer 1.0’ to ‘Consumer 2.0’
- Consolidation and Leveraging of IT and telecommunications infrastructure built during growth phase to harness greater efficiencies and launch innovative product / solution offerings for the end-customers by both large and mid-size business companies
- Increased adoption and acceptance of ‘game changing’ technologies such as a service (Software, Infrastructure or Platform based) delivered through the Cloud and Green Tech and 3G/BWA telecommunications networks
- Government initiatives in enabling financial stimulus to lagging end-use sectors, most notably through the launch of large scale public infrastructure projects to unlock untapped market potential

Figure 14: IT industry growth phase



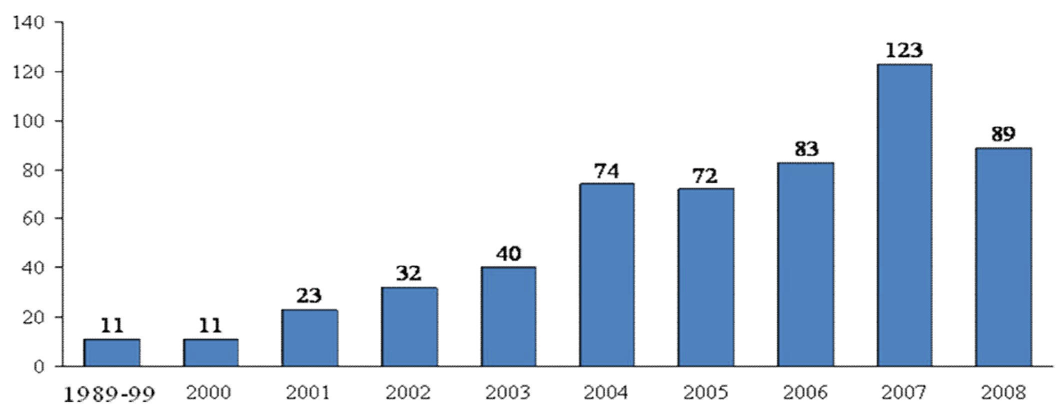
Source: Adopted from IDC

Growth Phase 2.0, which started in 2009, is built on the back of innovative services and solutions sought by consumers and enterprises alike. The technology behind these services—infrastructure, applications and connectivity—will need to harmonize and re-configure vastly to support their mass adoption and large scale penetration.

PATENT ACTIVITY

India through the years has primarily remained an IT service provider. The following chart depicts the patent filing activity over the past decade. It is evident that not much innovation activity happened in India from the 70's till the present millennium substantiating the prominence of the service segment. However, in the past decade there has been increased momentum within the industry to generate intellectual property to achieve technological superiority and in effect remain competitive in the market.

Chart 15: Patents filed



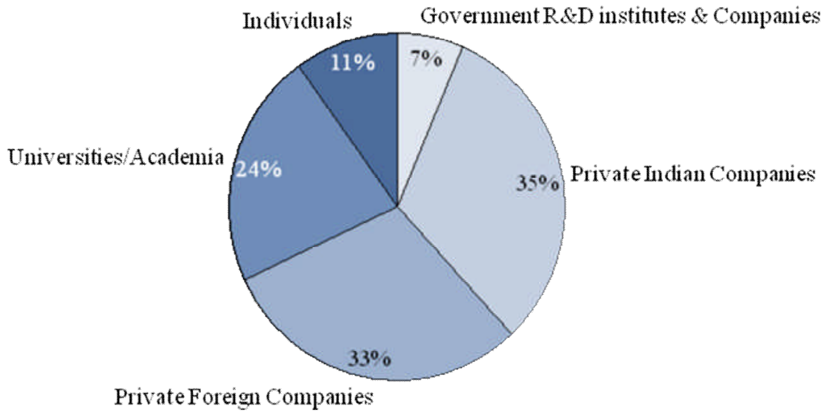
Source: Netscribes analysis

Patent assignees were categorized as;

1. Government R&D institutes and companies
2. Private Indian companies
3. Private Foreign companies
4. University/Academia
5. Individuals

The chart below shows the percentage split of patent filings amongst the assignee categories;

Chart 16: Patent filed by assignees (Total=558)

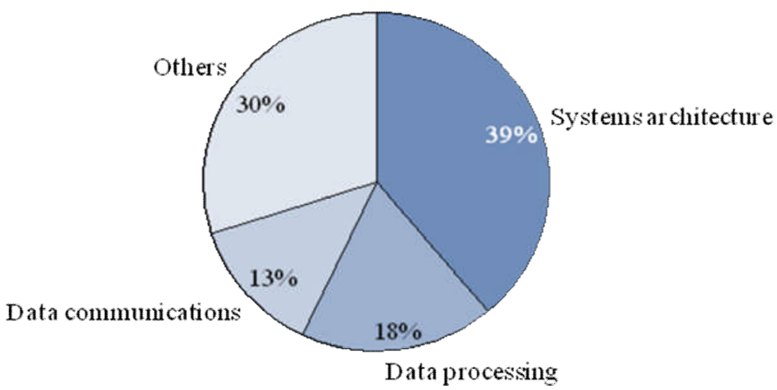


Source: Netscribes analysis

Private companies (Foreign and Indian) were the leaders in patenting activities with a combined share of around 60% followed by University/Academia with 25% and Individuals at 11%. Government institutes and public sector companies had a very low share during the same period with a meager 7%.

The nature of inventive activity projected through patents filed showed prominence of few areas, like data processing (creating, storing, retrieving and managing data), data communication (data transfer), systems architecture, mobile communication, multimedia applications (audio/video) and IT application for other industries.

Chart 17: Areas of patent filed



Source: Netscribes analysis

On further analysis, it is seen that most foreign companies focused on the hardware aspect like electronic circuitry while Indian counterparts worked on the data communication techniques. Government institutes and public companies on the other hand focused their efforts in IT application for other sectors and systems architecture. Most prominent government organisation in this area is CSIR, Center for development of Telemetric (C-DOT), Center for development of advance computing (CDAC) and Department of information technology (DIT).

Table 4: Thrust areas by assignee

	Data processing	**Data communication**	**Systems architecture**	**IT application for other industries**
Government Institutes & Public Companies			◑	◑
Private Indian Companies	◔	◔	◔	◔
Private Foreign Companies			◕	◔

Source: Netscribes analysis

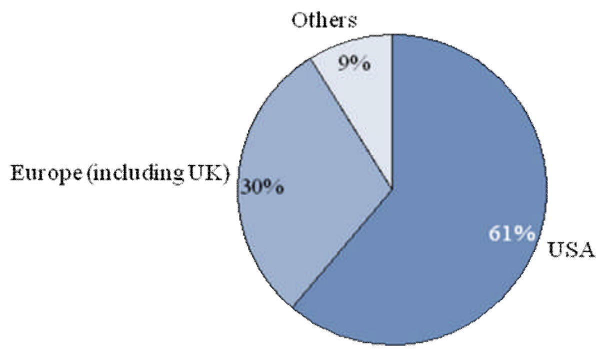
IP activity has picked up significantly over the past decade; innovation in order to differentiate products and services has become the mantra for most companies. It was a strategic focus area for many top players during the period of economic slowdown. With the economic environment rebounding back gradually, patenting momentum is likely to continue in the foreseeable future.

SOFTWARE & SERVICES

The Indian Software Industry is presently the fastest growing IT segment in India, earning valuable foreign exchange. The sector has added 240,000 new jobs in the past couple of years, taking the number of people directly employed by it to 2.54 million in 2010.

Infact, exports of software services has been instrumental in the overall success of Indian industry. Exports accounts for more than 65% of the total software revenues. NASSCOM, the Indian software industry association in one of its reports states that US is India’s largest export market with 61% share followed by Europe including the UK with 30%. The IT industry that bloomed after the economic liberalization of the Indian economy was built on exports hence has a strong correlation with innovations to sustain its competitiveness in the market.

Chart 18: Software exports by region



Source: NASSCOM, Netscribes analysis

One major reason for this success is, because of quality certifications of the top companies. Out of 23 SEI-CMM Level 5 certified companies world over, 15 are from India and this number is expected to grow as there are several companies that have already achieved CMM level 4. Also, according to the NASSCOM Perspective 2020 report, increasing IT spend and globalization of Indian corporations is leading to maturation in domestic demand in terms of product complexity, delivery flexibility and service levels. Going forward, these trends are expected to drive domestic consumption and increase the size of the addressable market.

SEGMENTATION

Software companies in India are engaged in varied types of business solutions catering to industries such as Medical, Telecom, Banking, Financial Services and Insurance Retail and Warehousing, Multimedia, Education, Travel and Tourism, Manufacturing, Transport and Government. The type of services offered can be classified into the following:

Types of business in the IT software sectors:

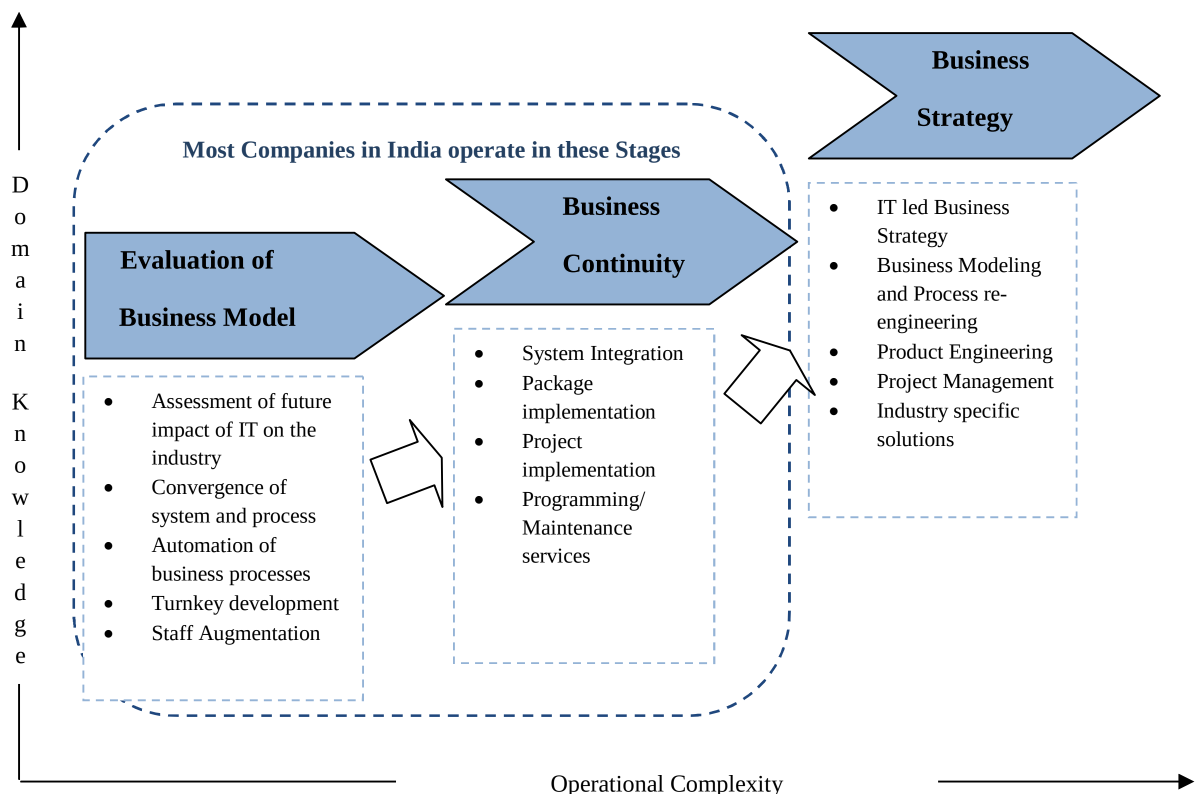
- Infrastructure Software; Includes Operating Systems, Middleware and Databases.
- Enterprise Software; Automation of business processes in diverse verticals and key functions like finance, sales and marketing, production and logistics.

- Security Software; Securing computer systems and/or networks.
- Industry-specific Software; Job management software for sectors and industries
- Contract Programming Software: Software tailor made for particular client company, or focus on configuring and customizing suites from large vendors

IT INDUSTRY VALUE CHAIN

The value chain demonstrates diverse range of activities within the IT industry. Many companies operate in multiple areas along the spectrum without restricting themselves to any particular stage. But, several companies have moved their focus on to software development as their core area in view of the changing situation in the market place and decline in margins from the hardware segment.

Figure 15: Software value chain



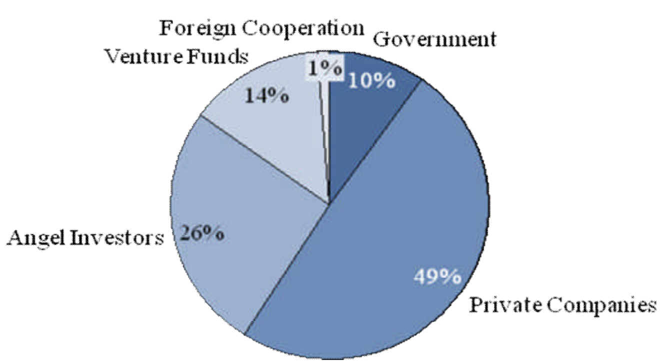
However, still a large section of IT companies in India operate at the lower end of the value chain mainly with distribution and implementation activities. These companies operate as principle re-sellers of products from software giants like SAP, Microsoft, and Oracle etc. There are companies providing network products/solutions require higher level of domain expertise as they work towards configuration of networks for the clients. Some companies have evolved from providing simple service oriented operations to developing their own in-house service products. Only a few companies like TCS, Infosys, Wipro etc. have reached the maturity and vertical integration levels to move to the final stage of the value chain in areas such as product development, embedded software, voice automation, etc. Also, there are some startups and MSME's working in specialised niches that lie on the final stage of the value chain.

R&D SCENARIO

R&D activities in India are shared by the government labs and private organisations for different areas of IT industry. While the government promotes basic research, industry focuses on ready to market technologies. Like most other countries the basic framework for research however is provided by the government in conjunction with different states.

Unlike most other sunrise industries, IT in India has had a good network of private investors. The market realizes the potential and wants to explore further opportunities there in. Based on a recently concluded conference on Euro – India ICT cooperation, the funding pattern for the industry was as follows. It is important to note the concentration of Angel investors and Venture funds in the ecosystem.

Chart 19: Sources for project funding



Source: Euro-India ICT cooperation conference, Netscribes analysis

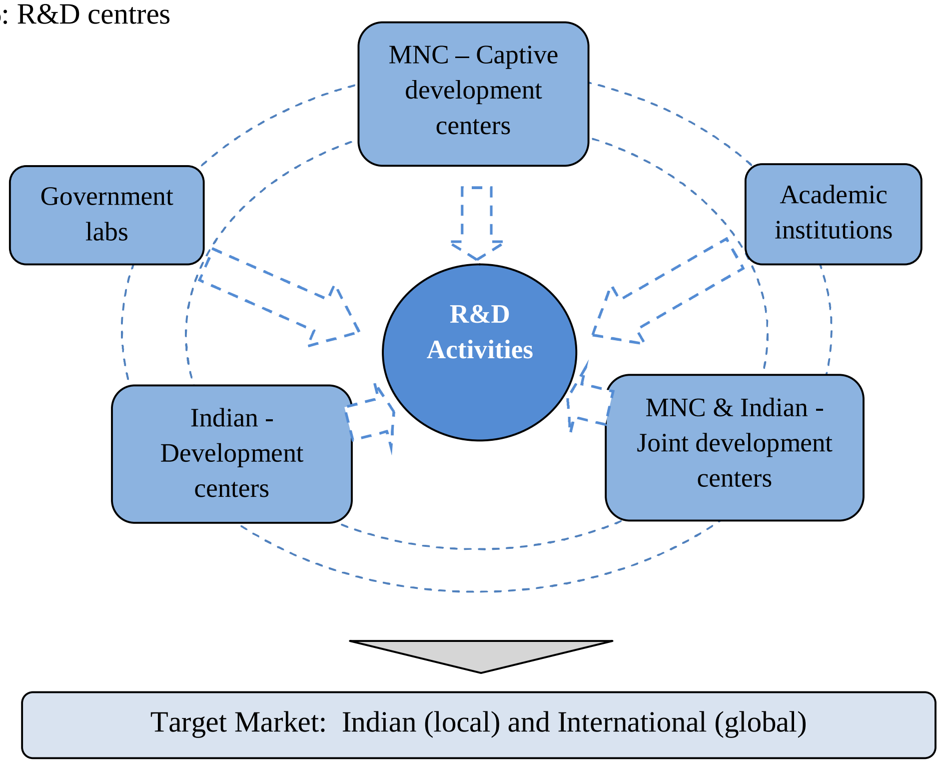
The Government too in its part for the 11th five year plan (2007-12), put forth a significant increase in funding for the ICT industry.

Table 5: Major research programs and funding

Research Areas	Proposed yearly funding (USD million)
Advanced Computing (Grid Computing)	24
Robotics & Automation	6
Sensors & Integrated systems	12
Distributed sensors & Networks	10
ICT security technologies	27
Telemedicine, Instrumentation & Diagnostics	5
Centre for Photonics	10
Centre for Molecular and Medical imaging	10
Centre for Mathematical and Computational sciences	24

Nonetheless, in its present state, most cutting edge R&D activities happen in subsidiaries set up by multinational companies. There are a number of such entities in India which were set up primarily to leverage cost advantages. Global giants like GE, Oracle, Microsoft and Cisco have set up captive development centers in the country. Then there are companies that have partnered with Indian counterparts to set up product development centers in the country, like BT with Mahindra. Further, many other international companies outsource functions such as design, testing, requirement and maintenance to Indian companies. Availability of technically skilled manpower at lower cost, coupled with improving innovation ecosystem, has been the prime mover for cost-effective R&D.

Figure 16: R&D centres



Since earlier days, Indian companies were reluctant to invest in product development because of poor resource base and expertise, and more importantly, because of the difficulties in designing products for distant and unfamiliar markets. At a later date, even with necessary resources, the companies found it tough to justify the high risks associated with product development. At the same time risks were much lower in providing services than in selling and marketing products, in part because of the lower financial risk.

Even today, in the software industry, product development is a small component of the overall costs. Software firms may spend as much as 50% of revenues on advertising and marketing and as little as 10–15% on product development. Only recently have Indian companies reached a size and maturity to consider investing in core R&D activities. Noteworthy, are products developed by companies such as Infosys, TCS, i-flex Solutions and Zenith Infotech for the banking sector.

AREAS OF RESEARCH BY MAJOR COMPANIES

Table 6: Areas of Research

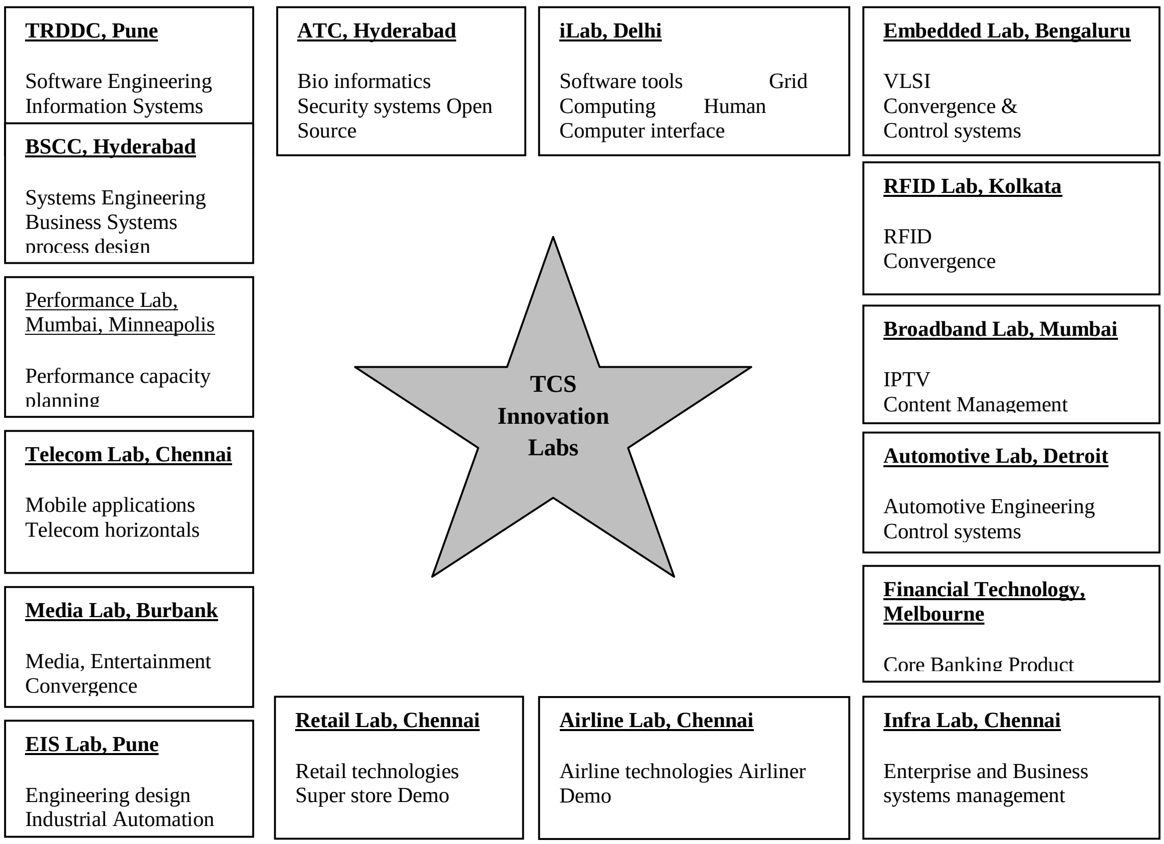
Companies	Research Areas
Microsoft Research India	▪ Cryptography, security and algorithms ▪ Digital geographic solutions ▪ Mobility, networks and systems ▪ Multilingual systems ▪ Software engineering ▪ Technology for emerging markets ▪ 4G network management
IBM India Research Lab	▪ Analytics and optimization ▪ Distributed and high performance computing ▪ Programming technologies and software engineering ▪ Knowledge and information management ▪ System management ▪ Service research ▪ Industry solution research ▪ Spoken web
Accenture Technology Labs, India	▪ Service-oriented and distributed software architectures ▪ Collaborative technologies and processes ▪ Automated quality management for software development ▪ Data quality management and data services ▪ Testing theory management and data services ▪ Testing theory and practice for software and systems ▪ Large-scale distributed workforce management techniques
Oracle's India Development Center (IDC)	▪ Grid computing ▪ Technology and applications deployment on Linux ▪ Java application development ▪ XML ▪ Warehouse management systems
Dell	▪ Enterprise solutions ▪ Server development
Texas Instruments	▪ Designing semiconductor based end-to-end chips
ST Microelectronics	▪ Electronic circuitry

Intel	▪ High end enterprise micro chips
Hewlett Packard	▪ Gesture recognition
Indian Companies	
TCS’s Innovation Lab (iLab)	▪ Grid computing ▪ Collaborative software development ▪ Human computer interfaces ▪ Service-oriented architectures
Wipro centers of Excellence	▪ .NET ▪ Data Warehouse ▪ Web services ▪ Enterprise security services
Infosys – SETLabs	▪ Web services ▪ Grid computing ▪ Ontology ▪ Business process management solutions
KPIT Cummins	▪ Embedded software for Automotives and Infotainment
Talisma	▪ CRM suites
Teneoris	▪ Integration of home digital entertainment with computing platforms

TATA CONSULTANCY SERVICES – INNOVATION ACTIVITY & COLLABOTATIONS

TCS is India’s largest IT services and consulting company. Over the years, the company has invested in creating building blocks for necessary innovation in order to be ahead of the competition. Be it through in-house R&D centers or collaborations with top ranked universities. Today, TCS has a global network of laboratories that provide an environment for sophisticated IT research in cutting-edge technologies in various domains.

Figure 17: TCS innovation labs



Source: TCS; Successful models for industry - Academia partnerships for R&D collaboration in India

Table 7: TCS's partnerships with the academia:

University	Country	Areas of Collaboration
IIT Mumbai	India	Centre for intelligent internet; training in VLSI/digital design
IIT Chennai	India	Computational engineering
IIT Delhi	India	Media Lab
Stanford University	USA	Data privacy
UW Milwaukee	USA	Business components

UC Riverside	USA	IP centric networking
Georgia Tech	USA	Software testing

With this network in place, patent filings from TCS have increased consistently in the past 4-5 years. For the year 2010, TCS had 90 filings compared to 25 in 2007. A number of innovative solutions emerging from these labs have won national and international awards vindicating the companies stand on innovation and partnerships.

INDIA- A KEY R&D HUB FOR GLOBAL TECHNOLOGY GIANTS

Global IT leaders such as Microsoft, Adobe, Oracle, SAP, Google and Yahoo have set-up fully owned R&D centers in India with spotlight on product innovation. The centers have been incubators for some of the most successful products these companies have launched. As a result, the Indian R&D units of many major companies have become the largest set ups (in terms of number of employees) outside their home country.

Texas Instruments has it largest R&D center in India, designing semiconductor based end-to-end chips since 1985. Over the years, other chipmakers including Intel, Qualcomm, Broadcom and NXP, and electronic design automation firms such as Cadence Design Systems and Synopsys have established strong R&D presence in the country.

Further, the linkages with international firms have expanded in breadth and scope and in some cases have translated into higher order vertical linkages. Leading firms such as Infosys, TCS, and WIPRO are involved in software development, product engineering services, protocol standards, participating in international innovation chains. A good example where Indian firm is a crucial player in the globally dispersed networked innovation is Infosys participation in Automotive Open Systems Architecture – **AutoSAR**. It is network of major global automobile manufacturers involved in R&D and standardization of software for auto electronics innovation. Firms such as Toyota, Bosch, BMW, Volkswagen, Siemens, Ford, DaimlerChrysler and Continental Tires are partners in this global network.

According to the latest findings, MNCs employ about 430,000 people in India out of which approximately 200,000 are engaged in R&D. Also, out of the total of 202,430 talent pool in the R&D industry, majority of them -89,383 come from the Software vertical. While Telecom and Semiconductors employee about 26,715 and 23,713 respectively.

Table 8: Global companies and activities

Company	**Activity in India**	**Location**
Hewlett Packard	Finance shared service centre and software R&D lab	Bengaluru
General Electric (GE)	GE is planning to invest approximately USD130 million over the period of three years in John F. Welch Technology Center in Bengaluru, the largest R&D center of its kind within the GE family outside US	Bengaluru
Novell	R&D center developing products and technologies relating to network and resource management solutions; security and identity management and core platform services solutions	Bengaluru
Oracle	OS for Oracle's Network Computer. Its Hyderabad center is dedicated to a newer area of development; e–business applications	Bengaluru, Hyderabad
Microsoft	India Development Center. Its R&D lab focusing on product development and applied research in web search and online advertising.	Hyderabad, Bengaluru
Boeing	R&D centers to develop advanced aerospace software and solutions for its next-generation products and services.	Bengaluru
Adobe	The company has earmarked around USD100 million for expansion, which together make for Adobe Systems' largest research and development (R&D) centre outside the US.	Noida and Bengaluru
Alcatel-Lucent Technologies	Bell Labs research center works on network management and network operations software.	Bengaluru
Mahindra - British Telecom	MBT R&D center SEI-CMM Level 5 certified for its software development processes.	Mumbai, Pune

SUN Microsystems	Invested USD100 million in R&D center. The company driving major innovation and projects in software areas related to Java, Web Services, Operating Systems, and SOA-related infrastructure.	Bengaluru
CSFB (iNautix)	After investing USD12 million in an ODC in Chennai. The company has undertaken next round of expansion plans	Chennai, Pune
VMware Inc	Invested USD100 million in 2010 on its R&D center. The center supports research and development across the company's entire portfolio of software solutions for datacenter and desktop virtualization.	Bengaluru
IBM	IBM India Software Lab employs 3,200 people across five cities, making India one of the largest software development hubs for IBM worldwide. The India lab develops software products across all five brands of IBM Software Group's portfolio.	Bengaluru, Gurgaon, Pune, Hyderabad and Mumbai
Dell	Invested over USD150 million in its R&D center specializing in systems software, hardware design, and testing.	Bengaluru
Huawei	Huawei has set up one of the largest R&D centers to develop a wide range of telecom software.	Bengaluru
Arista Networks	The company is opening its R&D centre which will focus on expanding Arista's Extensible Operating System (EOS) which is purpose-built for large data centre and cloud scale deployments.	Bengaluru
Rolls Royce	Quest Global currently manages Rolls-Royce's dedicated engineering and software development centre.	Bengaluru
Honeywell	Honeywell's Technology Solutions Lab provides Technology, Product and Business software solutions to 4 Diversified Business Lines: Aerospace, Automation & Control Solutions and Transportation Systems.	Bengaluru
Symantec	Operates its R&D center for software engineering, development, and	Pune

Corp	IT and technical support.	
Nokia	Nokia R&D centers are focused on next-generation packet-switched mobile technologies and communications solutions software.	Bengaluru, Mumbai
ABB	R&D center focuses on software development and Industrial IT. With this, the company is integrating its entire power and automation technology offerings to enable utility or industry customers.	Bengaluru
Samsung Electronics	R&D center which is certified as CMM Level 5 and ISO 9002, carries out software development encompassing a wide range of technology domains..	Bengaluru
SAP	SAP R&D Labs India researches, designs, and delivers leading-edge software applications that enhance SAP solutions	Bengaluru, Gurgaon
America Online	Software development centre	Bengaluru
Cisco	Technology development center, the company is planning for an investment of USD150 million to expand the center in India over the next two years	Bengaluru

CHALLENGES AND OPPORTUNITIES

The meteoric rise of the IT industry has its own pitfalls. Each challenge brings about the next wave of improvisation and innovation and opportunities there with for organisations to remain competitive in the market. The major challenges that face the Indian IT industry are as follows:

- The first two IT waves were based on cost differential of the 'Labour – for –Hire' model. In other words, it meant utilizing skilled English speaking technical manpower at a lower price than developed world. With time and the emergence of other countries like China, Philippines, Bangladesh and some eastern European nations cost arbitrage has been greatly nullified. This evolution has brought in a strong sense of development amongst companies operating in India. The earlier philosophy of having a centre in India to lower costs has given way to improve one's revenue by utilizing the India center effectively. Hence the challenge has prompted companies to add skill sets and move up the value chain.

- Manpower shortage is another roadblock that has impeded the growth of the IT industry in the past few years. Though India produces a large number of Science and Technology graduates, the demand from the industry far outstrips supply. As per NASSCOM most students passing out from universities are not employable directly. The curriculum and pedagogy in the institutes is not in sync with industry requirements. Pervasive change in technology has rendered existing courses obsolete. According to a recent report for the year 2009, the estimated shortage of manpower is 235,000 which is likely to increase to around 500,000 in the next 2-3 years.

Table 9: Manpower demand and supply scenario

Total Demand	Numbers (‘000)	Total Supply	Numbers (‘000)	Gap (‘000)
IT services (export)	460	Existing pool	360	100
IT services (domestic)	520	New supply expected	525	-5
Products & Technology services	140	-	-	140
Total	**1120**	**Total**	**885**	**235**

Having taken note of the situation, companies have started collaborating with educational institutes to bridge the skill set mismatch and get students industry ready. For instance, Cisco, the networking major, has set up more than 130 Networking Academies across 20 states and union territories in the country, which have more than 6,000 active students. Banasthali Vidyapeeth, Anna University, IIIT Hyderabad and Bengaluru, Thiagaraj College of Engineering and Guru Gobind Singh Indraprastha University are some of the colleges it has tied up with. Hewlett-Packard (HP) has formed an alliance with Jadavpur University. They have collaborated to facilitate mutual exchange of knowledge in mobile computing. Under this tie-up, HP will share industry knowledge on relevant IT innovations and foster talent in the form of grants and fellowships. Also, Zensar has forged an alliance with Symbiosis Pune, under which it has hired 180 students, teaching them the IT elements in a two-year programme, Symbiosis on its part focuses on teaching them the management part of the curriculum.

This trend has to be carefully observed over a period of time to see if it gets momentum and helps bridge the gap for the longer term.

- Limitation of the domestic market IT adoption has always been a cause of worry. Due to which, the primary focus has been to tap external markets like US, UK and other developed countries. Hence, exports have driven this sector since its emergence. However, with the evolution of the business environment, particularly with sectors banking, insurance, retail, telecom, education, media and entertainment and healthcare there is an added impetus to expand the domestic market particularly for product usage. More exposure to the domestic sectors will enable access to millions of customers and will facilitate refinement of the products which can then be launched in other markets to generate significant revenues.

  'According to the NASSCOM Perspective 2020 report, increasing IT spend and globalization of Indian corporations is leading to maturation in domestic demand in terms of product complexity, delivery flexibility and service levels. Going forward, these trends are expected to drive domestic consumption and increase the size of the addressable market'

- Lack of financial capability which has kept R&D spends for Indian companies at much lower levels compared to the global giants are another area that needs careful inspection. Also, US and European product companies spend as much as 30% of the revenues in marketing and sales, which is practically impossible for Indian companies. Therefore, the industry has to devise newer business models to be able to share the risks and rewards.

- Infrastructure though adequate is still a big hurdle that the industry has to grapple with in order to sustain momentum and realize its full potential. Unlike most developed countries, India has under invested in infrastructure both physical and social since independence. Power shortages, paucity of bandwidth are some of the prominent challenges. The country needs to improve its IT infrastructure significantly to help keep the IT growth story on track.

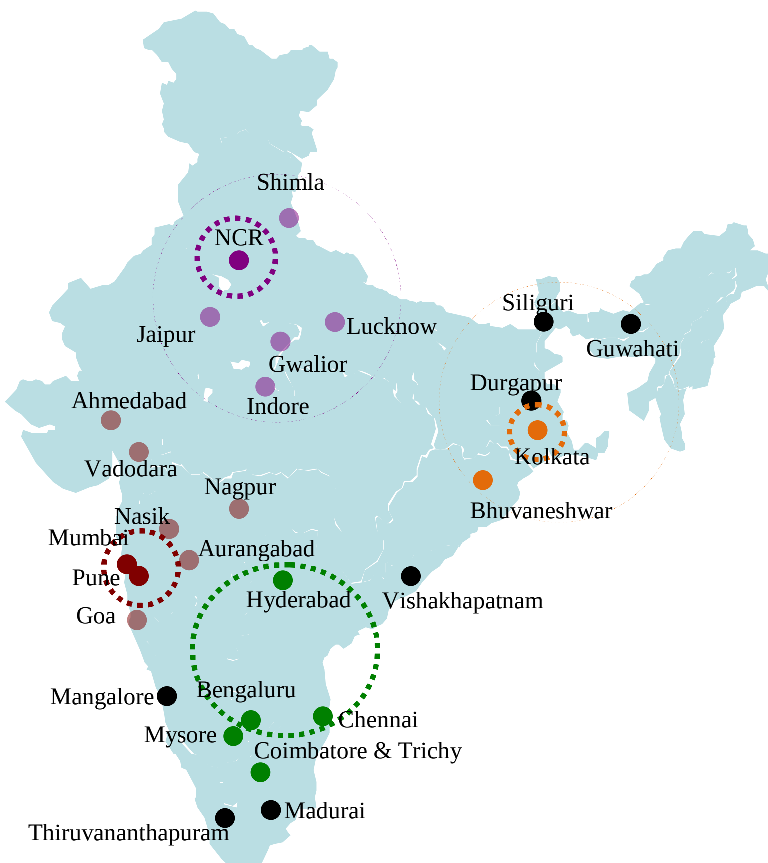
Each of the above areas offers excellent opportunities for European agencies and member companies to engage at multiple levels with Indian counterparts to increase the efficiency and effectiveness of the IT industry.

INNOVATION HUBS FOR IT NDUSTRY IN INDIA

IT companies from the developed world no longer just outsource their production activities to India but are also increasingly conducting their innovation activities through R&D centers and collaborations with select partners. Until recently, about 90% of the total direct employment in IT was confined to the seven leading locations of Bengaluru, Mumbai, NCR, Hyderabad, Pune, and Chennai and Kolkata.

REGIONAL IT CLUSTERS

Figure 18: Regional clusters



SOUTHERN CLUSTER

Bengaluru

Bengaluru continuous to hold the title of “IT Capital of India" and has been described as "a gateway to new global frontiers". Software exports from Karnataka amounted to INR 74,929 crore in 2009, an increase of 23% over the previous year. This makes Bengaluru the largest and fastest growing software-export hub not just in India but also in the entire developing world. The city offers good infrastructure, with large floor space office and great facilities and is therefore the most preferred destinations of all the big companies like, Microsoft, GE, Hewlett Packard, and Indian companies like Infosys Technologies, Wipro.

Hyderabad

The state of Andhra Pradesh, backed by the emergence of the city of Hyderabad as a major IT hub, ranks as the second IT hub of India. Hyderabad also called ‘Cyberabad’ is known as HITEC City of India. HITEC City stands for Hyderabad Information Technology Engineering Consultancy City, a major technology township which is at the center of the IT industry. Giants like TCS, Infosys, Wipro, AppLabs, Keane, Microsoft, Oracle Corporation, GE Capital operate offshore development facilities from here.

Chennai

Tamil Nadu boasts highest in bandwidth availability in India, 13.5 Terabit, consequently becoming profitable destination for IT and ITeS industries. The state is a pioneer in IT and software services, and has a 100 % digital exchange network thus having the potential to garner a major chunk of ITeS business. A large number of multinational companies set up their campuses in the city owing to its high level of literacy and the finest English language ability of the people. In addition, Chennai’s real estate value is comparatively cheaper because of the availability of large tracts of unutilized land and low operational cost and cheaper rentals.

EASTERN CLUSTER

Kolkata

The government of West Bengal is working towards showcasing the potential of Kolkata as an IT destination. It aims to become one of the top three IT states by 2011, contributing 15-20% of the country's total IT revenue banking upon Kolkata's low cost of operations, large talent pool, low attrition rates, abundant power and excellent infrastructure, the West Bengal government is hopeful that it would be able to attract more IT and ITeS companies to the city in the future.

WESTERN CLUSTER

Mumbai

Mumbai, the "Commercial capital of India", is one of the world's top ten trade centers. The city contributes 25% of industrial output and 70% of capital transactions to India's economy. The state of Maharashtra is the second largest exporter of software with annual exports of Rs 18 000cr (20% of India's software exports). The state has set up software parks in Pune, Mumbai, Navi Mumbai, Aurangabad, Nagpur and Nasik. With business talent and industrial resources available in abundance, Mumbai has seen big investments in the IT, ITeS and BPO sector. The city is residence to a huge talent pool and although its infrastructure is not as desired, it still is one of the best places to do business.

Pune

Pune, earlier considered as the industrial belt of Maharashtra is nowadays considered to be one of the most progressive and IT cities of India. It boasts of infrastructure necessary for setting up industries in both the IT & ITeS and manufacturing sectors. There is a proposal for Hinjewadi Phase II project of the Software Technology Park of India (STPI), which is proposed as the IT-BT Park in Pune, showing the governments keenness in promoting the IT industry in the city.

NORTHERN CLUSTER

NCR

The National Capital Region (NCR) is growing as the next big hub for IT and related industries. IT complexes in 3Q06, has brought in Giants like Accenture and further demand is expected to materialize soon. Noida is emerging as a preferred IT destination due to its fast developing infrastructure, proactive government policies and low costs.

OTHER EMERGING CITIES

In 2009, NASSCOM along with AT Kearney released the 'Location Roadmap for IT- BPO Growth. This was an assessment of 50 cities throughout India categorized locations into 4 groups, that is, Leader, Challenger, Follower and Aspirants. Following are the list of cities under each category.

Table 10: Other emerging cities

Categories	Cities	Strengths
Challenger	Ahmedabad, Bhuvaneshwar, Chandigarh, Coimbatore, Indore, Jaipur, Kochi, Lucknow, Madurai, Mangalore, Nagpur, Thiruvananthapuram, Trichy, Vadodara and Visakhapatnam	These cities are building an IT ecosystem to scale up the employment in the sector by promoting IT SEZs and attracting major companies to take advantage of reverse migration
Follower	Aurangabad, Bhopal, Goa, Gwalior, Hubli-Dharwad, Kanpur, Mysore, Nasik, Pondicherry, Salem, Surat and Vijayawada	These cities are working towards improving the infrastructure to levels of Challenger/Leader locations, with greater focus on academic and technical institutions.
Aspirant	Allahabad, Dehradun, Durgapur, Gangtok, Guwahati, Ludhiana, Patna, Raipur, Ranchi, Shimla, Siliguri, Srinagar and Varanasi	These cities are slowly enhancing their awareness about IT specific knowledge base, and are working towards improving infrastructure and promoting educational institutions to support the knowledge industry

The dispersion of IT centers will allow balanced economic development and reduce economic disparity. Apart from sharing the pressure from the top tier locations, this would also add considerably to the steadiness of employees and lessen migration to large urban areas. Further, this decongestion will enable IT industry stakeholders to play a proactive role in creating the ecosystem for research and development.

STATE SPECIFIC INITIATIVES AND POLICIES

Karnataka government has taken several initiatives to maintain its leadership position and propagate IT industry to a wider area within the state;

- The State plans to develop four Electronic Hardware parks in the clusters of Bengaluru - Tumkur, Shimoga - Hassan, Hubli - Dharwad and Mysore - Nanjangud
- The new IT Policy 2011 envisages promotion of the information technology industries and innovative parks in Tier II and III cities
- Cisco plans to assist in networking Bengaluru and has signed a MoU with the Karnataka government. As per the MoU, the project will focus on global sustainable solutions for public

safety and security, transportation, buildings, power distribution, energy utilization, health care, education and environment conservation

- To encourage Business with non-English speaking Countries**, t**he government will welcome and encourage initiatives from all these countries and will promote cross interaction initiatives as well as cross cultural activities. They will also be encouraged to set up their country specific IT Parks in the state

The state has also formulated policies for the IT industry;

- To effectively reduce unemployment by absorbing the major share of educated youth into the IT Industry
- To use e-governance as a tool and deliver a government that is more pro-active and responsive to its citizens to unleash the Karnataka Incubation engine
- Incentives in terms of areas of cost of land, registration charges, FAR, Zonal regulations etc. New companies that provide employment of more than 250 in Bengaluru and 100 in other areas will be eligible for these concessions
- Seeks to establish 225 training centres all over the state, primarily for the purpose of training the unemployed educated youth in various IT skills. The government will encourage private sector Initiatives in setting up such centres
- Fiscal Incentives:
    - Exempt from payment of entry tax and purchase tax on computer hardware, computer peripherals and other capital goods
    - Companies will be offered sales tax exemption for a period of 10 (ten) years or deferment for a period of 12 (twelve) years
- The concessions detailed above are primarily meant for IT companies where initial investment in a new company, or in expansion, modernization is less than Rs. 100 crores. If the investment is more than Rs. 100 crores, the government considers that project as a Mega project and a special set of initiatives and concessions will be worked out with reference to the needs of the company

- The Government is pleased to relax FAR for all IT projects set up outside the limits of the municipal corporations in the state 50% exemption from payment of stamp duty and registration charges on the first sales of land in the case of IT Parks

The Andhra Pradesh government too has formulated its own set of policies and initiatives to attract and grow IT industry within the state;

- Government has been contemplating promotion of IT industry outside Hyderabad including the VEPZ Visakhapatnam.
- The Andhra Pradesh Technology Development Corporation (APTDC) will set up a technology exchange to provide information to small entrepreneurs about the latest technological developments worldwide, including the scope for technology transfer. The exchange will operate in close association with industry associations such as the CII, FICCI etc.
- Areas such as smart appliances, next generation communications, broadband internet equipment and robotics will get specialised packages
- Planned to facilitate the development of a nanotechnology park near the hardware park in Hyderabad to encourage private enterprises to set up semiconductor manufacturing and related activities including R&D.

Policies

- Exemption of Software Industry from the purview of AP Pollution Control Act, excepting the power generation sets and exemption from the purview of the statutory power cuts
- Total exemption of payment of sales tax on the sales of the computer software under the APGST Act 1957
- Rebate in the cost of land allotted to an IT industry at the rate of Rs 20,000/- per job created subject to certain conditions
- Rebate in the registration charges, stamp duty and transfer of property charges on a tapering scale for the sale/lease of built up space to the IT industry
- Investment Subsidy to an extent of 20% subject to a ceiling of Rs 20 lakhs on the fixed capital investment.

- Mega projects investing more than INR 1 billion will be eligible for special package of incentives on a case-to-case basis.

Not to be left behind, Maharashtra government also has formulated its policies and initiatives to enable further growth IT industry in the state;

- The state government has drawn up an ambitious plan of establishing 325 more information technology (IT) parks in the state to give a fillip to the sector. The state currently has 55 such parks.
- Promote Nagpur, Nashik and Aurangabad districts as IT hubs
- Promote establishment of Knowledge/Resource Centres and Incubation Centres across the State
- Promote the development of special fields such as AVGC (Animation, Visual effects, Gaming and Comics) in which the State has particular strengths
- The Maharashtra Knowledge Corporation Limited (MKCL), Maharashtra State Board of Technical Education (MSBTE) and other agencies will institute training based certification and placement programmes in collaboration with NASSCOM and local IT-ITES industry to better understand their resource requirements

Policies

- 100% additional FSI shall be made available to all registered IT/ITES units in Public and Private IT/ITES Parks approved by the Directorate of Industries
- 100% Stamp Duty exemption for the following transactions to all new registered IT-ITES units and expansions/ areas, in C, D, D+, No Industry and Low HDI Districts
- 100% Stamp Duty exemption for the following transactions to new IT-ITES units and expansions in public IT parks, in IT, IT hardware, and Telecom hardware manufacturing SEZs
- IT-ITES units shall be exempt from octroi/ entry tax or other cess or tax levied in lieu of these.
- IT-ITES units (except IT hardware and Telecom Hardware Manufacturing Units) will be allowed in any Zone (including residential and no-development zones, etc).

SOFTWARE TESTING AND EVALUATION AT CENTERS

IT Centre, Delhi: A large number of E-Governance projects from state and central ministries have are being undertaken in Delhi. This includes Ministry of Corporate Affairs (MCA21) Annual Audit, India Portal (National Informatics Centre, New Delhi), E-Procurement System (CRIS, Ministry of Railways), Rashtriya Swastha Bima Yojna (Ministry of Labour), Agriculture Portal, Human Resource Management System, E-class and Commercial Data Vault (Govt. of Uttarakhand, Dehradun). IT Centre, Delhi is the leading laboratory for creating test processes and domain based test case designing.
IT Centre, Bengaluru: The Centre undertakes testing of various software systems namely SPARK (Service and Payroll Administrative Repository of Kerala), E-payment-website (Commercial Taxes, Govt. of Kerala), E-Learning (Infotech Corporation of Goa Ltd), National Population Register (Bharat Electronics Limited), Income Tax (Income Tax Department.-CPC-E-Filing) and Jeevan Project (Govt. of NCT of Delhi). In addition, mission critical software of Defence projects are evaluated for quality here.
IT Centre, Hyderabad: The Centre carries independent Verification & Validation, Code Walkthrough and Review of Design document (along with IT centre, Chennai) for the Electronic Counter Measure part of Ellora. The centre also completed functionality, security and performance testing of Combined Entrance Test Software for Web based Counseling for seat allotments for the professional colleges in Andhra Pradesh (AP).
IT Centre, Kolkata: The Common Criteria (CC) Test Lab, at IT Centre Kolkata, is accredited by American Association of Laboratory Accreditation (A2LA, USA) for EAL2 evaluation capability last year. India has become a signatory to Common Criteria Recognition Arrangements (CCRA). The Lab aims to meet the needs of the Government and industries for evaluation and certification of IT security products. IT centre, Kolkata also undertook third party audit for Quality and Security assurance for important E-Governance mission mode and other projects like Passport Seva Project, E-Chips, E-District Assam, E-Nibandhan Jharkhand etc. The testing of some of these projects is in progress.
IT centre, Chennai: The Centre undertakes Application Security Auditing / Testing for the Web-Portals of Commercial Tax Dept. (Govt. of Tamilnadu), Tamilnadu Police Housing Corporation Ltd., Online Learning System of National Instructional Media Institute (Govt. of India), Tamilnadu Veterinary & Animal Sciences University and Transport Department (Govt. of Tamilnadu).
IT Centre Pune: The Centre obtained accreditation for 'International System Examination Board/International Software Testing Qualification Board (ISEB/ISTQB) Intermediate Certification Course in Software Testing by taking lead role. The Centre also conducted Testing and Evaluation of e-Governance projects of Maharashtra state namely GRAS and BEAMS.

Based on literature analysis and expert views the following points are likely to emerge and drive IT companies to develop products and services in order to address changing customer needs in the years to come.

Product Development through Cloud

The cloud environment and SaaS have opened up a new product development environment that will result in faster and better enterprise solutions. It will allow IT vendors to work with clients to test, revise and iterate on subsequent versions. Companies are developing newer applications and delivering them as a service in much shorter time unseen in the past.

Evolution of Mini-Vendors

In current environment will foster growth of a new generation of startups called mini-vendors. As developers get free from the related investments, these mini-vendors can concentrate on creating products for newer applications or for specific areas that might not have been financially tenable in the past. Further, the emergence in vendor ecosystems will enable IT entrepreneurs position their products to compete in a more cluttered market environment and still survive.

"Product" Potential of Indian IT companies

Advantages of cloud environment, a strong services-sector workforce coupled with brain circulation has generated a growing market of mini-vendors in India. These startups are not only developing products for the global market but for their domestic market. While other regions are booming, like China, Brazil etc India's combination of talent and entrepreneurial spirit will place it on better footing for the future.

Financial strength of Mega vendors

Large companies with requisite financial muscle will continue to acquire smaller and creative startups to augment their rate of innovation in niche areas in the years to come.

Market Expansion

With the expansion of the economy, it can be assumed that domestic enterprise IT spending will grow in the coming years. Most CIO's are keenly looking at solutions that leverage the cloud's potential. Our interactions reveal that organisations will spend significantly building private clouds to serve both internal and external customers. Therefore, vendors are expected to be successful in helping clients to innovate in these key areas.

New Technical Employee Base

In IT sector paradigm, with the cloud reshaping typical departmental functions. Many management duties will move to the vendor. This will need retraining internal IT staff for business-oriented functions and, analytical skills. Given this circumstances, IT companies have an opportunity to help other companies with innovative solutions in the fields of training, recruiting and workforce management.

More Demanding User Base

A recent EIU study sponsored by a leading IT company in India evaluated the overall concept of the next generation workforce. It was found that no user in tomorrow's workforce will stand for green screens and software training sessions. They are likely to demand more progressive, cutting-edge applications or they will move on to an organisation with better work environment.

Mobility in the Enterprise-class

With millions of smart phones being possessed by enterprise employees it is unimaginable to envision future business solutions without mobile connectivity. IT companies are working on ways for securely integrating mobile devices and application solutions for their overall IT objectives. Vendors will see innovation opportunities for both employee- and customer-facing applications in these new mobility realms.

Social Networking for Enterprises

The success of Facebook and LinkedIn has shown the potential for leveraging these tools in the business environment. The IT industry responded with new and different applications to meet the needs of this emerging base, including Yammer, Box.net, Spiceworks, Salesforce's Chatter, and more. As the market expands, more opportunities for innovation will present itself in niche areas. The future is anticipated to be a breakout for enterprise social networking and collaboration applications.

Eco-friendly Software

Increased corporate responsibility about sustainability will continues to play a leading role in optimizing efficiencies. In the past, SAP, IBM, Microsoft, Autodesk and other IT industry leaders launched game-changing solutions to help their clients operate more responsibly. IT vendors face innumerable innovation opportunities to develop green products in the areas of energy efficiency, manufacturing, supply chain, distribution, data center optimization, building and operations.

FUTURE AREAS FOR IT INNOVATION IN INDIA

Based on the current market trends and opinions of a cross-section of industry participants, the following market segments could gather significant momentum for IT companies and start-ups and generate lot of interest from the investor community.

Cloud Computing – with applications and software made available on pay per use model, India is keen to build a cloud computing environment. According to Zinnov Management Consulting, Indian cloud computing market is expected to touch USD1.08 billion by 2015, from the current USD110 million. In addition, cloud computing will offers new advantages to reach low income group through larger scales of operations and increased transparency.

Mobile Payment Gateways - This segment is gaining a lot of popularity among the investors especially easy money transfer services over mobile phone would be a big area of innovation in India.

SaaS Model – Indian entrepreneurs could also look at better, faster, cheaper innovative SaaS models like Zoho, Vembu and DimDim. These companies have paved way and inspire companies to innovate in SaaS model in many other segments.

Mass Reach – Naukri.com was a good example of this, though not high on innovation but it came as a scalable product with simple user interface. Very few start ups have been able to replicate similar scalable product capabilities and none have been able to match the success that Naukri.com.

Micro-financing – Blow-up of big banks in last few years indicate a fundamentally new model may be needed and Indian entrepreneurs can assertively look to tap this huge untapped market opportunity. As per BCG "unbanked" population in the BRIC countries could generate USD85 billion in banking revenues by 2015.

Voice recognition – Mobile voice recognition is growing at a frantic pace. Indian start ups like Ubona and Mscriber have made good inroads in this area but there is more room for innovative voice recognition.

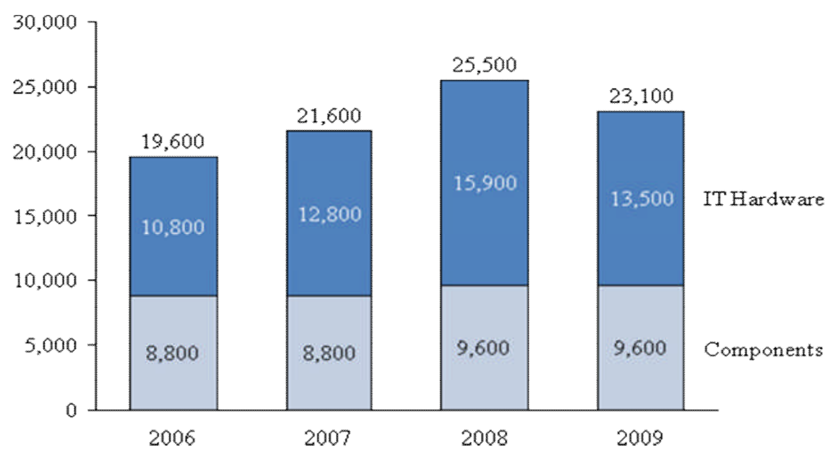
Mobile advertisement networks – Advertising through mobile phones will be a challenge but and area for innovative activity. A few companies like mKhoj, dealmaadi and dealaajtak have entered this space, with mKhoj having been able to capture a section of the market.

Embedded software and design - India is on the edge of a huge market opportunity in the embedded computing segment, where some of the world's largest embedded device and software suppliers are gaining traction from a design and development perspective. ISA expects that embedded software will register revenues of around USD11.8 billion in 2010 because of the growth in retail automation, industrial electronics, consumer electronics, wireless infrastructure, medical products and automotive segments. *According to Mr. Ravi Pandit (KPIT Systems); areas like infotainment and navigation systems will see a lot of action due to the increase in automation in domestic appliances and automotives in the coming years.*

HARDWARE

Unlike its illustrious cousin, the IT hardware industry in India is relatively underdeveloped even though it started with manufacturing of valves and vacuum tubes way back in the 1920's. This sluggish growth can be attributed to low domestic investments because of the signing of ITA-1 under WTO. However, from 2002 onwards there has been considerable rise in the R&D activities of the industry in light of booming consumer spending, penetration of IT and growth of mobile telephony.

Chart 20: Domestic hardware production

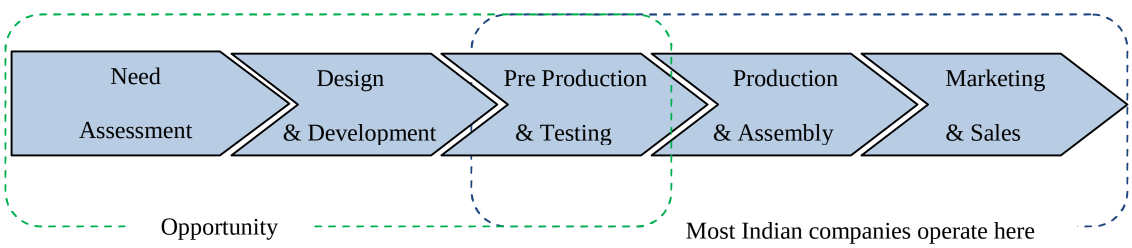


Source: Department of Information Technology, Netscribes analysis

The domestic production for IT hardware including components during the year 2009 was estimated at INR 23,100 crores and saw a dip in the same year due to the economic slowdown. The demand for hardware is much higher which makes India a net importer of hardware with about 70% of its requirements coming via imports and this trade deficit is likely to continue in the next few years if the government does not take firm steps to boost local manufacturing. IT hardware includes, personal storage devices, printers, servers, Personal Computers (PCs),supercomputers, data processing equipment and peripherals such as monitors, keyboards, disk drives, plotters, SMPS, modems, networking products and add-on cards. Till recently, this segment was dominated by local assemblers and some branded Indian companies. A number of MNCs (such as Compaq, HP, IBM, DELL and ACER) have entered the Indian market space. However, it should be noted that much of the production of IT Hardware in India is still largely dominated by assembly and packaging, and not production of high end IT sub-assemblies.

VALUE CHAIN

Figure 19: Hardware value chain



Indian hardware industry primarily operates in the later stages of the value chain barring a handful of companies that have their integrated R&D set ups. Most companies are assemblers of machines and devices with components being imported from different parts of the globe. This is one aspect that points towards India’s very high imports of IT hardware. In effect with demand estimated to rise multifold in the next decade or so, this situation offers a great opportunity for companies and research houses to engage with Indian counterparts to design and develop cutting edge products both for the local and global market.

DRIVERS FOR IT HARDWARE

The growth in the IT hardware industry has been due to;

- Rapid urbanization with increasing disposable income
- Increased per capita spending on IT and Education

- Ease of financing options
- Increased demand from other Indian companies because of IT adoption
- Government demand based on initiatives like National E-Governance Program, Sarva Shiksha Abhiyan
- Growth of the IT/ITeS industry

These factors are likely to boost demand for hardware further in the future and as Indian companies gain better foothold of exports in other emerging markets there lies great scope for European companies and agencies to engage with domestic companies to capitalize on the opportunity.

MAJOR COLLABORATIONS IN IT HARDWARE

- **HP Labs** India supports open innovation by working in collaboration with various academic institutions. The collaborations include joint PhD Fellowships, sponsored research students and sponsored research project. The company has research collaborations with ISI – Kolkata, University of Canterbury - New Zealand, University of Bristol, University of Toronto, Indian Institute of Science, IIT Bombay, IIT Delhi, IIIT Bengaluru, UFSC, Brazil, UFPE, Brazil, SUNY, Buffalo, Center for Advanced Studies and Systems and University of Southern California. Further, HP Labs has ongoing PhD Fellowships with BITS Pilani and IIIT, Bengaluru. The company currently in India, has alliance with 250 Independent Software Vendors (ISVs). These alliance partners collaborate with HP to deliver solutions that can be tested across servers, storage, management software, networking, power & cooling, security and services.
- In 2007 **ACER** officially established its Indian subsidiary ACER India. The company is focused on working in partnership with classroom teachers, school leaders, education consultants, system leaders, parents and learners themselves to improve educational outcomes and develop local solutions to local problems. ACER India offers Assessment Services, Professional Learning for teachers and Leadership Training for principals. In addition to this, ACER India enables institutions in India to benefit from the extensive expertise and resources of ACER.
- **Dell** with most of its products available in India through its online channel its distribution in India remains different from that of the other countries. Dell adopted a proper channel partner that distributes the Dell products in the same old fashion that the Indians are used to. Its online solution database is exhaustive with problems categorized by topics, making things easier for the customer.

The site offers technical support in a language that is comprehensible even to customers who are not technically literate. Recently, the company launched the Connected Classroom solution in India, combining innovative technology, products, services, software and training.

R&D LINKS BETWEEN MULTINATIONAL CORPORATIONS AND ACADEMIA

The huge influx of foreign direct investment (FDI) in India's electronics and IT sectors has led to a growing number of university-industry partnerships for undertaking R&D. The Indian Institutes of Technologies (IITs), Indian Institutes of Science (IISc), and other specialty institutes have become hubs for innovation fueled by investments from overseas IT companies.

Following are the break-through innovations happening in Indian labs and incubation centers, which will enable companies to lead in the next wave of opportunities from other rapidly growing economies.

Multi-touch Technology Gaining Momentum

Touch in the PC world is the ability for users to interact directly with on-screen objects by touching the screen with their fingers. Multi-touch allows two or more finger contacts which are independently recognized and acted upon.

Dell is working towards balancing best-in-class customer experience with cost. For its products Latitude XT2 and the Dell Studio One 19, the company is using capacitive touch, which is more complex and expensive to implement, but has significant usability advantages. Capacitive touch does not require pressure to activate, allowing the system to respond to the lightest of touches.

Currently, multi-touch is breaking free from one-mouse, one-pointer paradigm, and is expanding into more intuitive and natural interactions. In coming few years, Dell anticipates to be able to integrate a multi-touch digitizer onto the liquid crystal display (LCD) itself. That could drive touch into many more products.

Human Computer Interaction

The Intuitive Multimodal and Gestural Interaction project at HP Labs India is exploring new technology that recognizes human gestures and eliminates the need for a keyboard. This shows that natural input modalities such as touch and hand gestures are becoming main stream and redefining human computer interfaces for personal systems.

The Next-Generation Display Interface

DisplayPort is an edge-cutting, desktop and laptop PC endorsed by the Video Electronics Standards Association (VESA).

The technology offers new advantages, such as: fewer display inputs for more compact and sleek display designs with twice the scalable performance for DVI for higher resolutions and color depths. It also offers two-way capability for simpler, single-cable connectivity to multiple peripherals. It has micro-packet architecture for capabilities such as network routing and, in the future, daisy-chaining of displays. Most importantly, it offers scalable display lanes for improved interoperability, reducing electromagnetic interference (EMI) and the number of wires required within a display cable

This introduction of DisplayPort has not only ushered in a new era of visual performance and usability. It has also laid the groundwork for critical developments to come.

Simplifying Web Access and Interaction

Web Access and Interaction project at HP Labs India aims to fundamentally simplify web experiences that will help everyone realize the value of the web. A user's web interactions require to be encapsulated so that the interaction is personally familiar, organized and reachable with minimal effort. The aim of the research is to make web interaction as simple as using a phone, watching TV or reading a magazine or newspaper.

Device, Connectivity and Cloud services

This research is about the current state-of-the-art of the devices and their future evolution towards an ideal converged device which would be more than a phone but less than a PC, yet portable and/or pocketable. Further, research is being conducted in bridging the gap between user experience in the mobile domain and the stationary domain such as when the user is at home or in the office. In the services research area, the companies can leverages the immense wealth of capabilities available in the cloud and wireless area to improve performance, increase reliability, and minimize cost both to the end-user and the service provider.

Mobile & Immersive Experience Lab

HP is developing multimedia technologies to deliver interactive, mobile, and immersive audio-visual experiences. The idea is to develop natural and intuitive forms of interaction between people and technology. Further, researchers are also working on creating the next generation of 2-D and 3-D display technologies and information surfaces for mobile and immersive environments. This enhancement in technology will change how people collaborate, communicate, socialize and entertain.

Optical Storage Technology

Dell is working on Next-Generation Optical Storage Technology, Blu-ray Disc which will meet the storage and performance requirements of next-generation data and high-definition video applications, and is well-positioned to succeed CD and DVD technologies. The higher capacity, additional features and transparent content protection of Blu-ray Discs will provide the required headroom to meet industry needs for at least the next decade.

GOVERNMENT POLICIES

- With Government initiatives the sector has attracted significant amount of FDI (Foreign Direct Investment) over the past decade. The special preference given to the IT sector has helped enormously in promoting investments. Infrastructure has also been improved in a great way. A separate ministry 'Ministry of Information Technology' was set up to expedite swift approval and implementation of IT projects and streamline the regulatory process.

- Several 'Software Technology Parks of India' (STPI) have been set up by the 'Ministry of Information Technology'. These technology parks have world class infrastructure and offer various concessions to encourage foreign investment and promote software development in India. For example, 100% foreign equity is permitted and approved under the 'Automatic Route' powers of the Directors of STPI, and tax holiday until March 2011.

- However, STPI Tax benefits are scheduled to expire in March 2011. This could provide a demand boost to SEZs (Special Economic Zones), which could become the next tax haven for IT/ITeS companies in India. But, the government could still extend STPI tax holiday via a notification before the expiration date as per IT industry requests till the proposed Direct Tax Code (DTC), under consideration, is implemented.

- Special Economic Zone (SEZ) Scheme: SEZ's are being set up to enable hassle free manufacturing and trading. Sales from Domestic Tariff Areas (DTA) to SEZ's are being treated as physical export. This entitles domestic suppliers to Drawback/Duty Entitlement Pass Book (DEPB) benefits, Central Sales Tax exemption and Service Tax exemption. Certain exemptions like Income Tax exemption on export profits is available to SEZ Units for 5 years, 50% for next 2 years and 50% of ploughed back profits for 3 years thereafter are available for units in these designated areas/zones.

- Export Oriented Units (EOUs) Scheme: The purpose of the scheme is basically to boost exports by creating additional production capacity. 100% EOUs fall into 3 categories

    - (A) EOUs established anywhere in India and exporting 100% products except certain fixed percentage of sales in the Domestic Tariff Area (DTA) as may be permissible under the Policy.

    - (B) Units in Free Trade Zones in Special Economic Zones (SEZs) and exporting 100% of their products.

    - (C) EOUs set up in Software Technology Parks (STPs) and Electronic Hardware Technology Parks (EHTPs) of India for development of Software & Electronic Hardware.

- Export Promotion Capital Goods (EPCG) Scheme: The EPCG Scheme allows import of capital goods for pre-production, production and postproduction at 5% customs duty subject to export obligations.

- Profit earned from software export are exempted from income tax under section 80HHE of the Income Tax Act

- No custom duties are levied on the import of software and software licenses.

- Indian direct investment in Joint Ventures wholly owned subsidiaries abroad was simplified and a fast track window is made available for large investments. IT companies in India can acquire companies overseas through American depositary receipt / Global depository receipt stock without prior approval for up to USD100 million or ten times the export earning of the previous years.

- India being a signatory to the information Technology Agreement (ITA-1) of the world Trade Organization it is exempted from customs duty on ITA items.

SUPPORT INITIATIVES FOR THE IT INDUSTRY

Government of India has taken measured steps towards encouraging and achieving full potential of the Indian IT industry. For example, venture capital has been the main source of finance for the IT industry around the world. However, majority of the software units in India fall into the small and medium enterprise category where there is a critical shortage of capital. In order to ease this situation, the government has set up a National Task Force on IT and Software Development to examine the feasibility of strengthening the industry ecosystem. In addition, the government is also actively providing fiscal incentives and liberalizing norms for FDI and raising capital from abroad.

Recently, IT committee was set up by the Ministry of Information Technology, Government of India, comprising Non Resident Indian (NRI) professionals from the United States to seek expertise and advice and also to step up U.S. investments in India's IT sector. The committee is chaired by Minister of Information Technology, Government of India, and the members include Secretary, Ministry of Information Technology and a large number of important Indian American IT entrepreneurs.

This group will:

- Supervise global IT developments and filter Indian IT policy to meet global requirements. This would particularly, help angel investors, venture creators and incubation

- Encourage the growth of human resource development in the IT sector with the aim of creating quality-based education

- Promote R&D in the sector by recognizing thrust areas and drawing up a blueprint for action

ONGOING INNOVATION SUPPORT PROGRAMS

Innovation in Indian Languages Technologies

In order to increase the penetration of IT in different Indian languages, the government has taken a major initiative to provide free access of Software tools & fonts in various Indian languages to the general public. Software tools & fonts for 22 constitutionally recognized Indian languages have been released in public domain for free use by the population.

Establishment of BOSS Support Centers & Business Development (NRCFOSS)

National Resource Centre for Free & Open Source Software (NRCFOSS) in C-DAC Chennai has developed GNU/Linux Operating System distribution named as Bharat Operating System Solutions

(BOSS) with wide Indian languages support. The project "Establishment of BOSS Support Centers & Business Development (NRCFOSS)" has been initiated for proliferation of BOSS in the country through building support centers and business development.

Screen Access for All (SAFA)

SAFA, a screen reading software has been developed in different vernaculars to enable visually impaired people to operate computers using speech output support for MS Word applications in windows environment. It is being used by more than 1,000 visually impaired users in Hindi and English.

Software for visually impaired women

Shruti-Drishti (Text to Speech & Text to Braille) software is deployed along with the necessary hardware and training in 40 special schools for visually impaired women throughout the country. Computers with Shruti-Drishti software have been supplied to schools benefiting 4000 blind students.

E GOVERNANCE & E-HEALTH- ACASE

E-Governance

The Indian government has identified e-Governance as an area where it is investing heavily. It has initiated the National e-Governance Plan to make all government services easily accessible to the common man, while bringing in efficiency and transparency through the process. The Indian government has separately allocated USD 9 billion for investment in National e-Governance Plan (NeGP) projects.

Scope of e-Governance as envisaged is as follows:

a) Government to Citizen (G2C) – It will aim at connecting to citizens by talking to them and supporting accountability, by listening to them and supporting democracy, in order to improve public services.

b) Citizen to Government (C2G) – This will mainly constitute of areas where citizen interacts with the Government. It will include areas like election when citizens vote for the Government; Census where he provides information about himself to the Government; taxation where he is paying taxes to the Government.

c) Government to Government (G2G) – This can also be referred as ***e-Administration.*** It will involve improvement in government processes by cutting costs, by managing performance, by making strategic connections within the government.

d) Government to Business (G2B) – This will constitute of various services a business house needs to get from the Government, which includes getting licenses etc. In a similar scenario, it can also flow from a business house to the Government as in the case of procurements, from such business houses by the Government (G2B)

e) Government to NGO (G2N) – Building interactions beyond the boundaries of government by developing communities, by building government partnerships, and by building civil society. It will involve building various associations or interest groups that will ensure the betterment of the society

As of Dec 2009, the government approved budgetary sanctions to 31 states and Union Territories. 6 states are already well into this programme and have completed the bid process for selection of the data centre operator, while it is still in progress with other 9 states.

Some of the key requirements for implementing successful e-governance are :

- e-Governance framework with enough bandwidth to service a population of 1 billion
- Connectivity framework for making the services reach rural areas of the country or development of alternative means of services such as e-governance kiosks in regional languages
- National Citizen database which is the primary unit of data for all governance vertical and horizontal applications across the state and central governments (UID cards)
- e-governance and interoperability standards for the exchange of secure information with non-repudiation, across the state and central government departments seamlessly
- A secure delivery framework by means of virtual private network connecting across the state and central government departments.
- Datacenters in centre and states to handle the departmental workflow automation, collaboration, interaction, exchange of information with authentication.

In 2009, the government announced one of its biggest and most ambitious projects – The Unique Identification Number (UID) also known as 'Aadhaar' to over 1.2 billion residents of the country. This proposed system will create substantial IT opportunities.

E-Health

The E-Health Care project aims at improving the efficiency and effectiveness of India's antiquated healthcare system by use of ICT by delivering solutions to a wider population living in distant places. It is a web based patient care system that tracks a patient's health record from the time of their joining the network and for as long as the patients manages to provide their health data. It offers them an opportunity to maintain their health record and authorize their physicians to access it as needed. The main focus for this programme is;

- Electronic communication and telematics in health care
- IT solve common problems & streamline process
- Decrease bureaucracy and paper mess
- Higher quality service and satisfaction for patients
- More Productivity For Doctors & healthcare providers
- Help monitor performance & achieve goal faster

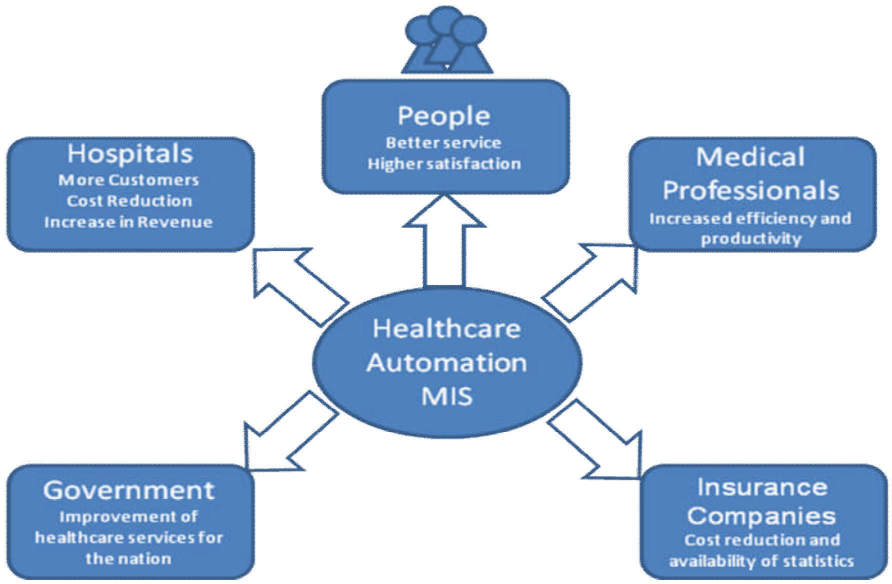
Currently, healthcare services in rural areas where majority of Indians live is desperately inadequate. Majority of diseases in these areas are treated by untrained people. Because of poor infrastructure, qualified doctors do not want to serve in rural areas. Also, poverty prevents most people to consult a qualified doctor even when available.

Table 11: Healthcare Delivery System

Level	Public	Private
Primary	Public health centers (PHC)	Private practitioners
Secondary	District Hospitals	Small private hospitals & Nursing homes
Tertiary	Teaching Hospitals	Large Nursing Homes & Corporate Hospitals

While E-health programme is considered mainly for its ability to deliver healthcare solutions to large sections of the society, it also has multi fold benefits for all stake holders.

Figure 20: e-Health ecosystem



Source: e-healthcare solution.com

India is steadily progressing with its e-Health initiatives. Currently, most tele-medicine initiatives are in the project phase with ISRO (Indian space research organisation) as its backbone and the support of state governments. Few private healthcare providers have also established their own tele-medicine networks like Apollo telemedicine network foundation. Some of the countrywide projects being undertaken by Ministry of Health are Integrated Disease Surveillance Project (IDSP), the National Cancer Network (ONCONET), the National Rural Telemedicine Network, and the Digital Medical Library Network.

The National Knowledge Commission has also set up a Working Group for the development of an Indian Health Information Network. This working group was mandated to design, develop, and integrate an end-to-end electronic health care informatics network framework in India. A National Resource Center on Telemedicine & Biomedical Informatics is being set up at Lucknow with the support of the IT department of the Government.

Table 12: Major areas of work and participating organisations

Fields	Areas of work	Organisations
Electronic	Hospital information system (HIS)	Center for Development of Advanced

Medical Records and Hospital Automation	software Health Highway (national health data network)	Computing (C-DAC) in collaboration with Sanjay Gandhi Post Graduate Institute of Medical Sciences (SGPGIMS) The Apollo Hospitals Group with IBM
Telemedicine Initiatives	DIT has established more than 100 nodes all over India, mostly in collaboration with the state governments. These include the telemedicine network in West Bengal for diagnosis and monitoring of tropical diseases, the Kerala and Tamil Nadu Oncology Network for facilitating cancer care, and the Northeastern states and Himachal Pradesh ISRO is deploying telemedicine nodes under a GRAMSAT (rural satellite) program through Indian Satellite System (INSAT. In collaboration with state governments, it has established a telemedicine network for 300 hospitals. A total 257 remote/rural district hospitals and health centers have been connected to 43 super specialty hospitals located in major states. Implementing the Integrated Disease Surveillance Program Network, which will connect all district hospitals with medical colleges of the state to facilitate tele consultation, tele-education, training of	Department of Information Technology (DIT), Ministry of Communication, and IT (MCIT), Government of India Indian Space Research Organization (ISRO) Ministry of Health and Family Welfare (MoH&FW)

	health professionals, and monitoring disease trends	
E-Learning in the Health Sector	Establishment of the Indian Medical Literature Analysis and Retrieval System (MEDLARS) Center to cater to the information needs of the medical community of India Setting up the Tele-training Center at National Institute of Health & Family Welfare in New Delhi to create a facility that will offer tele-training of public health professionals across the country through various e-learning modules e-Continuing Medical Education (e-CME) Plans to network all the government medical colleges with high bandwidth fiber optics to facilitate an e-Continuing Medical Education (e-CME) program	National Informatics Center (NIC) and the Indian Council of Medical Research (ICMR) Ministry of Health and Family Welfare (MoH&FW) Ministry of Health and Family Welfare (MoH&FW)

In terms of Technology, India is now capable of meeting its needs for Software, Hardware, Connectivity and Services to roll out the E-Health projects. The prominent private organisations providing support to the program are:

Table 13: Prominent private companies involved in e-Health

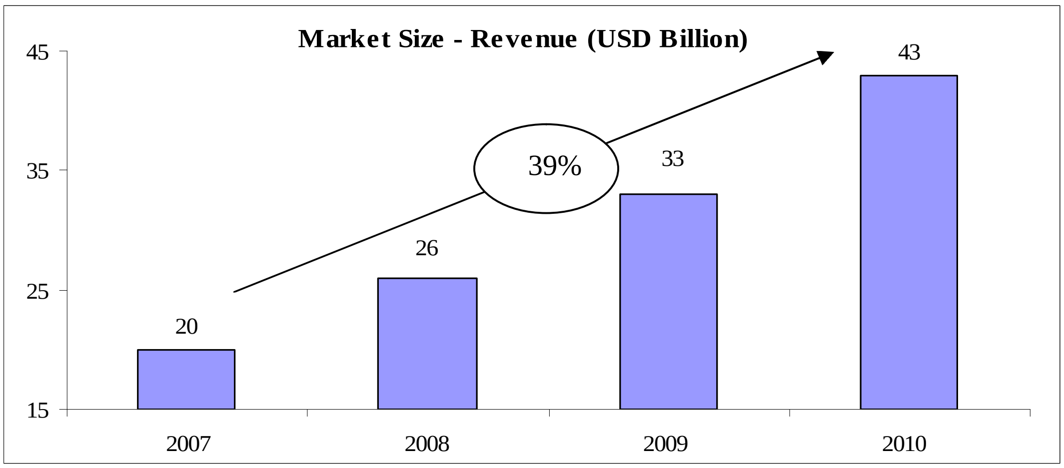
Company	Location
Apollo Telemedicine Network Foundation	Hyderabad
Online Telemedicine Research Institute	Ahmedabad
Televital India	Bengaluru

Vepro India	Chennai
Prognosys Medical Systems Pvt. Ltd.	Bengaluru
Medisoft Telemedicine Pvt. Ltd.	Ahmedabad
Idiagnosis Technologies	Ahmedabad
Karishma Software Ltd.	New Delhi

7. TELECOMMUNICATION

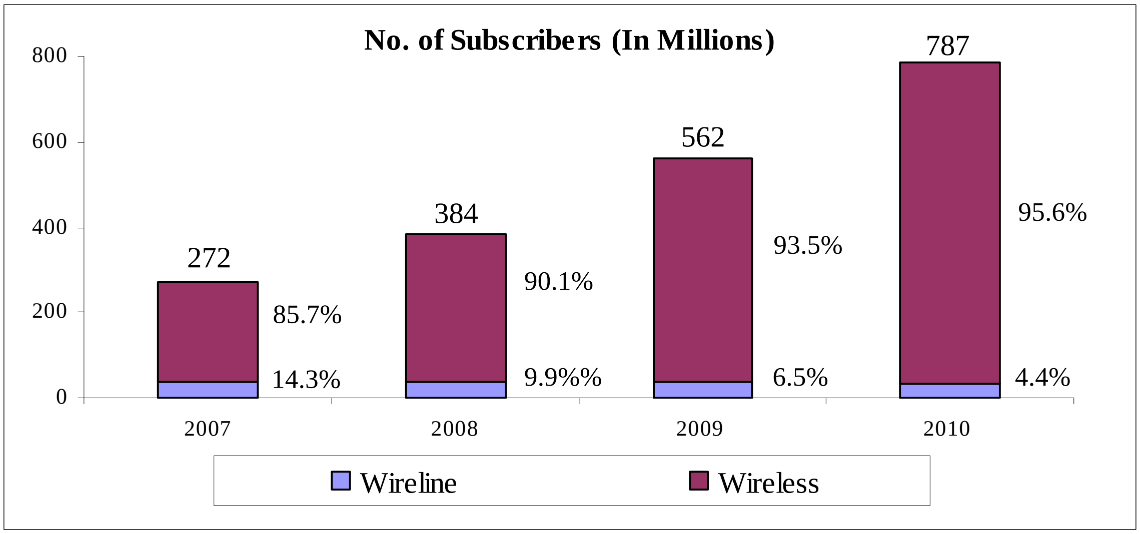
The Indian telecommunication sector has experienced phenomenal growth in the past decade. As of 2009, India was the world's fastest growing telecommunication industry. The total telecom market, including hardware and services, has grown at a compound annual growth rate (CAGR) of 39% from 2007 to 2010.

Chart 21: Market size



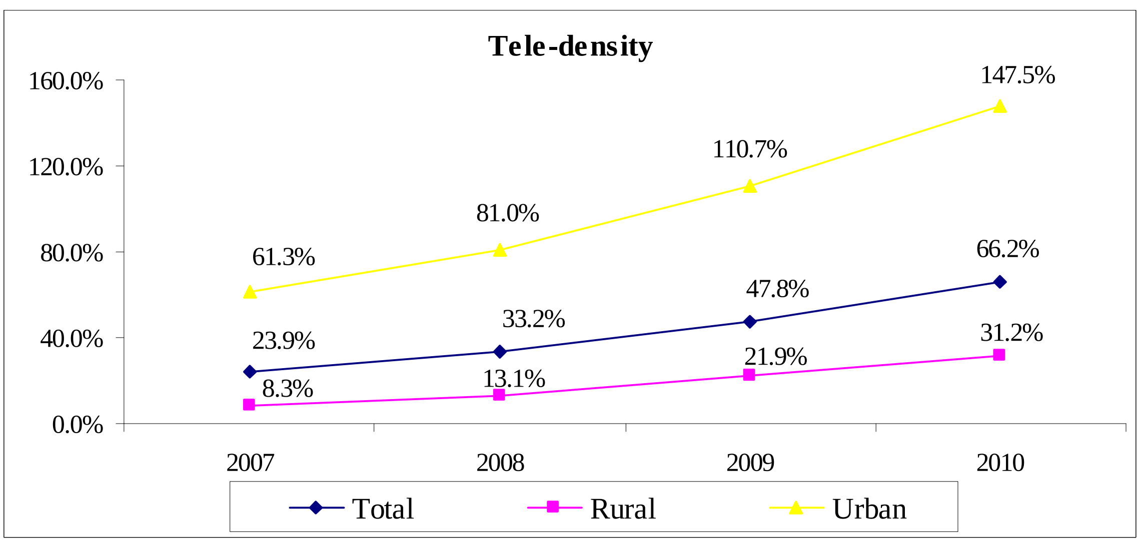
This growth has been driven by the wireless revolution - India has the world's second largest mobile subscriber base and is only surpassed by China's. The growth will be further boosted by the upcoming services that promise to provide broadband and data-based services for all. The industry is evolving through the introduction of the 3G networks and R&D on Broadband Wireless Access (BWA) technologies - WiMax and Long Term Evolution (LTE).

Chart 22: Number of subscribers



Although India has a high subscriber base, there is a huge difference between urban and rural tele-density. With a tele-density of 147.5%, there is a high degree of penetration in the urban areas while tele-density is quite low at 31.2% in rural areas. Therefore, there is an enormous untapped market in India waiting to be served. According to a report published by Gartner Inc in June 2009, the total mobile services revenue in India is projected to grow at a CAGR of 12.5 per cent from 2009-2013 to exceed USD 30 billion[13].

Chart 23: Teledensity



The sheer volume of the untapped potential offered by India attracts a large number of foreign players which includes both service providers and equipment manufacturers. As per 2008-09 FDI statistics,

[13] Gartner.com – Gartner predicts Indian Mobile Services Market to reach USD 30 Billion by 2013

Telecommunication is third most attractive sector, attracting almost 8% of total FDI, amounting USD 9 billion. Several foreign companies are investing in establishments of Indian subsidiaries and captives. Also, while in 2008-09, the domestic industry produced telecom equipment worth USD 11.5 billion[14], India spent USD 10.2 billion[15] on imports for telecom equipment. Telecom equipment imports account for 4 % of India's total imports. The total requirement for telecom equipment is expected to scale from the current USD 20-30 billion to USD 70-100 billion by 2015.

With foreign players accruing benefits of the growth in the Indian telecommunication industry, the government along with homegrown companies is making efforts to develop the domestic industry. Though the total production of telecom equipment increased from USD 3.1 billion in 2002-3 to USD 11.5 billion in 2008-09 at a CAGR of 24.4%, the domestic players still have a long way to go to develop and market globally competitive technology.

DECODING INNOVATION IN THE INDIAN TELECOM SECTOR

India has always been perceived as a small R&D spender. However, with the availability of talent and cost-leverage offered by emerging countries, most of the global companies have been focusing on boosting their R&D spend in emerging countries like India, China and Russia. In 2009, global telecom R&D spend was approximately USD 38 billion, of which one-fourth was off-shored to low cost countries like India and China. India's share in the off shored telecom R&D was around one-third of the low cost countries' share for 2009[16] – amounting to an approximate USD 3.1 billion.

The telecom R&D expenditure in India is expected to grow due to demand for broadband and data-based services powered by the next generation networks. Each new generation is characterized by upgraded frequency bands, higher data transfer rates and non-backward compatible technology. Thus transition to 3G, 4G, LTE, etc all over the world is boosting demand for telecom infrastructure equipment which translates into upgraded components & terminal equipment and advanced Value added services. This demand is bound to impact the innovation requirements across the value chain, triggering increased investments into R&D.

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[14] Telecom Equipment & Services Promotion Council (TEPC) - Policy Recommendations to Increase Domestic Telecom Growth & Exports of Telecom Equipment & Services

[15] Telecom Regulatory Authority of India (TRAI) – Consultation paper – Encouraging Telecom Equipment Manufacturing in India

[16] Knowledgefaber – In-depth Analysis of Telecom R&D in India – An MNC & Vendor perspective

The R&D in the telecommunication industry is mainly conducted by global equipment manufacturers like- Nokia Siemens Network, Ericsson, Qualcomm, Alcatel-Lucent, ZTE, Huawei etc. The hardware platform is difficult and expensive to develop and hence is kept common. However, it is the software that brings about the product differentiation and is often outsourced to countries like India.

Telecom R&D in India is led by captive centers of MNCs. Very few Indian companies are working on the hardware part and as such India has not been able to develop its own IPR wealth. Although India leads in software, the country does not have the IPR ownership since software development emanates from hardware and is not an independent project.

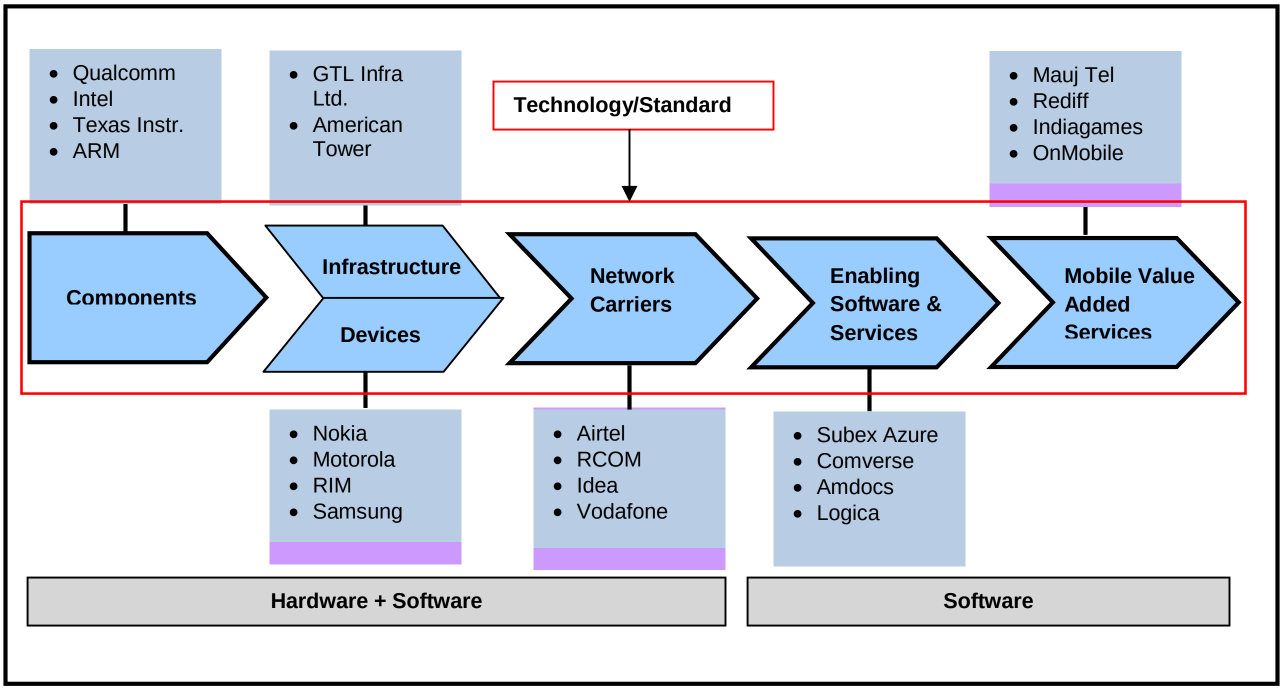
In the past few years, India has been emerging as a destination for R&D. This can be credited to availability of quality talent, people with knowledge of product development process moving back to India, cost arbitrage, MNC R&D centers and several other advantages. This scenario is far more prominent in "software" domain. R&D in the "non-software" domain is insignificant and is dominated by comparatively small domestic companies. Indian IT vendors such as Wipro, TCS, Tech Mahindra and HCL provide outsourced R&D services to major global players. They have a 52% share in the Indian telecom R&D worth USD 3.1 billion.

Telecom R&D in India is expected to further grow, with several players like ZTE, Nokia Siemens, Nokia, Huawei, etc. expanding or planning to expand their R&D operations in India.

INNOVATION AREAS

Innovation in telecom is dependent on the evolution of technologies/standards and transition to next generation networks and has a cascading effect on different areas across the value chain.

Figure 21: Telecom value chain



Component: Component companies make semiconductor chips, microcontrollers and others that are used by Original Design Manufacturers (ODMs)/Electronic Manufacturing Services (EMS) and Original Equipment Manufacturers (OEMs) who manufacture telecom equipment and handsets.

Infrastructure (physical and transmission) & Devices: Physical infrastructure providers install towers, fiber, duct or other passive infrastructure while Transmission infrastructure companies are involved in manufacturing MARR systems, Multichannel Digital Equipment, Opto Electronics Equipment, Subscriber Carriage System, Base Transceiver Station (BTS), Mobile Switching Centre (MSC), Base Station Controller (BSC) etc. used by service providers (Network carriers). Device companies manufacture telecom handsets and equipments used at customer premises.

Network Carriers: These service-providers provide network access services to the final customer.

Enabling Software and Services: These software players offer Enterprise Class Software and Carrier Class Software. Enterprise Class Software integrates different business functions across the enterprise. Carrier Class Software is specific to the Network Carriers and includes Business Support Systems (BSS) and Operational Support Systems (OSS). BSS deal with customers, supporting processes such as order taking, bill processing and payment collection. OSS deal with the telecom network, supporting processes such as configuring network components, maintaining network inventory, provisioning services and managing faults.

Mobile Value Added Services (VAS): Companies in this space provide customer focused VAS in the areas of Entertainment, M-Commerce and Information.

INNOVATIONS

Technology

The Indian telecom industry is growing at a very fast rate. Apart from increase in number of subscribers, there has been considerable growth in telecom manufacturing and R&D in the country. However with increasing competition, there is saturation in urban areas resulting in falling Average Revenue per User (ARPU). It is expected that the next phase of growth will come from introduction of 3G and Broadband Wireless Access (BWA) networks and focus on rural areas. With introduction of these networks, falling revenues from voice based services are likely to be compensated by rise in data services.

Although the Indian telecom industry is growing at a fast rate, the country way behind in developing technologies and products related to such technologies compared to other countries. Even China has developed its own TD-SCDMA technology and is also developing products that support this technology. CorDect developed by the TeNet group is a rare example of technology developed in India for improving rural connectivity. Based on Wireless in Local Loop (WLL) technology, CorDect supports simultaneous data and voice channels and caters to subscribers within radius of 10 km from location of broadcast. The technology is easy to deploy, cost effective and requires less maintenance and is well suited for improving rural connectivity. In spite of these advantages, major operators have not deployed it widely because of lack of relevant ecosystem that includes standardization body and equipment manufacturers.

Vihaan Networks has developed a solution for the rural market based on GSM technology named WorldGSM. The system can be easily linked with existing networks increasing reach, easily installed, runs on solar power and requires less maintenance.

Ericsson has developed a High Speed Packet Access (HSPA) based broadband network for rural areas to deliver advantages of 3G including distance learning and medical treatment through high speed internet connection. Alcatel-Lucent has set up a joint venture with Centre for Development of Telematics (C-DOT), the Telecom Technology development centre of the Indian Government, to focus on exclusive WiMax solutions that are targeted towards rural connectivity. However, the availability of spectrum by the Indian government is hampering the prospect of commercial launch of WiMax.

Components

India doesn’t have a presence of many homegrown companies in this category. However, it is host to development centers of world’s leading companies like – Qualcomm, Intel, AMD, Texas Instruments, etc, which are working on development of chipsets for 3G wireless devices (3G-enabled mobiles). These companies are also provided with chip-designing services by IT vendors like Wipro and Sasken. India also lacks domestic ODM companies that can facilitate production for component manufacturing companies. However, MNCs like Flextronics, Solectron, Jabil Circuit, Elcoteq, Celestica, D-Link etc. have presence in India for ODM/EMS operation.

Infrastructure

Passive infrastructure, being non hi-tech, is not the area of focus from an innovation perspective. Very few Indian companies have been able to create a niche in the global technology market, on the transmission equipment front. There are a few relatively small, domestic companies who are working towards developing innovative infrastructure equipment. Most of this innovative infrastructure equipment is intended towards increasing rural-connectivity by customizing products to suit the short-comings and topographic diversity in these areas. Homegrown companies that are working on innovative products in this space include Tejas Networks, Vihaan Networks, Coral Telecom and Svarn Telecom. These companies spend a reasonable chunk of their revenue on R&D and are working on a diverse set of products. These companies are growing at a fast pace and are aggressively looking at global acquisitions. Their innovations are diverted towards,

- Reducing the service providers' capital expenditure on equipment, when they move to the next generation networks. Thus maximizing the use of their existing assets (which are well suited for voice traffic), while making their network future-proof for the explosion in data traffic.
- Facilitating rural connectivity. Products are tailor made considering the challenges faced in the rural areas

Apart from homegrown companies, India is also home to captives of Infrastructure equipment majors like Ericsson, Nokia Siemens, Qualcomm, Alcatel-Lucent and Huawei which provide R&D services to their parent companies. These R&D captives are majorly focused on the software component of infrastructure equipment. The major differentiation in today's networking and telecom products comes from the proficiency in software capabilities, where India is clearly a global leader. The nature of R&D work by captive centers include hardware and ASIC design, software for next generation mobile technologies, wireless solutions for mobile messaging and voice and product engineering on different protocols.

C-DOT has been active into R&D and has launched a host of switching and transmission equipment hardware products and software products for network management, EMS and intelligent networks. It has entered a partnership with Alcatel-lucent and set up C-Dot Alcatel Research Center for R&D on end-to-end WiMax solution.

Devices

The device space in India is currently undergoing a transformation. In the past decade not only have the global majors – Nokia, Samsung, Motorola and LG have set up their R&D centers and manufacturing plants here but also India has seen the rise of an number of homegrown handset manufacturing companies.

The homegrown companies such as i-Mate, Lava, XL Telecom, Spice Mobile, Karbonn, Maxx, Byond and others etc have stuck to a safer assembly model rather than R&D and innovation. Therefore, they haven't been able to capture the market and are perceived equivalent to their cheap China-made counterparts. India's Micromax has proven to an exception to this scenario and has worked on creating innovative devices (handsets) with pioneering features and has hence managed to maintain positive growth in its market share in spite of competition from MNCs. With thorough understanding of the Indian market, Micromax is flooding the local market with multiple options aimed at different consumer segments, not just the rural segment. Micromax has come up with the cheapest 3G-enabled handset, cheapest android powered smart phone, handsets with 30 day standby battery, phones with in-built Yamaha amplifiers, phones that can also be used as a remote control for consumer durables in a household, say a TV, an AC or a DVD player, etc.

On one hand Indian players have been ignoring R&D, while on the other hand R&D captives of Nokia, Samsung, and Motorola have used India as a R&D hub for developing products for the emerging markets, including India. Technology used across the globe in terms of ASIC design and software platforms is developed in Indian R&D centers. These firms are assisted by Indian IT services like Wipro, HCL Satyam, MindTree, Infosys, Tech Mahindra etc., which provide R&D services.

Network Carriers (Service Providers)

Indian top service providers Airtel, Reliance Communication, BSNL, Tata Teleservices, Idea etc. do not indulge in any technology R&D. Even the foreign entities with joint-ventures in India such as Vodafone, Uninor etc do not have any R&D initiatives for India. Indian service providers haven't built their independent expertise in emerging/next-generation technologies and are completely dependent on outsourcing management and absorbing foreign technology through imports.

In fact India's largest service provider Airtel has outsourced almost everything including IT operations, fixed network management, network equipment and also the management of its value added services. On the contrary, global operators like NTT Docomo, Verizon, AT&T, China Telecom etc are entering in to tie-ups to develop their own technology.

Enabling Software & Services

India is a hot-bed for innovation in OSS/BSS software applications. India's software expertise has compelled MNCs to set-up their R&D centers in India for developing enabling software for the telecom infrastructure equipment. Global infrastructure vendors like – NSN, Ericsson, Qualcomm develops OSS and BSS in their Indian R&D captives. These companies are also supported by India's major IT vendors – Wipro, Infosys, HCL, TechMahindra, etc.

Also, several homegrown companies such as Suntec, Aricent, Sasken, Elitecore, Comviva, etc. are developing cutting-edge solutions in this space for the global market. But one company which has managed to stand out with its innovations and capture a large chunk of the global market share is Subex. 16 of the world's 20 largest service providers are its clients. It has also managed to takeover several global players including Magardi, Alcatel's Fraud management Systems (FMS) Business, Lightbridge's FMS Business, Syndesis and also the UK-based Azure Solutions.

Mobile Value Added Services (VAS)

Indian VAS companies at all level – Content Providing/Creating, Aggregating and Technology enabling have been continuously innovating. India has seen massive growth in demand and supply of VAS.

In terms of content creation – there have been a host of new applications developed by Mauj Telecom, Hungama Mobile, Indiagames, One 97, etc catering to demand for Entertainment VAS. An SME – Eka has been focusing on developing VAS for M-commerce.

IT vendors like Wipro, TCS and TechMahindra have also started focusing their efforts towards developing utility-based VAS catering to rural population. They have also started partnering device/handset manufacturers to develop Application stores (collection of VAS).

Indian Content aggregators and Technology enablers like OnMobile, Cell Next and IMI Mobile have created world-class technology/platforms to support 3G-based application services.

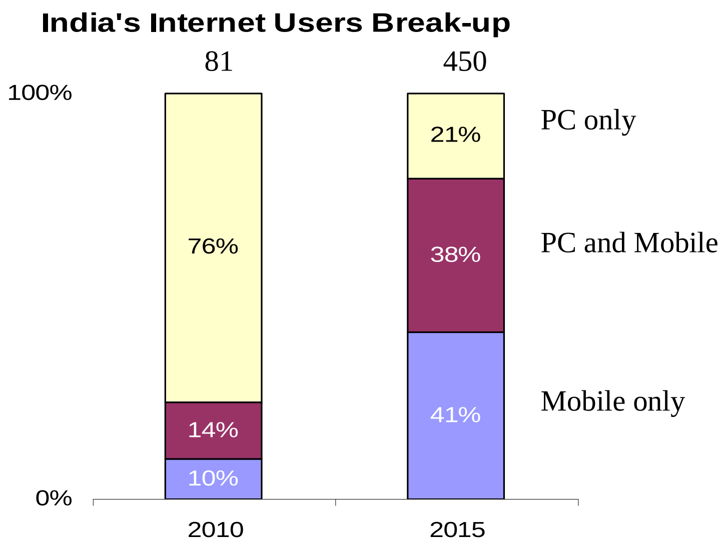
DRIVERS OF INNOVATION

Figure 22: Drivers

GROWTH IN ADVANCED SERVICES – DATA-BASED SERVICES

Demand: Increasingly mobile is becoming responsible for the growth in internet penetration. Despite the low reach of Internet services in the Indian market, the data-based services segment is expected to grow in the next decade in terms of number of subscribers. India is expected to feature among the top 10 broadband markets by 2013. With an increase in internet access, the demand for data-based services is on the rise.

Chart 24: Internet user base (millions)

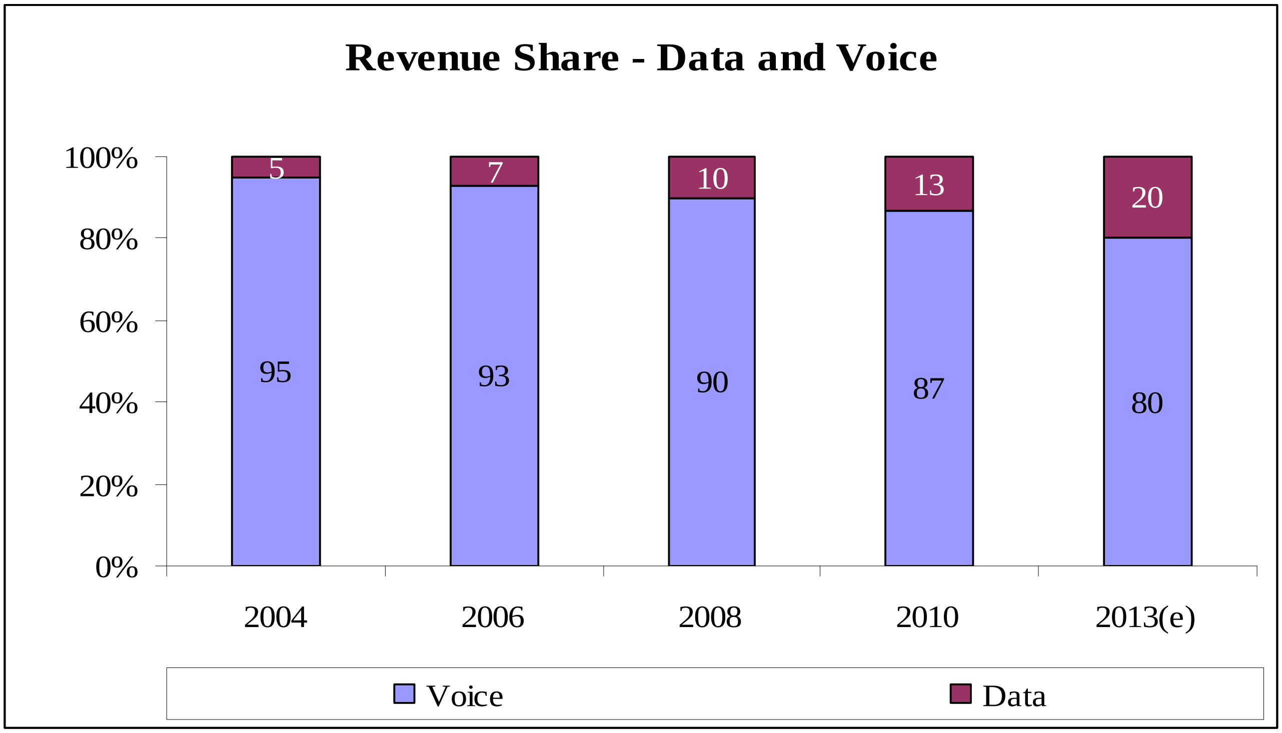


Penetration % (Total Population)	7	35

The nature of this demand is diverse, as it is mounting not only in urban areas, but also in rural areas. Also it is evolving from its initial focus on entertainment to utility. Though entertainment remains to be dominant in rural areas, there is also an increased awareness and demand for m-health, m-education services. This evolved demand of the Indian telecom consumer has triggered major innovation and development of newer services (contents) and platforms.

Supply: With the rapidly falling voice ARPUs in India; mobile data will drive revenue growth for Service providers. The share of data-based services has consistently shown an increment in the service providers' revenue share. With the onset of 3G services this growth is all set to accelerate. In India the market size for Mobile-Value-Added-Services is set to expand from USD 1.37 Billion in 2008 to USD 3.53 Billion by the end of 2011.

Chart 25: Revenue share



Considering the lucrative opportunities in this industry – device manufactures and service providers are partnering various IT vendors to develop their own host of applications (collection of Value added services). In fact certain service providers – Tata Docomo were even considering to set-up independent R&D services for VAS.

This explosion in the data-traffic also triggers innovation relating to products or solutions in infrastructure equipment.

PUSH FOR SELF RELIANCE:

India, in spite of being the 2nd largest and the fastest growing telecom market is not independent, in terms of fulfilling domestic infrastructure requirement. This makes the industry's growth unsustainable. Most of the service providers import their equipment. India's telecom imports amount to 4 % of India's total import. Most of the telecom manufacturing in India is based on technology developed abroad; the resulting benefits of these sales are accrued by foreign companies.

Availability of indigenous equipment will reduce cost, increase availability and will cut down time for new service rollouts and expansion of telecom players. Timely emphasis on domestic production will also reduce the country's imports. Therefore, the Government is aiming to change the existing scenario and develop domestic industry. TRAI is also currently working on developing suitable means and policies to encourage telecom equipment manufacturing.

With the need for developing indigenous technology and infrastructure (switching and transmission) equipment and increased government focus, more and more companies will be willing to invest in developing infrastructure technologies and equipment.

CUSTOMIZED INFRASTRUCTURE EQUIPMENT REQUIREMENT FOR RURAL NEEDS

Growth in the Indian telecom industry will be driven by the bottom of the pyramid. As the urban market expands towards more sophisticated equipment like smart phones, the need for connectivity in the rural region will drive its growth. With a rural tele-density of only 37% there is an untapped subscriber base of approximately 576 million[17]. Rural connectivity needs to be enhanced in terms of telephony/mobility and internet (broadband). However, expanding connectivity in rural or under-served areas needs to be addressed differently than that in urban areas. The equipment needs to be designed considering the uneven environmental conditions and uncertain availability of indispensible infrastructure like electricity. This drives product innovation to go beyond conventional solutions – E.g.: VNL's solar powered base stations

These innovations are further being driven by government support. The Indian Government is making several efforts for the growth and development of rural connectivity. One of the initiatives by the Government has been has setting up of the Universal Service Obligation (USO) fund - which facilitates provision of public telecom, creation of mobile-services infrastructure, provision of broadband connectivity, etc.

LEADING ORGANIZATIONS & NATURE OF INNOVATIONS

The innovation in the Indian telecom market is driven by a mix of MNCs captives, IT vendors, relatively small domestic companies, Government institutions and academic institutions (centers of higher learning and education). Innovation is being carried out across the complete value chain (except wireless carrier service providers). However, break-through innovation in India is lead by software-based telecom products – Infrastructure equipment (software), Enabling software services, VAS category, and software components for devices (handsets).

Most of the R&D is focused towards aligning telecom technology with next-generation network – 3G, LTE and WiMax. Certain products are globally competitive and the rest are customized to serve the local

[17] Netscribes analysis

demand. Local demand simply translates into developing cost effective that provide easy scalability and suit India's diverse weather and power conditions.

Software based innovations are India's strengths; hence India produces world-class telecom software products.

- Major portion of R&D is conducted by MNC captives - the top international infrastructure equipment manufacturers. These R&D captives in India are in the form of software centers, developing software for 3G and LTE core network infrastructure. These Indian R&D centers work on equipment and OSS/BSS for global application.
- Indian IT vendors partner the world's best telecom companies to help them develop a range of software for Core and Access Networks, Service Enablement (for VAS), OSS, etc.
- Homegrown companies in the Enabling software segment (OSS/BSS) have developed path-breaking products for the world's top telecom service providers.
- Captives of foreign device/handset makers in India, have their R&D focused on developing software platforms or VAS for the global market.

As far as the **Telecom hardware segment** is concerned, Government is making major promotional efforts towards developing India as a manufacturing and R&D hub for these products. Currently, R&D/innovation in this segment has been comparatively sparse and diverted towards domestic markets.

- World's major ASIC companies have set up their design centers in India and develop products meant to cater to the global next-generation-networks demand
- TCOEs and a few homegrown (relatively small) companies have managed to create world-class infrastructure products.
- Also a few JVs, TCOEs and local companies are focused towards enhance rural connectivity. They are developing products to cater to the huge demand from India's 'Bottom of the Pyramid'. India's rural areas require customized/modified products to suit their topographic and infrastructural diversity.

Currently, the major investors in telecom R&D in India are

Infrastructure	Alcatel-Lucent, ZTE, Huawei, Nokia Siemens, Ericsson, Qualcomm
Semiconductor	Intel, Motorola, Texas Instruments, Qualcomm
Software	IBM, Microsoft, Cadence, Accenture

Apart from in-house R&D by telecom companies, the following are major Indian Telecommunication R&D Centers

IT vendors	Tata Consultancy Services (TCS); Wipro, Infosys, Tech Mahindra
Government organizations	C-DOT, CDAC
Academia	IISC Bengaluru, IIT Delhi, IIT Mumbai, IIT Kanpur, IIT Kharagpur, IIT Chennai/Madras, IIT Guwahati, IIT Roorkee

MNC captives constitute a major portion of the total R&D in the Indian telecom industry. The Component, Device and infrastructure equipment space is dominated by the MNC's whereas passive infrastructure, enabling software services and VAS space is dominated by the Indian players.

However, none of the products made by Indian start-ups are a break-through in scientific sense, but they do represent adaptations for the local requirement and transformation in the functioning of individual parts. Indian start-ups possess strong skills in architecture design, prototype building and adaption as per local needs. However, they do lack testing capabilities, which are mostly outsourced.[18]

ECOSYSTEM FOR INNOVATION IN THE INDIAN TELECOM SECTOR

India has evolved over the period of years and today, has the key strengths required to become a manufacturing and R&D hub for the telecom industry. Most important factors contributing to the conducive ecosystem are:

- **Market:** Unprecedented growth in the telecom sector, and massive growth plans Indian telecom operators, provide a huge market for telecom companies, including manufacturers and network operators/ service providers.
- **Know-how:** To serve this huge market, it is necessary to have an understanding of the needs of operators in India. This also helps in developing solutions applicable to other emerging markets. A thorough knowledge of these details helps in developing technologically-leading, yet cost-effective products. Such products provide far more value to customers, as compared to products developed for advanced/matured markets which are then retro-fitted to address the needs of emerging markets.

[18] Netscribes analysis & "An exploration into technological capabilities among early stage Indian product based telecom start-ups" – IIMA, Idea TCOE

- **Manufacturing linkages:** The presence of foundries, EMS companies and auxiliary component manufacturing base forms a base to set-up telecom manufacturing units. This is further enhanced by the existing network of MNC's production and R&D captives – who are willing to expand their Indian capabilities to cater to domestic and international demand.

- **Manpower availability:**
    - The R&D capabilities are also supported by an unmatched availability of software developers. India's abundant technological talent has already proven its dexterity in the IT services, and the same talent can be harnessed to develop top-notch products. India has talent that facilitates indigenous in-house development of algorithm implementations, protocol suites, graphical user interface and also embedded systems to manage the interaction between hardware and software.
    - India also has an enormous workforce - competent & experienced in management.
    - Lastly, India also has a host of skilled & trained shop floor workforce for electronics circuit assembly, testing and integration from Industrial Training Institutes and Polytechnics.

- **Cost Advantage:** In India four times more R&D and innovation can be conducted for the same costs, as compared to companies in the west. This gives domestic companies an opportunity to use their R&D leverage and excel in products for the next generation. It also translates into an opportunity for the MNCs to benefit from the cost-advantage provided by the lower facility establishment cost and inexpensive labour.

- **Government initiatives**: Government policies are evolving to be more and more conducive to R&D promotion – policies are being framed to give monetary benefits – in terms of taxes. Government is also working towards IP laws being made more secure.

Challenges:

- **Grants and Funding:** Since telecom product development requires significant upfront investment, innovation needs to be encouraged with R&D funding. Currently in India, the government has only one funding scheme – Multiplier Grant Scheme, where it bears almost half the cost of R&D, it is available only to those companies which collaborate with academia for R&D. The existing schemes are not sufficient as their scope of support is very narrow – the application process time of 9 to 12 months is not congenial in fast changing technology. Man power costs, market development costs etc are not supported under the existing programs. The Indian telecommunication industry also needs increased attention from VCs. However, this scenario seems to be gradually changing.

- **Lack of incubators and programs:** Grants for start-ups are available from TePP program of DSIR, conditional grants available for pre-commercial stage R&D from TDDP program of DSIR and soft loans are available from TDB of DST for technology commercialization but none of the programs are sector specific. Besides, India doesn't have any national policy or program for supporting telecom R&D or entrepreneurship. Also considering the quantity of entrepreneurial talent in the Indian telecom industry, there are very few incubators as a part of national initiatives.

- **Limited availability of talented man power for hardware:** Even though India has a strong IT prowess, there is a scarcity of talented personnel for hardware development. Moreover, the talented few are also absorbed by the service industry in India. Indians do have the capability to design the hardware themselves. However, the engineering, development and manufacturing of hardware is outsourced or conducted in the home-country. This challenge can be overcome by increasing the reimbursements of hardware R&D professional up to the software services level.

INNOVATION SUCCESSES

Company: Vihaan Networks Limited.

Founder, Chairman and CEO: Rajiv Mehrotra,

Location: Gurgaon, India

Number of employees: 350

Year Founded: 2004

Origins: Entrepreneurial start-up

Considering the variable topography in India's vast landscape and the lack of power-generation infrastructure, it is extremely difficult to connect rural villages with sophisticated telecom equipment. Besides, not many companies were interested in developing customized products to suit the specific rural requirements. However, VNL changed this scenario – it has developed a solar-powered GSM system specifically for remote and rural areas where people have less than USD 2 a month to spend on their phone bills. Its base stations, which cost one quarter of traditional equipment, only require as much energy as a 50-watt light bulb, while traditional base stations powered by alternative energy require 3,000 W. VNL's units can easily be transported over rough terrain and come with easily comprehendible instructions that use pictures and colour codes instead of text so that illiterate people can take charge of the assembly. And, thanks to software, the base stations can be managed remotely. This effort will bring mobile phone service to the more than one billion people who live in the world's poorest and remotest areas, reducing maintenance costs by 90%. The equipment is being tested in India by some of the world's largest mobile operators.

The inspiration for this revolution to take telecom to the masses by installing wireless village telephones in over 100,000 Indian villages, comes from Mr. Mehrotra's earlier ventures. In 1974, as a young electronics engineer, Mehrotra pioneered the manufacture of satellite TV equipment that brought cable TV to millions of village homes in India.

Why the company is a pioneer?

VNL's WorldGSM technology can help bring the reach of the current mobile infrastructure to billions more people.

Company: Tejas Networks

Chairman: Gururaj Deshpande

Co-Founder, Managing Director and CEO: Sanjay Nayak

Location: Bengaluru

Number of employees: App. 700

Year Founded: 2000

Origins: Entrepreneurial start-up

Tejas Networks is a pioneering Indian telecom transmission product company. Today it is counted among the top 10 vendors in the world in the Optical transmission market. It has won several prestigious awards like NASSCOM Innovation Award, CSIR Technology Award, TEMA Award, etc- for its' excellence in R&D.

Its' path-breaking innovation has been – Carrier Ethernet over SDH/SONET.

The provision of converged services* brings along challenges like – sporadic nature of data traffic, multiple services over a single channel and restrictive nature of point-point transmission. To solve all these challenges Tejas Networks created the Carrier Ethernet over SDH/SONET technology. It makes it possible for service providers to provide users Carrier Ethernet-based services to consumers in the converged environment, without major investments in new transmission equipment. It upgrades the existing circuit switched networks equipment with a Carrier Ethernet over SDH on a single card (PCB/blade); the fibers are also re-configured by the card (PCB/blade). Therefore, it makes use of the existing infrastructure to provide multiple services. This saves up to 90% of investment that service providers would make into alternate new equipment and 50% of investment that would have been made in new fiber and bandwidth.

*This technology finds its' application in 3G/WiMax backhaul, Broadband, IPTV and Enterprise Data Services.

Why the company is a pioneer?

Tejas' technology will help service providers provide a variety of services - Broadband, IPTV, data-based services (requiring 3G networks), without investing major amounts in drastic replacement of equipment.

EXISTING COLLABORATIONS

India is currently in a transition phase, it is in the process of transformation of telecom technology. The government comprehends the importance of R&D in the telecom sector and its' impacts on the economy. Hence the government completely supports and facilitates knowledge transfer through collaborations. Telecom's governing bodies propagate R&D collaboration for mutual benefits.

Though R&D collaborations are not very rampant in the manufacturing/"non-software" sector, the increase need for self-reliance has compelled India to promote such collaborations. Most of the technology developments are either imported or adopted from international technology companies. Some amount of R&D is conducted by domestic companies independently and the rest of it is conducted by the Governments' R&D body – C-DoT (either independently or in collaborations with foreign companies, Indian and international R&D organizations). More recently Government has also taken up a new collaborative model as an initiative to boost innovation - "Telecom Centers of Excellence". These centers are housed in the crème de la crème educational institutes in India, are funded by private companies and function as PPP (public private partnership). For foreign partners, collaborations provide an opportunity not only to use India's skills but also to capture the large local market by developing products for the domestic market.

Academia - Industry

The Indian telecommunication industry lacks extensive and deep connection between academia and industry. Moreover, there are very few institutes dedicated to the study of Telecommunication technology. And very few companies venture to collaborate with educational institutes for R&D purposes.

The Indian government is working towards changing this scenario – It has established Grants/Funds for companies entering collaborative R&D with educational institutes. Another major step in this direction is – establishment of Telecom Centers of Excellence.

These TCOES will be the leading supplier of technology catering to technology requirements of Telecom companies[19]. The Telecom CoEs will provide a platform for innovation activities – each focusing on a niche area. The activities are intended towards developing India-specific applications, undertaking exchange of industry best practices world over, management planning of network –infrastructure, grooming talent, benchmarking and developing manufacturing standards and most importantly promoting an environment of innovation in the top academic institutes.

A unique model of collaboration between academia and industry and supported by the governments is in the form of consortiums formed by multiple Indian and European companies and educational institutes to contribute towards collaborative R&D effort in pre-determined areas. E.g.: IUAT (Indo-UK Advanced Technology Center, funded by the two governments and formed by various TCOEs (at various Universities- IITs, IIM and IISc) and companies like Wipro, TCS, Infosys, Sasken, British Telecom, etc.)

Private partnerships – R&D collaboration between companies:

India hasn't witnessed major R&D collaborations between domestic and foreign companies, in the manufacturing segment of the telecom sector. On the hardware front, most of the MNCs in India have independent captives for R&D, they only depend on collaborations for setting-up manufacturing base However, this doesn't hold true for the software segment. India being one of the most advanced players in Software, Telecom companies from all over the world outsource their R&D by collaborating with Indian companies to develop software solutions for their telecom products. These software solutions cater to telecom requirements ranging from OSS/BSS (product development, feature enhancement, sustenance, maintenance services, convergent billing), elements for the core infrastructure, interoperability tests, software platform development for devices and applications development. In the software segment India has not only seen R&D outsourcing collaborations but also M&As. The Indian companies developing software solutions for telecom have evolved to reach a level of maturity, where they have acquired international players. A few examples of M&A's are – Subex Azure, Mauj Tel's Mobango takeover, etc.

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[19] TCOE Website – EFY report

EUROPEAN CONTRIBUTION TO INNOVATION

The presence of EU companies is visible across the value chain. They have managed to capture major market share in many categories. Apart from the direct presence, EU exports majorly to the Indian telecom sector- in the form of exporting equipment, setting-up turnkey projects, technical and billing solutions, testing/maintenance services, and consulting. EU accounts for approximately 21% of India's telecom imports amounting to USD 2.2 billion. (as per 2008-09 data). EU companies, including companies that export to India, benefit from the growth in the Indian telecom sector and its requirements.

Most of the European telecommunication companies with direct Indian presence indulge in R&D. However, among all, the hardware companies - Infrastructure equipment manufacturers and device manufacturers account for a major portion of European presence in terms of R&D in the Indian telecom market. All these companies have set-up their R&D centers in India solely to work on their software components (embedded software, software platforms for mobile phones, VAS & software to support infrastructure equipment). Apart from independent captives European companies have been outsourcing major software components to Indian IT vendors. Major European companies with direct presence in India include ARM Holdings, Elcoteq, Infineon, Ericsson, Alcatel-Lucent, Nokia Siemens, Nokia, Sony Ericsson, Vodafone, Telenor, Logica, etc. The following table lists down a few major European companies which have active captives for telecommunication R&D in India.

Table 14: Collaborations

Company	No. of Patents (filed in India)	Location of R&D Center	R&D Focus
Infrastructure Equipment			
Ericsson (Sweden)	19	Gurgaon & Chennai	Enabling software solutions (OSS/ BSS) – Mobile Pre-Paid solutions, Convergent Charging Solutions & Mediation Products, Data mining & Data warehousing
Nokia-Siemens (Finland)	5	Bengaluru	Enabling software solutions (OSS/ BSS) - Charging software, Voice and multimedia communication enablers, Wireless access solutions for mobile voice and messaging
Alcatel-Lucent (France)	17	Bengaluru	Low cost mesh networking for emerging markets, Sensor networks, Cognitive radios and dynamic spectrum access, low-cost broadband access for rural areas, applications for wireless 3G networks, design of WiMax networks and applications for emerging markets, designing for video distribution on WiMax networks and algorithmic contributions for better and easier management of networks.
Devices (Terminal equipment)			

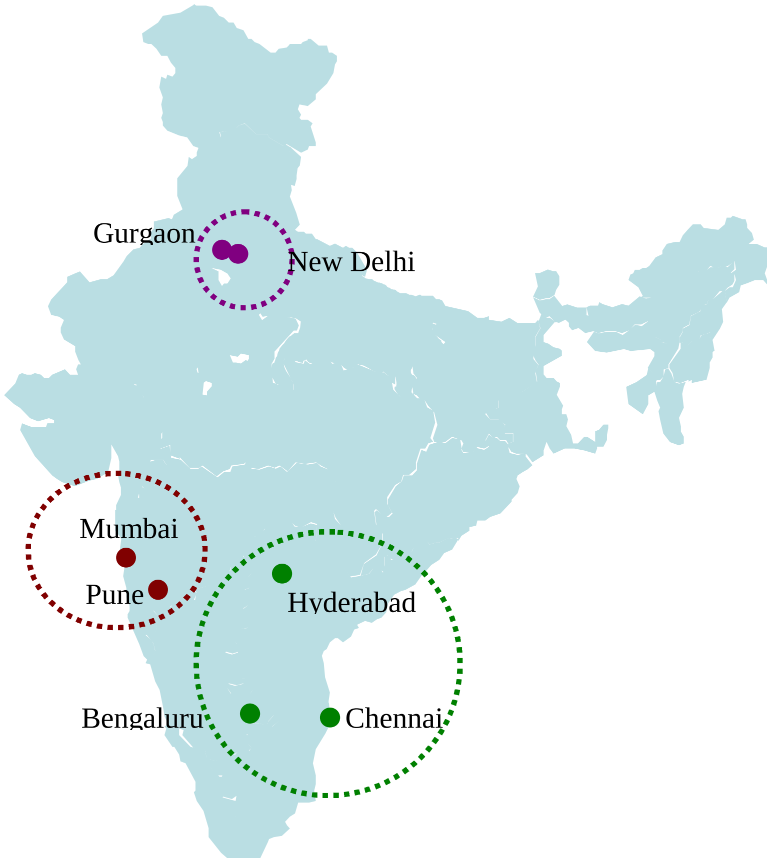
Nokia (Finland)	19	Bengaluru & Mumbai	Next-generation packet-switched mobile technologies, designing chipsets, developing software platforms and communications solutions. Indian R&D center works on global projects and also on assimilating information to customize products as per tastes and needs of the local market.
Wireless Network Carriers			
Though there are no companies currently active in R&D – Vodafone has plans to establish an R&D center for its Indian arm – Vodafone Essar.			
Enabling Software Services (OSS/BSS)			
Most of the Infrastructure equipment companies are simultaneously working on OSS and BSS			
Content and Portals			
Logica (UK)	2	Bengaluru & Chennai	Interactive advertising solution

INNOVATION CLUSTERS

India has over 120 telecom R&D captive centers of global telecom giants, working on varied products and technologies. [20] Bengaluru is the most favorable location for setting up a telecom R&D center in India and has over fifty R&D centers. Chennai and Hyderabad comes in a close second. Mumbai and Pune are also emerging; however are not the best choices today. Currently, both cities combined have eleven R&D centers.

Figure 23: Innovation clusters

[20] Complete Telecom Products "Made in India"? – Knowledgefaber, September 29, 2009



South Zone ●	
Bengaluru	Nokia Siemens, Alcatel-Lucent, Logica, ZTE, Huwaei, Texas instruments, LG, Tejas Networks, Sloka Telecom, Micromax, Samsung, Cisco, Motorola, IISC Bengaluru
Hyderabad	Motorola, Qualcomm
Chennai (Madras)	Ericsson, Logica, IIT – Madras – Center of Excellence in Wireless technology
West Zone ●	
Mumbai	Nokia, IIT – Mumbai - Rural application
Pune	C-DAC
North Zone ●	
Gurgaon	Ericsson
NCS (New Delhi &	C-DoT, Micromax, IIT- Delhi - Centre for Excellence in Telecom technology and

Noida)	management, TRAI, DoT

SOUTHERN CLUSTER

This zone is the largest cluster for telecommunication, as it houses the highest number of MNC captives as well as a host of telecommunication technology start-ups. There are two major factors that make the south zone the most active area for R&D in telecommunication.

- IIT Madras, Chennai: The Indian Institute of Technology Madras, located in Chennai, has become the leading organization in terms of R&D for telecommunication. It houses the Center of Excellence in Wireless Technology (CEWIT). Several companies working on telecom technology have been incubated at this institute – E.g.: OnMobile. It partners several MNC captives in India to assist them with their developments. Among all TCOEs, IIT Madras has the strongest presence in with several international consortiums to develop telecommunication technology E.g. India-UK Advanced Technology Center of Excellence in Next Generation Networks, Systems and Services (IU-ATC)[21]
- IT hot-spot: Post the Software Technology Parks of India (STPI) Scheme Bengaluru achieved unparalleled success in establishing itself as IT hub of the country. Today cities like Hyderabad and Chennai are also treading the same path. Apart from the Central government's investment in the STPI scheme to grant tax holidays to IT companies, the state governments are also working towards maintaining regulations conducive for attracting MNCs. They have also invested in creating world-class infrastructure in terms of roads, public transport, electricity supply, internet infrastructure, etc. However, majority of the software-based telecommunication R&D takes place in India's Silicon Valley – Bengaluru.

WESTERN CLUSTER

Mumbai and Pune have good infrastructure (tech parks or space available; rail, road and airport connectivity) and favorable city ecosystem (educational institutes, recruitment firms and support to ex-

[21] IU-ATC Website – List of Indian Partners

pats). These two emerging cities have a very small base of installed talent for telecom R&D, but a sizable pool of fresh engineering graduates and good infrastructure which can attract new R&D centers to the city.

North zone: Most of the government organizations – C-DoT, Department of Telecommunication, TRAI, etc are located in the country's capital - New Delhi. Moreover, Gurgaon is also one of India's emerging IT hub and provides strategic benefits to MNCs – in terms of proximity to the country's well-developed capital and availability of affordable space.

Gurgaon does not have its own adequate talent pool, academic institutes or fresh graduates to boast of. However, over the past 5 year several qualified professional have migrated there considering its establishment as an industrial and IT hub.

Few companies, organizations and Academic Institutes with active R&D; telecom regulatory bodies present in these clusters are as follows:

GOVERNMENT INITIATIVES

The Indian Government has recognized the importance of R&D in the telecom industry and has introduced number of initiatives for promotion of R&D.

- **Tax incentives:** The government allows 125% to 150% of the expenditure on R&D to be deducted from taxable income.
- **FDI Limits:** The FDI limit for telecom services in 74%-100% (FIPB approval required for foreign investments exceeding 49%). 100% FDI permitted in telecom equipment manufacturing on automatic approval basis.
- **R&D programs:** For the promotion of innovation in the telecom sector, both the DoT and the DIT have incorporated certain programs –the most prominent ones being - Support International Patent Protection in Electronics & IT (SIP-EIT) and The Technology Incubation Centers. These programs are aimed at
    - Promotion of IP protection for SMEs, by partially funding the IP expenses
    - Bridging the gap between R&D and commercialization by creating incubation facilities for entrepreneurs
- **Promoting link between industry and Academia:** DoT has set-up the Telecom Centers of Excellence through pubic private partnership mode. These centers of higher education are

governed by an independent Government body and financially supported by willing corporate sponsors.

Table 15: TCOEs established till date

Telecom Centers of Excellence		
Field of Excellence in Telecom	**Associated institution**	**Sponsor**
Next-generation network & network technology	IIT, Kharagpur	Vodafone Essar
Telecom technology & management	IIT, Delhi	Bharti Airtel
Technology integration, multimedia & computational math	IIT, Kanpur	BSNL
Telecom policy, regulation, governance, customer care & marketing	IIM, Ahmedabad	IDEA Cellular
Telecom infrastructure & energy	IIT, Chennai	Reliance
Disaster management of info systems & information security	IISc, Bengaluru	Aircel
Rural application	IIT, Mumbai	Tata telecom
Spectrum management	WPC, Chennai	Govt. with Industry consortium

- **Providing funds:** Currently, the DIT funds projects working on low-cost broadband Internet access devices, broadband on power lines, broadband services for rural areas, convergence of fixed/mobile networks, next generation communication, broadcast and convergence technologies (e.g. 3G, 4G wireless communications), software defined radio, wireless sensor networks, integrated access devices, IP Multimedia subsystem, cognitive radio, communication system with high spectral efficiency and low power consumption, smart antenna/ broadband antenna, Ultra Wide Band (UWB) radio applications and networking, SATCOM products (for use in distance education, Telemedicine and other E-Gov. applications), communication software, wireless technology deployment optimization for urban-rural connectivity (e.g., Wi-Fi, WiMax), packet technologies for remote and inaccessible areas via satellite, streaming multimedia, etc.

The department's most prominent means of funding is - Multiplier Grant scheme. It enables any company to receive grant from the Government funding almost 2/3rd of the project cost. This grant can be accessed only if the company partners an educational institute for R&D and commits resources to it.

However, the scope of support of the existing funding programs is narrow and has an application process time of 9 to 12 months, not congenial in fast changing technology. Man power costs, market development costs, etc are not supported under the existing programs.

OUTLOOK

The Indian telecom sector is likely to envisage following trends in the coming years.

- Software-based innovations are prominent in India and would remain to be in the near future. India's software strength is backed by its massive talent pool and the innovations made here will continue to serve the best telecom companies of the world.
- With all the government support, the infrastructure equipment (hardware) segment may see an increase in the innovations, but most of them will be intended to cater to the domestic demand.
- In terms of adoption of next-generation-networks – LTE is being rapidly developed and will soon be adopted, due to its "future-proof" nature.
    - Cost-effective technology will be developed for application of LTE across the country.
- BWA technologies will make it possible to provide wireless internet/broadband access to all on their mobile phones - India might be one of the top players in VAS

RECOMMENDATIONS

Means of Collaborations

EU has several means to partner India and work cohesively towards developments and innovations in the Telecommunication sector.

- Companies could partner Indian IT companies and outsource development of software components to them.
- Companies with presence in India could sponsor Indian TCOEs OR enter into partnerships with them for specific projects.
- Large amounts of investments are required to boost the technological capabilities of the Indian telecom industry. The Indian telecom start-ups and spin-offs from universities require funding from VCs. European VCs can capitalize on the technical prowess of these Indian technology start-ups.

- Government funded Consortiums can be formed – involving Indian academia, IT companies and interested telecom companies from both the regions. These consortiums deal with development of technology that can be beneficial to both EU and India.

The Government needs to frame policies to attract MNCs to set-up manufacturing bases in India. Innovation in telecom is currently restricted to the software component in India. An ecosystem that encourages innovation across the telecom value chain does not exist in India. Encouragement to set-up the complete development life-span in India, from concept to manufacturing to after sales/maintenance, will encourage global players to set up hardware R&D in India. This in turn will create demand for talent necessary for hardware R&D. To support this requirement, the educational system too needs to work close with the industry to identify and develop suitable academic course structure specific to the telecom domain and create a culture that fosters innovation among students.

Therefore, Indian Government is bound to offer support and benefits, if

- European companies with Indian presence will go beyond their R&D establishments and to set-up their manufacturing centers and supply chains in India.
- European companies with direct or indirect R&D presence in India, file for the Intellectual property (IP) in India. The government is working towards development of the country's IP wealth.

Areas of Collaboration

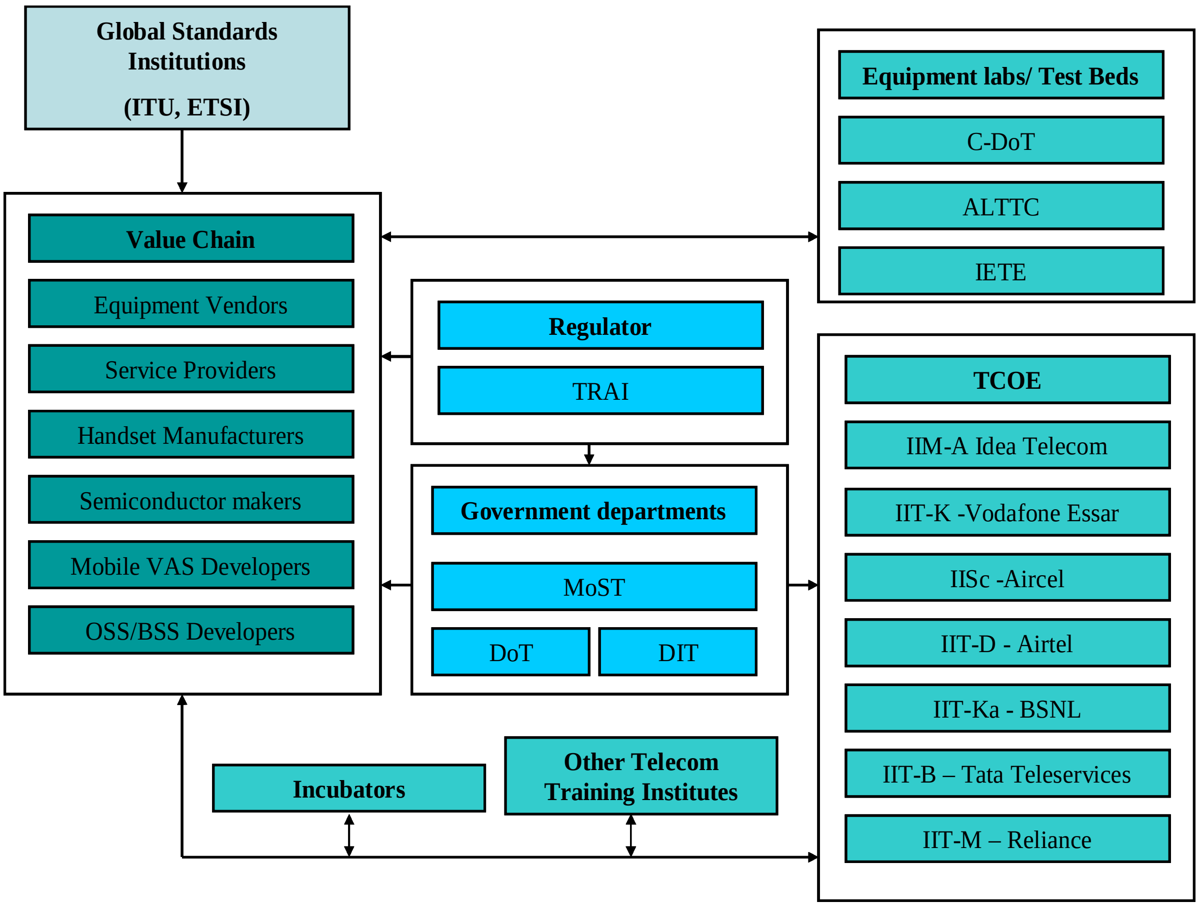
- **VAS –** Currently, the technology in India for 3G has matured and has been implemented by major telecom players. Therefore there will be negligible R&D on infrastructure. However, there will be increased focus on developing 3G-based VAS. Currently, several companies are focusing on developing youth driven VAS - social networking and online gaming are major trends. Several companies who wish to tap the rural potential are developing data-based services for rural areas – m-education, m-health, m-banking and most importantly information services are a major trend.
- **LTE –** Post 3G India's attention is focused towards BWA technologies. LTE seems to be more prominent among WiMax and LTE. Most telecom giants consider LTE as the future of Indian telecom. The Head of Next generation Networks project at C-DoT - Mr. Manish Sharma states LTE as the future or Indian markets. He says, "*LTE is future proof, the use of an Ipv6 address for telecom will end the requirement for space for the infrastructure equipment*". The availability of man-power makes it feasible to establish an R&D captive to develop the Layer 1 of the core networks for LTE. C-DoT has also been working on LTE and its customization to suit India's topography, price sensitivity and most importantly scalability. Broadband Wireless Consortium of India (BWCI) is also working in association with CEWiT to develop LTE.

Nature of Innovation/Development

- India provides a conducive ecosystem to breed innovations for global application. Therefore, EU can benefit from the cost leverage and availability of talent, if they set-up their core R&D centers in India.
- If European companies wish to monetize the growth of the Indian telecommunication sector, then it is advisable to develop technology, equipments and products to increase rural connectivity.
- Besides technology, equipments and products developed in India to suit the Indian need will also find their applications in other regions of the world
  - LTE developed by Indian players ill find its application in South East Asia, due to the common TDMA channel.
  - Cost-effective OR rurally conducive technology developed in India will find its application in emerging nations.

STAKEHOLDER IN THE INDIAN TELECOM INDUSTRY

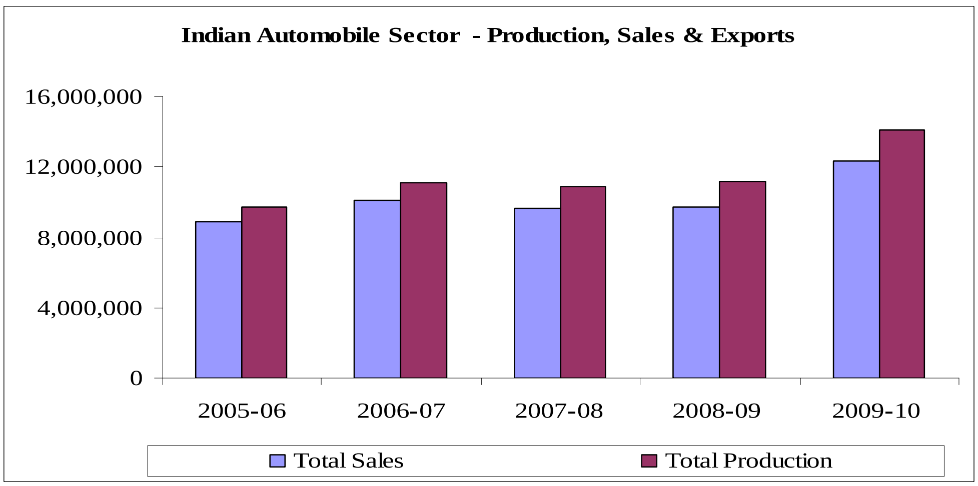
Figure 24: Stakeholders in Indian telecom innovation system


Global Standards Institutions
(ITU, ETSI)
Value Chain
Equipment Vendors
Service Providers
Handset Manufacturers
Semiconductor makers
Mobile VAS Developers
OSS/BSS Developers
Regulator
TRAI
Government departments
MoST
DoT
DIT
Equipment labs/ Test Beds
C-DoT
ALTTC
IETE
TCOE
IIM-A Idea Telecom
IIT-K -Vodafone Essar
IISc -Aircel
IIT-D - Airtel
IIT-Ka - BSNL
IIT-B – Tata Teleservices
IIT-M – Reliance
Incubators
Other Telecom Training Institutes

8. AUTOMOTIVE

Automotive industry is one of India's largest industries. It forms approximately 7% of India's GDP. The industry has shown a growth and stability over the past 20 years. Automobile production in India has grown at a rate of 9.4% cumulative average growth since 2002. The growth in the automobile sector is fairly stable and hasn't been majorly affected by the downturn. Post a minor drop in sales and production in 2007-08 & 2008-09, the sector is back on track and has recorded double digit growth. The sector recorded approximately 25% growth for the year 2009-10, reaching a production of 14 million units.

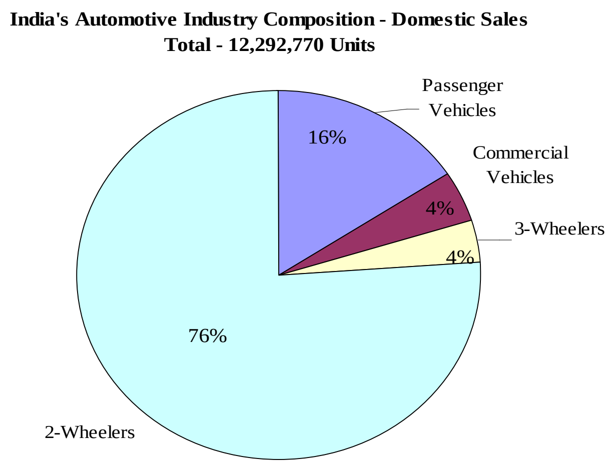
Chart 26: Automobile production and sales



Source: SIAM

Even during the downturn, the 2-wheeler and 3-wheeler segment reported positive growth. The Indian automobile demand composition differs from the other top automobile markets – with the exception from China. The 2-wheeler and 3-wheeler segment constitutes more than 3/4th of India's automobile market. Catering to this huge demand, India has emerged to be the world's second largest manufacturer of two wheelers.

Chart 27: Indian Automotive industry, domestic sales



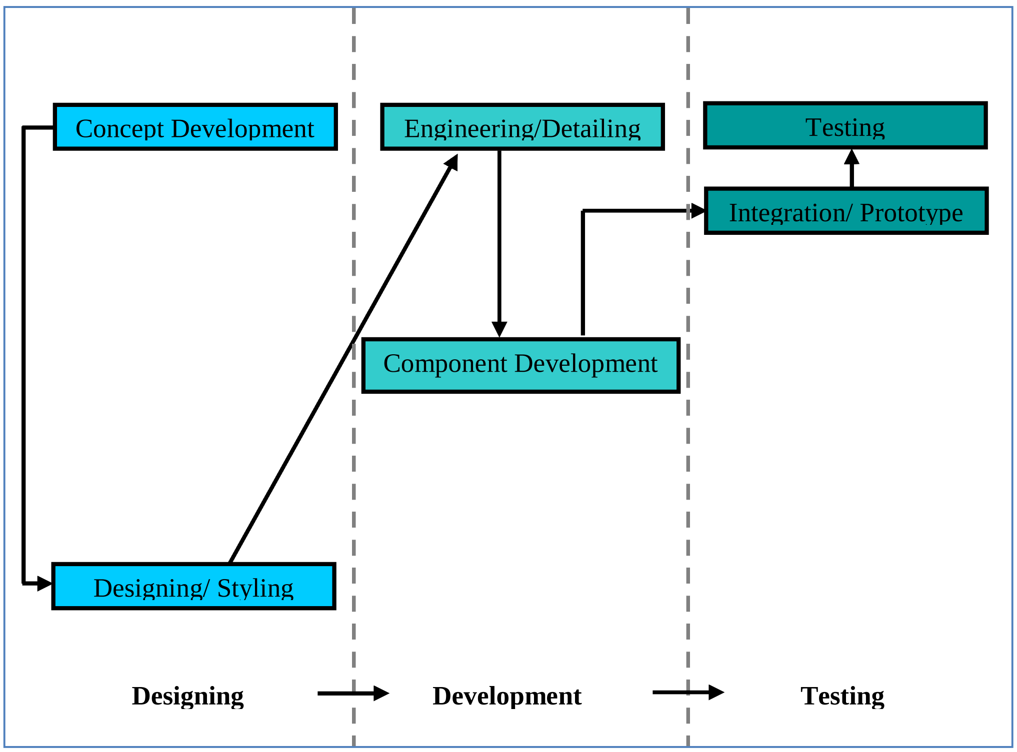
Source: SIAM

At present, there are 15 manufacturers of passenger cars and multi-utility vehicles, 9 manufacturers of commercial vehicles, 16 of two/ three wheelers and 14 of tractor, besides 5 manufacturers of engines. India has very strong domestic players in the heavy commercial vehicle and two-three wheeler segments. India's passenger car segment is set to boom. As per Automotive Mission Plan (AMP) 2006-16, India's capacity for passenger cars is all set to reach 3 Million in 2015, from the mere 1 Million in 2003-04. **India's passenger car segment offers huge scope for foreign players to enter Indian market or tie-up with Indian partners for technology-sharing purpose.**

INNOVATION IN AUTOMOTIVE INDUSTRY

Innovation in the automotive industry is driven by two factors – legislative requirements and competitive requirements. The legislative requirements compel the OEMs to keep up their fuel efficiency, emission control systems, NVH and safety features competent enough to meet the latest regulations. The competitive requirements prompt OEMs to develop new products and also improve the vehicle dynamics and ergonomics of the existing products.

Figure 25: New Product Development process



Note: This process is a generalized description of the New-Product-Development process undertaken by Indian OEMs

The new products development in the Automotive industry can be divided into – Designing, Development (engineering/detailing & production) and testing. The OEMs initially develop the concept of the new product. Then the designs of various components (mainly the chassis & power-train) are built upon on the basis of the concept.

Indian OEMs tend to outsource the design process. On the other hand, the **MNCs design their products at their home-country**. On finalization of these designs, the OEM begins to construct the engineering details of the components. This engineering process includes development & simulation through CAD, CAE, CAM drafts and maintaining the Product Development life-cycle Management (PDM). **Indian OEMs conduct this development and simulation process in their in-house R&D centers and several MNCs conduct it in their R&D captives in cost-effective emerging countries**, **with India being one of the most preferred destinations**. These captives are carefully guided and overseen by the parent company overseas. Once the details are drafted, the design and engineering requirements are forwarded to Tier I suppliers to be produced.

This development/production is overseen by the OEM. The Tier I suppliers develop the Forged and casting components (Chassis & alloy wheels), Engine & exhaust, Electrics & electronics, Transmission and steering, Suspension & brakes, Interiors , Wheels and other metal, rubber and plastic components.

Ultimately all the components are integrated together and a prototype is created. This prototype is then put through several tests across several parameters, like fatigue, impact of a crash and suitability of materials. The prototyping and testing process may be conducted in-house or outsourced.

INNOVATION IN INDIA

Japan and Europe have always dominated R&D in the global automotive industry. However, more recently, India has seen establishments of several automotive R&D centers and they are well positioned for growth.

Initially, the domestic automotive industry had been focusing on achieving scale; product development always took a back seat. However, in the past 5 years the focus is shifting towards investing in R&D, especially towards New Product Development. Domestic companies have started investing in R&D towards breakthrough product designs and manufacturing technologies. The average R&D expenditure as a percent of the turnover has scaled from a mere 0.5 to 3%[22] for the Indian automobile industry, coming at par with the industry average of 3.95%.[23] It is necessary for domestic players to benchmark their products/technology against the global players.

India also has a fair amount of presence of MNCs in its automotive sector. These **MNCs have active R&D in the country being conducted for domestic and global applications**. However most of them have not localized their R&D significantly. 30% of MNC R&D centers remain to be “offshore units”. Besides, these centers are under the tight control of the company’s R&D headquarter, which defines processes, standards and interfaces and monitoring quality. Apart from using Indian captives, MNC also

[22] Indian Council for Research on International Economic Relation – Determinants of Competitiveness of the Indian Auto Industry, January 2008

[23] Beyond borders, Global innovation 1000 (2008) - Booz & Co.; Netscribes analysis

resort to major development and simulation off-shoring to India due to its software expertise. Another 55% of foreign auto companies having R&D presence in India are engineering nuclei, which are responsible adapting hardware components such as suspensions, front ends and seats. Only 15 percent of these foreign R&D centers are centers of competence and have more autonomy than the global R&D headquarters.

This trend is also undergoing a gradual change, with **India building its designing capabilities**. India's independent technological advancement combined with the domestic skill set and cost leverage will work towards transformation of India into an Automotive Hub.

FOCUS AREAS

Ultra low cost cars:

Majority of the companies in the western world have conventionally targeted the wealthy 700-800 million consumers of the world mainly in the developed countries. However, with the focus in the global economy shifting towards emerging nations, addressing the needs of almost one-third of human population requires solutions that are drastically different from what established global companies are used to. Serving the "bottom of the pyramid" offers great growth prospects, which has brought into focus the – the ultra-low-cost-cars in passenger vehicle. With Tata Motor's "Nano" India has brought about a revolution in this segment. It has redefined this segment with Nano being officially the world's cheapest car, priced at USD 2,500. Several other companies are trying to follow Tata motors in close steps. The Bajaj-Renault JV has been working to develop a rival to the Nano. This technology will not only find its large scale market in India, but will also be demanded from other emerging countries.

Success in this segment is dependant on a combination of radical thinking, innovative product design and engineering and lastly the company's supply chain, vendor management and development.

Green automotives:

Indian automotive industry started its pursuit of green technologies with CNG and LPG. The Electric vehicle phase entered India with the entry of Electric two-wheelers. There is a lack of a long term strategy in the green technology segment. Each OEM in India is trying to pursue multiple green technologies – bio-fuel, hybrids, hydrogen fuels and Electric Vehicles (EVs). A consensus will help the industry partner with the government and draft appropriate incentives and regulations for the growth of the chosen technology.

However, in recent times, there is an increased focus on both EVs and alternative fuels (hydrogen and bio-fuels). The AMP 2006-16 introduced several incentives for research in these technologies. The 2011 Indian budget has provided several benefits for the EV manufacturers; the Finance Minister has even proposed the National Mission for Hybrid and Electric Vehicles.

While the PPPs are working on the alternative-fuel segment, the OEMs have started focusing on EVs (especially four-wheelers)

The EV market is currently in a nascent stage, but it is predicted to grow in double digits. There are several domestic companies using locally developed technology in the electric 2-wheeler market, however, Reva is the sole electric four-wheeler developed in India. **Several MNCs (Hyundai, GM and Renault) and domestic majors (Tata motors and M&M) are planning to launch EV versions of the existing four-wheeler conventional models.** But the technology for these projects is generally outsourced from US, EU or Japan, where this market is far more matured. However, with the presence of a home-grown REVA, one of the first electric cars in the world to go in for mass production, India is trying to catch pace in this zero-emissions-vehicle race. **India does not lack the basic technology, but the technology needs to be worked on in terms of power-train and the engine management systems – which can enhance the speed and distance (covered in one charge) of the EV.**

India still has major gaps in its EV ecosystem, in terms of charging infrastructure and component manufacturers. Moreover, the success clean-tech in India will be dependant on how cost-effective it can be made.

Increasing importance of Electronic components – Increasing India's foothold over Automotive R&D:

With the advent of electronics, computing and communication technologies, we are now in the era of the 3rdGeneration Automobile – the "software cars" as General Motors calls it. Today, 80% of innovations in automobiles comes from electronics. This technology innovation finds its application in Hi-Tech, more intelligent automotives and also in Green automobiles.

Moreover the cost of developing these components is perpetually increasing.

- The approximate cost of electronics in luxury automobile is approximately 23% of the total product cost
- The average automotive electronic cost per vehicle is forecast to increase by 50% in 2010[24]

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[24] Defiance Technologies – 3rd Generation Automobiles – India can lead this opportunity

This makes India an ideal destination for development of components like Engine Management Systems (EMS)/(ECUs), Capacitive Discharge Ignition (CDI), Instrument clusters, Anti-lock Braking Systems (ABS), Flashers, Regulators, Alternators, Wipers, Remote key, Taxi Meters, Power windows, Glow plug timers, Electronic power steering and Air bag control units. Not only does it provide personnel who have proved their prowess in IT but also a cost-leverage.

The 30% of MNC R&D "offshore units" develop software, electronics and other contents rather than developing entire cars or engines. One of the examples in this segment is Daimler Chrysler, which has been working on encryption, image signal processing and telematics in its Bengaluru facility.

EVOLVING AUTOMOTIVE R&D IN INDIA

Indian OEMs establishing their own Design facilities:

India has always lacked the capabilities in automotive designing. Therefore domestic OEMs have always resorted to outsourcing their design functions to global majors like Pininfarina, Bertone, Aria, etc for styling and AVL, Ricardo, etc for engines.

However this trend is changing and India is attracting foreign talent for product designing. **India's rapidly growing automobile sector is on the look-out for international design talent, with several top auto-makers hiring designers and engineers from different parts of the globe in the past year.** When the global automotive industry was running into crisis, India's two-wheelers and four-wheeler market were on a roll registering record sales in 2009-10. This had triggered a major displacement of top automotive professionals, including engineers, designers and researchers**. This trend not only helps Indian companies develop mew models/products, it also helps them train and groom their next breed of in-house designers and engineers.** This has till a great extent facilitated transfer of know-how.

India has been successful in attracting auto-designers with expertise in design and model-making relating to hybrids, engines and transmissions. E.g.:

- **Maruti Suzuki** hired several Detroit-based auto engineers, specializing in auto design, styling and modeling, and engine development and manufacturing
- **Tata Motors, Mahindra & Mahindra (M&M), Bajaj Auto** and **Royal Enfield,** also negotiated with international auto designers for launching ambitious in-house design capability expansions
- **Bajaj Auto** hired BMW Motorcycles' Edgar Heinrich to head its design function

- **Royal Enfield** appointed Venki Padmanabhan as Chief Operating Officer, who has worked with the advanced engineering team of General Motors in the US and served in the DaimlerChrysler Mercedes car division

This “reverse brain drain” has majorly affected the global design majors. The crisis combined with the loss of talented personnel has left even the likes of legendary Italian design house Pininfarina looking for a total sell-out or at least a partial sale of equity stake. Several Indian OEMS have grabbed this opportunity to take over such design houses. Therefore, **the design functions that used to be carried out in France, Italy and UK are now being conducted in India.** Indian companies are looking forward to leverage the strong European skills and technologies. Increasingly, both domestic and international firms are investing in setting up design facilities in India.

- Among the Indian OEMs, M&M recently acquired G.R. Grafica Ricerca Design Srl (GRD), an Italian auto designing, body-engineering and feasibility and styling company based out of Turin.
- Among the MNCs, GM and DaimlerChrysler have R&D centers and Renault has a design center in India. These centers are not only working on India-specific projects but also on projects meant for global application.

Adding to this trend, global design houses have begun to establish their back-end operations in India, post the ideation stage. **India is also seeing a rise of start-ups which are positioning themselves to cater to the design requirements of the global market.** E.g.: Argentum, which has tied up with the French software major Dassault Systems to provide power-train solutions. **These trends are all driving India towards filling the missing gaps in its automotive product development capabilities.**

India - Hub for Development & Simulation:

The abundance of engineering talent pool has been attracting global OEMs and suppliers to set up R&D captives in India and other developing markets. India has been a one of the preferred destinations - several global OEMs have in the recent years have either set-up or relocated their design centers to India to leverage the country's IT expertise in development and simulation.

These processes are not only conducted in captives of MNCs, but several global players, actually outsource this work to Indian companies who provide these specialized services. E.g.: Mahindra design Center and several other IT vendors (Wipro, HCL, etc). This segment is very important for MNCs and accounts for their largest presence.

The domestic OEMs have been outsourcing their Design processes to foreign players; however they conduct the development and simulation processes in-house in India. In fact **Indian OEMs are**

completely self-sufficient in terms of engineering capabilities. Off late, they have begun to conduct engineering and detailing without the requirement of any third party- Indian or foreign. Some of the indigenous product developments include – Sedans like Indigo, Ace and Nano by Tata motors; SUV like Scorpio by M&M and Motorbike like Pulsar by Bajaj.

Indian companies and captives providing these services are not only catering Indian demand but are also working on projects with global application.

India's very strong capabilities in Testing:

India has always been an attractive geography for automotive testing. Mr. Ashish Shah, employee of a large Indian OEM producing off-road HCVs says "If a vehicle is India-proof, it is world-proof". India has to offer the most diverse environmental conditions for testing automotives. Besides with the Indian Government taking special efforts in this segment, India is bound to be the global hub for Automotive testing. The Indian government's initiative – the NATRIP project worth USD 380 Million has been set up with the objective to help India become a major force in global product development. The infrastructure under NATRIP will offer a wide range of product development and validation services for both domestic and global automotive industry. The project consists of[25],

- Full-fledged testing and homologation centers within the automotive hubs of north and south India at Manesar and Oragadam, respectively.
- Up-gradation of existing testing and homologation facilities in the western hub at the Automotive Research Association of India (ARAI), Pune and at the Vehicle Research and Development Establishment (VRDE), Ahmednagar.
- A world-class proving ground on 4,098 acres of land in Central India at Pithampur.
- A center for testing of tractors and off-road vehicles in the Northern region of the country, with a national facility for accident data analysis and specialized driving training at Rae Bareilly.
- A specialized hill area driving training center and a vehicle management center in the North Eastern region at Silchar.

The launch of NATRIP will provide a major boost to India's fast growing automotive industry. It will result in better use of India's strengths in the areas of automotive engineering, information technology and electronics by achieving a high degree of convergence.

[25] Defining the Role of the government in the transitionalisation efforts of the Indian SMEs in the Auto components Sector – August 2008, DSIR

Increasingly Foreign OEMs planning new R&D centers in India:

As a result of India's speedy progress across Design, Development and Testing several global players are planning to set-up their R&D centers in India.

INNOVATION SUCCESSES

Company: Tata Motors Ltd

Managing Director and CEO: Mr. Carl-Peter Forster

Headquarters: Mumbai, India

Number of employees: 50,000 (2010)

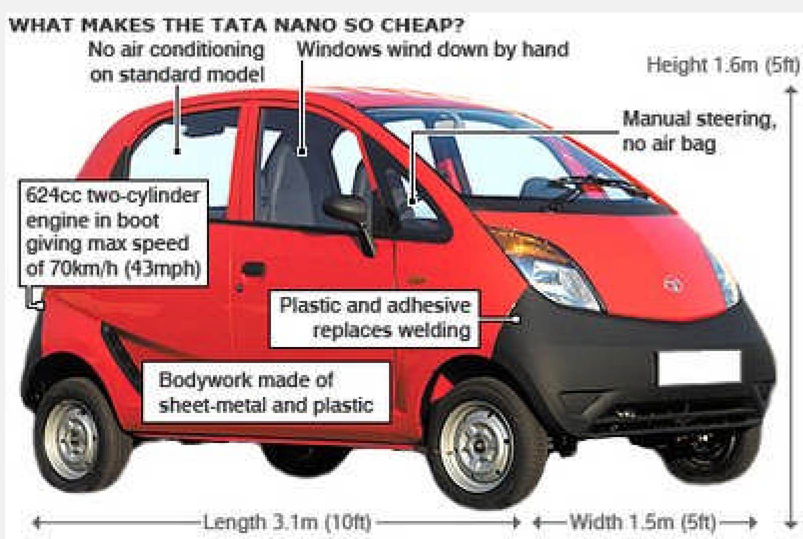
Year Founded: 1945

Origins: Tata Group

With the introduction of Tata Nano, Tata Motors created a revolution in the ultra-low-cost-car segment. They redefined the price bracket for this segment, by developing the world’s cheapest car, priced at USD 2,500.

Though small car segment has always been given most importance in India and Indian OEMs are well-versed with the challenges in the development of small cars, developing Nano came along with its own set of challenges. It was developed considering the 2-wheeler owners as the target audience; hence it came along with an unimaginably low price benchmark.

It is an integration of several smaller innovations; all put together, Tata Motors filed for 37-plus during the manufacturing process of the car (as compared to 280 patents that GM files while new product development). Developing Nano required radical thinking and the will to switch from conventional processes of New product development.



The Nano was a result of innovations in product, processes and business-model. The main principle behind the Nano's product innovation that enabled its cost-effective manufacturing were – use of alternative material, frugal consumption of material. Though the designs were outsourced from Italy, they were closely overseen by the OEM. Moreover, the development was conducted at the premises of the OEM and partially at the Tier I suppliers like Bosch, Johnson Controls, Saint-Gobain, etc. In spite of all the developmental constraints, the car successfully meets all the emission and safety norms of India.

The major structural and technical modifications that differentiate Nano from other ultra-low-cost-cars are

- Structural design that keeps the length limited, but provides 20% more inner cabin space than its immediate competitor Maruti 800, due to height and positioning of the wheels right at the edge of the car and Instrumental console placed in the center.
- Used alternatives to steel to make the car lighter + Tubeless tires, reducing weight by 2 kgs and adding to the cost saving
- Low capacity and lighter engine positioned in the rear - To reduce the transmission length using a balancer shaft
- All aluminum engine – Higher thermal conductivity than cast iron

The model added to the cost-saving by eliminating features that are taken for granted by western car manufacturers. E.g.: automatic windows, air-conditioning, power brakes, radio, etc.

Company: Mahindra Reva Electric Vehicles Private Ltd.

Founder and CEO: Chetan Maini

Headquarters: Bengaluru, India

Number of employees: 300-500

Year Founded: 1994

Origins: JV - Maini Group, Bengaluru and AEV LLC, USA; Currently, acquired by M&M

REVAi is one of the first companies to introduce EV worldwide – it is one of the first for-wheeler EV to go for mass production. Reva was claimed to be India's first zero-polluting, battery-driven car with a running cost of just Rs 0.40 per km.

The REVAi electric vehicle was launched in India in 2001 and in UK in 2004 (Under the G-Wiz brand). A year ago, the company unveiled two new models, the four-seater REVAi NXR and the two-seater REVAI NXG. Today, Reva has one of the largest deployed fleets of electric cars in the global market and the accumulated data from more than 100 million km of user experience.

However, REVA has fought against several challenges, in a country that has several gaps in its ecosystems for developing electrical automobiles. The Maini group of companies itself supplied all the components of the car, except the battery (Exide), motor (Kirloskar Electric), motor controllers (Curtis) and accessories (Modular Power Systems). They supplied the composite car body, all stampings, axles, brakes, suspension, wheels & hubs and a host of electrical parts, including the wiring harness, charger and integrated circuits.

It is also fitted with some small but efficiency-improving innovations. E.g: The energy management system used in the Reva, which is activated remotely by the company, this IT-enabled system has the ability to optimize battery usage for the car owner. So, for instance, extra-battery capacity can be released for someone, if they are stranded without a charging point around.

The company’s recent acquisition by the Indian giant M&M, will not only improve the product in terms of safety and ergonomics but also will take it to several countries – UK, Norway, Italy, South Africa, Chile and Brazil.

DRIVERS OF INNOVATION

Retaining competitiveness of the industry:

The Indian automobile industry has shown consistent growth over the past years and has achieved a considerable scale today. For the industry to progress further, it needs to achieve global levels of competitiveness. If it needs to scale beyond exports to emerging nations it needs to invest in R&D and develop world-class products.

The Government of India realizes the importance of this situation. It is also aware of the economic significance of the automotive sector to the nation. Considering this the Automotive Mission Plan 2006-16 was drafted. The plan aims to reach an output of USD 145 billion, accounting for 10% of the GDP and providing additional employment to 25 million people by 2016.

The plan recognizes innovation and investment in R&D as one of the main means to achieve its goals. This plan proposes several increased benefits and privileges for companies in the automotive sector investing in R&D. (Few details of the proposed initiatives to boost R&D expenditure are listed in Appendix)

The whole drive in the Indian automotive industry, to emerge as the global hub, is triggering increased focus on R&D, innovation and new product development.

Catering to the local demand:

The Indian local demand is characterized by low-cost vehicles that are non-expensive for maintenance and are also highly fuel efficient. There are very few companies in the world catering to India-specific requirements. There is a huge market at the bottom of the pyramid waiting to be served. The Tata Nano was the first step in this direction. However, several domestic and foreign players will follow suite by developing rival products to the Nano or vehicles falling in the "low-cost-vehicle" segment.

Recently created design capabilities:

The Indian automotive industry received one of it most glorious opportunities disguised in the form of the downturn. It is a known fact that when the global automotive industry was seeing double digit negative growth, the Indian automotive sector was meagerly affected by the global fiasco. The crisis had led to several automotive design houses to look for acquirers and global designing talent to look for lucrative opportunities. Several Indian companies capitalized on this situation and created substantial design capabilities, both domestically and abroad.

This newly created design capabilities will help Indian companies to curb their outsourcing requirements and develop complete products indigenously. The past few years have changed the Design/prototyping scene in the Indian automotive industry.

Vast and Sturdy Auto-component industry

For Automotive industry to flourish, it needs to be supported by a strong auto-component industry. The auto-component industry of India is significant in size and has shown consistent growth over the past decade, it has grown at a CAGR of approximately 23%, to reach a turnover of USD 22 Billion in 2009-10. Not only have the number of domestic players increased, but the capacities of the MNCs have also significantly increased. The industry has grown in terms of value and it has also matured. Indian component manufacturers have willingly embraced modern Manufacturing and Quality control practices like Lean Manufacturing, TPM, TQM, Kaizen, 6 sigma, 5-S, 7-W to compete with other countries. Indian companies have won 9 Deming awards, the highest among companies outside Japan, Japan quality medal and TPM award[26].

This matured industry has started advancing to the next level of value chain. They have invested in setting up design center as more and more **OEMs have started outsourcing partial R&D to Tier I suppliers**. Though these processes remain to be managed and guided by the OEMs.

The Indian automotive major – Tata Motors was pioneer in triggering this change. They moved from the conventional procurement model, where a company creates the technical specifications for parts and then asks suppliers for their bids. Today, they float the proposals providing the output they expect and allows suppliers to leverage creativity in design, material and prices[27].

Availability of Low-cost skilled man-power

India has a large availability of skilled engineers. This combined with India's prowess in IT provides the perfect breeding ground for talent ideal for automotive R&D.

India has already been providing talent for the development & simulation (engineering/detailing) phase but with increased emphasis on developing domestic design capabilities, a new breed of talent is being groomed for the same. Educational institutes have also started offering courses specializing in automotive design.

Easily accessible financing & Regulatory benefits

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[26] Defiance Technologies – 3rd generation Automobile – India can lead this opportunity

[27] E & Y and CII - Enhancing Role of SMEs in Indian Defence Industry

India is all set to become a hub for the global automotive industry. This intention is driving several favorable regulations. There are numerous measures of tax concessions available for automotive companies spending on R&D. With the Automotive mission plan 2006-16, there are proposals to increase the benefits from tax concessions. (Few details of the AMP 2006-16 are listed in Appendix I)

Challenges:

Slow policy making

The government is successful in drafting long-term plans. However, when it comes to passing legislation and altering regulations to fulfill the long term plans, the government slows down. Several initiatives and legislations which can trigger faster innovation are blocked or are proceeding at a very slow speed. For instance in the green technology, apart from the R&D grants, several policies are required, which are still jammed.

- The green technology segment needs to be incentivized for consumers. Currently, green technologies are expensive and hence under-utilized in the Indian market. Such incentives can increase the acceptance of nascent technologies and boost OEMs to increase their R&D in this segment.
- Setting –up of infrastructure for greener technology vehicle. E.g. Charging stations OR Battery rentals.

Niche manpower requirement

India has to offer abundance of talent for product development; however it lacks the specialized skilled labor. As per AMP 2006-16, a 62% increment will be required in the current number of skilled workers. The country needs to work on this area, to maintain smooth progress in the automotive industry. Even though there are several educational institutes to groom automotive professionals, there is a lack of institutes to impart automotive assembly skills to develop skilled labor. The Indian automotive industry being a labor-intensive set-up, this issue can raise several implications in the future.

PREVALENT COLLABORATIONS

Collaborations in the Indian automotive industry have played a very important role. However, the collaboration for product development has only followed an outsourcing/technical collaborations and Joint Venture model.

- Indian OEMs have never produced a product indigenously. Though the engineering and testing was conducted in-house, the designing was done in collaboration with a foreign design house.
- In case of absence of a domestic captive, MNCs tend to collaborate with firms providing specialized development & simulation services.
- India's proven IT prowess, also attracts several projects for developing embedded systems and electronic components for the products
- Several global players have also partnered domestic players to capitalize on the Indian market by collaboratively developing India-specific products.

Technical collaboration involves the foreign partner generally providing only the product design, drawings and methods and the process engineering being conducted in India. And Joint Ventures developing new products also involve both parties sharing their technologies on royalty basis. Therefore, all these collaboration have always involved very negligible knowledge-sharing in terms of technology.

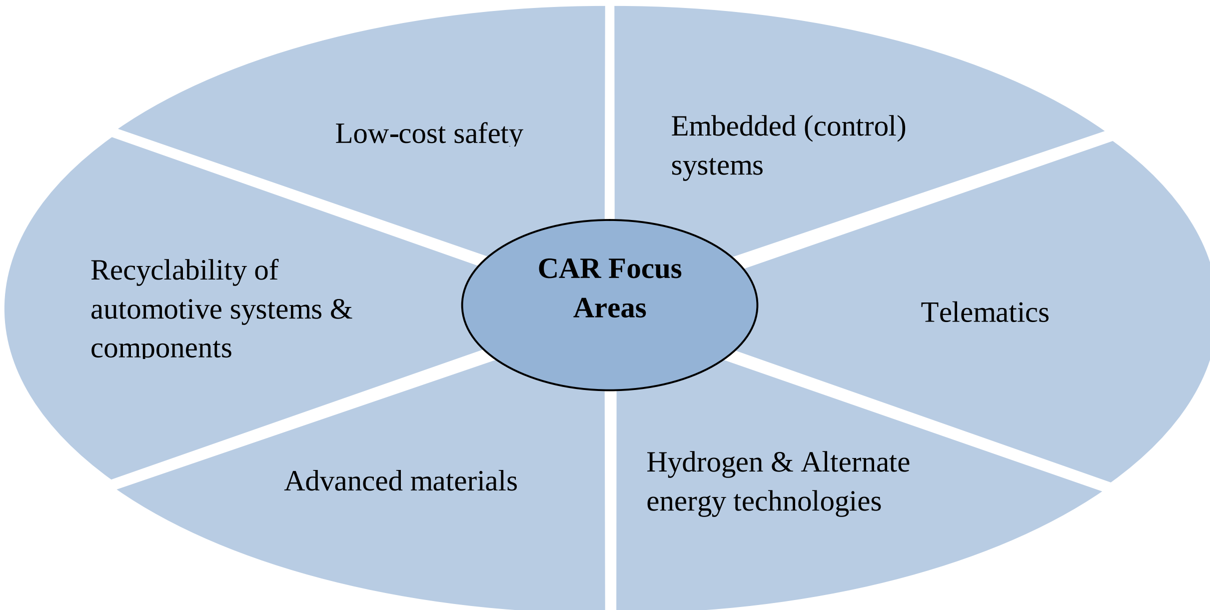
(Details of the collaborations in India are listed in Appendix II)

Moreover, until the last decade, the government associations, research bodies and academic institutes were not visible on the automotive collaborative scene. However, with the establishment of Core group of Automotive R&D (CAR), this scenario is changing.

Core group of auto R&D

The Government of India recognizes the importance of R&D in India and also the existing gap between the Indian academia and industry. To fill these gaps, the Core group of Automotive R&D (CAR) was set up in Indian by the then Finance Minister, in 2003. This Private Public partnership has identified certain areas of focus for the automotive R&D.

Figure 26: Core R&D areas



The CAR has appointed TIFAC as the secretariat to co-ordinate R&D projects under these focus areas. These projects are taken up by several companies (domestic and foreign) and academia (the elite educational institutes – IITs, IIM, IISc, etc) which collaborate to work on a particular project.

(The details of the completed, ongoing and new projects under the CAR can be found in the Appendix III)

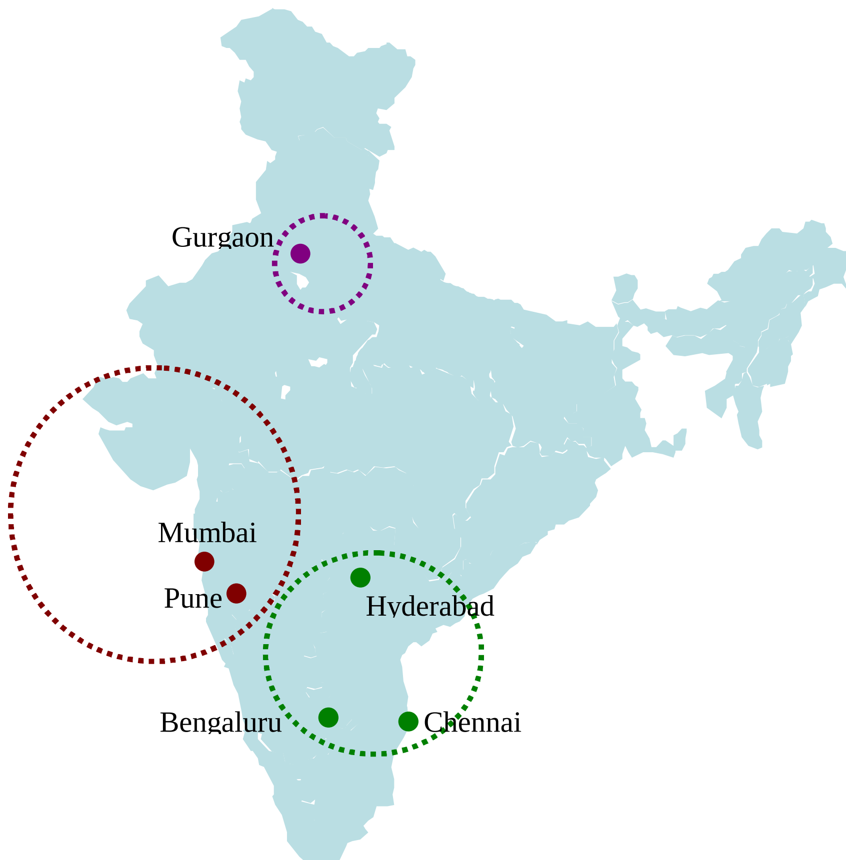
Where collaborations with Europe are concerned, both the regions share a healthy relationship.

- Most of the European OEMs have either R&D captives or outsourced functions in India.
- India also majorly resorts to European design houses.

INNOVATION CLUSTERS

The Automobile sector in India has always followed the cluster approach. The state of Maharashtra and Tamil Nadu have been always been the hubs for Automobile industry in India. Currently, Pune (in Maharashtra) is largest geographical concentrate for automotive industry in India. Also there are other regions which act as pockets for the automotive industry – Indore (MP), Kolkata-Jamshedpur belt (West Bengal).

Figure 27: Innovation clusters



West Zone ●		
Pune	Chakan – Talegaon	Tata Motors, Bajaj Auto, Fiat, John Deere, ARAI, Auto Cluster Development & research institute (ACDRIL)
Mumbai		Renault
South Zone ●		

Chennai	Hosur and Ennore	Mercedes—Benz, Ashok Leyland, ARAI, NATRIP
Hyderabad		Hyundai
Bengaluru		GM – Chevrolet, Chrysler
North Zone ●		
Haryana, Gurgaon	Manesar, Rohtak, Lucknow	Maruti Suzuki, NATRIP

WESTERN CLUSTER

As per SIAM statistics, **81% of the total R&D expenditure of the country is made in the west zone**[28]. This is a cumulative result of a few factors,

- **Deep roots of the automotive sector in Maharashtra**

  This cluster houses the two Indian automotive majors - Tata Motors & Bajaj Group. These companies were established in the 1940s-50s, thus laying an early foundation stone of the automotive industry in Maharashtra (compared to 1980s for the northern cluster and 1990s for the southern cluster). Even today, the western zone, primarily the state of Maharashtra accounts for 33% of the country's automobile output (in terms of value). The Chakan-Talegaon in Pimpri, has become one of the most dense automotive clusters in the world. It is safe to say that the state of Maharashtra is one of the automotive hubs of the country.

- **Presence of a complete ecosystem for OEMs**

  Being an automotive hub, Maharashtra boasts of the existence of the complete ecosystem for the OEMs, to set up their design centers, R&D facilities and manufacturing plants. Apart from Pune, cities like Mumbai, Nashik, Aurangabad, Ahmednagar, Kolhapur and Nagpur have notified SEZs and have been active in the automotive sector for a long span. There is a fair presence of Tier I suppliers, automation firms (robotics), design firms, prototyping facilities and IT firms catering to the automotive industry. The state also has the presence of government institutions into research (ACDRIL), testing (NATRIP) and certification (ARAI) organizations.

[28] Refer Appendix

- **Abundant availability of engineers and IT professional**

  Factors like the age old establishment of the automotive industry in the state, industrial nature of Pune city has managed to make the west zone a breeding ground for engineers and automotive professionals. This combined with the fast growing IT talent in this area leads to abundant availability of human resource for the industry.

- **Higher technical comprehension and faster technology absorption**

  Maharashtra has not slowed down in terms of its technological growth. Even today it attracts the highest international attention as it has the capabilities to adapt to newer better technology. Most of the foreign OEMs have set-up their R&D centers in Pune. The western zone has attracted 34% of the FDI in the automotive sector in the past decade.

Even though the labor in this part is slightly more expensive than the rest of the country, the ages old establishment of the automotive industry, the ecosystem availability and the faster pace of advancement and growth provides safe establishment grounds.

SOUTHERN CLUSTER

The automotive cluster in the Southern zone churns out approximately half the gross turnover as compared to the West zone. It is the most recently established automotive cluster (around 1990s), this factor is compensated by the Government’s drive to establish their states as automotive hubs. Hence, this zone manages to contribute 13.7% of the country’s automotive R&D expenditure.

The state of Tamil Nadu is very speedily developing into the country’s second largest automotive hub. Also, being the IT hub, Bengaluru has also been increasing its presence in the Indian automotive industry, with increasing importance of electronic systems.

The success of this zone can be attributed to – Education infrastructure and Government support available.

- **Educational institutions**

  The Southern zone also boasts institutes providing of automotive-centric education resulting in creation of specialized human resources. Automobile Research Institute of India is based out of Hyderabad. The IITs at Madras and Bengaluru offer specialized courses in automotive designing, CAD and CAE along with the standard mechanic engineering.

- **Government Support**

The government of Tamil Nadu is putting serious effort in attracting investments in the automotive sector. The best state government incentives are provided by Tamil Nadu. The state of Karnataka along with Tamil Nadu is also continuously in the pursuit of improving the infrastructure for the industry.

- For instance the Tamil Nadu has actually planned to draft an Automotive policy (separate from the industrial Policy) in 2011. Currently, mega-projects in this state are eligible to benefits like - land allotment at concessional price, 100% exemption from Stamp Duty, Dual feeder lines for power supply (with the cost of feeder lines borne by the state government), Exemption from Electricity tax for 10 years, Refund of Gross output Value Added Tax (VAT) and Central Sales Tax (CST) (without any set off) for 21 years, Exemption from entry tax, VAT on capital goods, works contract tax, Octroi (if any) and other State levies
- The Tamil Nadu government works towards providing an ecosystem. In 2005-06 it had set-up an SEZ for auto-components near Chennai, covering 300 acres. The SEZ was also equipped with a facility tor training in high technology in auto-components. Polytechnics and Industrial Training Institutes (ITIs) around Chennai, Hosur and Coimbatore were oriented for automotive sector.
- The State Government of Karnataka has set up many Auto parks. One at Bidadi (442 acres) in Bengaluru, one at Shimoga (250 acres), and the third one at Dharwar. These auto parks house many automobile ancillary and servicing units. Government has also proposed development of Suvarna Karnataka development corridors and special industrial zones for the automobile industry.

NORTHERN CLUSTER

The Northern Zone comes in a close second, in terms of attracting FDI and churning a gross turnover in the Indian automotive industry. However, its share in the country’s automotive R&D expenditure is a mere 5%.

The North zone is a successful manufacturing hub, the Gurgaon-Manesar-Bawal region has been identified as an Auto Hub by the Government of India. But this zone lacks R&D capabilities. This can be attributed to a more recent establishment of the automotive industry (around 1980s).

However, if the existing automotive cluster is prompted to harnesses these IT capabilities for the engineering, embedded systems and electronic components of automotives, the current situation might see a gradual improvement.

GOVERNMENT INITIATIVES/SUPPORT PROGRAMS

FDI: Automobile and components manufacturing in India are permitted 100% FDI under the automatic route.

Tax Deductibles: The government provides encouragement to R&D expenditure in the automobile and component sector by

- Providing benefits in the form of a weighted tax deduction on the amount spent on R&D – it is set to be further improved from the current level of 125%.
- Accelerated depreciation rates for equipment purchased for R&D purposes.
- Rebate on the applicable excise duty for every 1% of the gross turnover of the company expended during the year on Research and Development either in-house under a distinct dedicated entity, faculty or division within the company assessed as competent and qualified for the purpose or in any other R&D institution in the country.
- Encourage setting up of independent auto design firms by providing them tax breaks, concessional duty on plant/equipment imports and granting automatic approval.

Cess Fund: Allocations to automotive cess fund created for R&D of automotive industry is going to be increased and the scope of activities covered under it will be enlarged.

NATRIP: Under the provisions of the AMP 2006-16, the Government has made investment of USD 380 million to set up the National Automotive Testing and R&D Infrastructure project (NATRIP). This has been the most critical intervention by Government to promote R&D in the automotive sector. NATRIP aims at facilitating introduction of world-class automotive safety, emissions and performance standards in India and also to ensure seamless integration of Indian automotive industry with the global industry. The project aims at addressing one of the most critical handicaps in the overall automotive industry today, i.e. major shortfall of testing and pre-competitive common R&D infrastructure. The following centers of excellence are being established under NARTRIP.

Table 16: NARTRIP Centers of Excellence

Niche area of Research	Location
Noise, Vibration & Harshness Centre	ARAI, Manesar
Auto Components	ARAI, Manesar
Power-train (Transmission)	ARAI, Pune
Fatigue Testing	ARAI, Pune
Material testing	ARAI, Pune
Automotive Infotronics	Chennai
Crash testing	Chennai
Testing track	Indore
Vehicle dynamics	Indore

OUTLOOK & RECOMMENDATIONS

The Indian automotive sector is likely to envisage following trends in the coming years

IT Prowess:

- India will continue to be the top destinations for Engineering processes as it involves CAD, CAM, CAE and PDM. India's abundant human resource combined with English-speaking skills will help India out-do competition.
- Apart from the conventional Development & Simulation work, several Indian companies and IT players are involved in developing Electronic components (E.g.: Encryption, Image signal processing, Telematics) and embedded control systems and will continue to do so to reach the leading positions.

Efforts to win the zero-emissions-vehicle race:

- In terms of Electric vehicles, several global OEMs like Renault are way ahead in leading the Electric vehicle segment; Indian companies are making all efforts to develop Electric vehicles that are low-cost and in-expensive on maintenance. Indian companies do not lack the basic technology; they need to work on the ergonomics and the power-train of the product. Collaborations will be needed in this segment to develop EVs which are efficient performance, comfort and cost-wise.

- India is also focused on research on alternate fuels, especially Hydrogen and bio-fuels. If successful, the time to market such products will be very less due to the country's existing infrastructure and acceptance towards CNG.

Huge market and opportunities in the low-cost segment:

- India's large unexplored market at the "bottom of the pyramid" combined with the expertise in the low-cost vehicle technology, forms an attractive business opportunity

Labor intensive industry with negligible/low-cost use of automation:

- The cost-leverage achieved during manufacturing has always been one of the core factors contributing to the Indian automotive industries success. The major contributor towards this cost-leverage has been the labor–intensive nature of this industry. Several automotive companies in India use negligible or low-cost automation.
- Therefore Mr. Shrikant Pangarkar, project Manager, Bosch India suggests "All foreign partners while entering technical collaborations in India must be aware that their success depends on the suitability of their technology/product/design to the Indian cost and manufacturing capabilities"

Testing capabilities:

- India always had to offer the most diverse environments for vehicle testing at an in-expensive costing
- With the added government's focus on developing testing facilities in India (USD 380 million NATRIP project), India is bound to attract global attention for its automotive testing capabilities.

Indigenous developments:

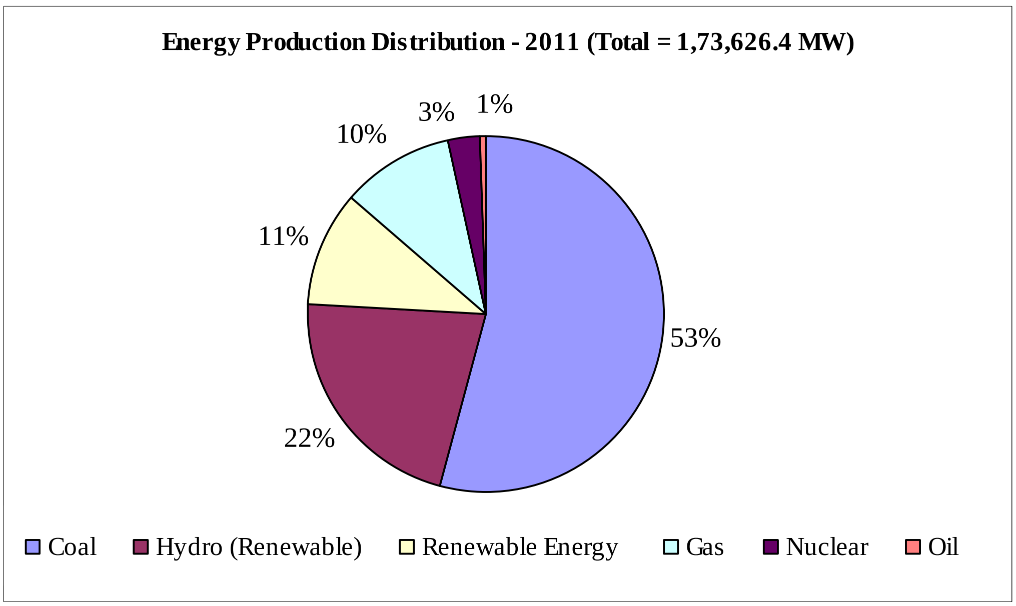
- India has finally evolving into a holistic automotive sector with capabilities in Designing, Developing/Engineering and Testing. The IT capabilities also give an edge, towards developing the next generation vehicles. The industry is also supported by an ecosystem of auto-component manufacturers and suppliers. It is also diverting its focus from only achieving scale to attaining globally competitive standards. If India achieves high degree of convergence of its strengths in the areas of automotive engineering, information technology and electronics, it will emerge as a global hub and the domestic OEMs will be capable of independently developing indigenous products and technologies that can compete with global OEMs.
- However, this requires an integrated approach, where – Industry, Academia, Research institutions, Technology alliance partners, industry bodies come together as an ecosystem with a cluster approach. Successful innovation can happen only by breakthrough collaboration between

the different key stakeholders. This collaboration needs to happen not only within India but also at a global level involving the global automotive community.

9. ENERGY

India is the world's eleventh largest producer and the sixth largest consumer of energy in the world. With an installed power capacity of 164,835 MW, India has 4% of the global capacity. However the rapidly growing economy and rising demand for power requires number of power projects and huge investments. Though the government and industry are making increased efforts to ramp up the supply through new power projects, the demand far outpaces the supply. Historically, the Indian power sector has been driven by fossil fuel power, predominantly coal. Though fossil fuel based power plants are expected to be the dominant source over the next few years, the industry has also started focusing towards renewable and alternate energy sources. The energy production distribution of India has been summarized in the following chart.

Chart 28: Energy production distribution, 2011

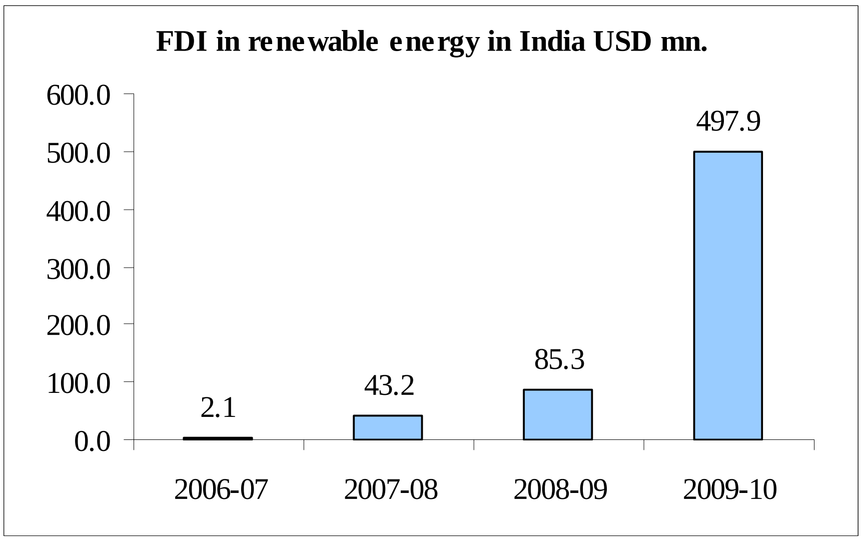


*Renewable Energy includes: Small hydro projects, biomass gasifier, biomass power, waste power

Poor quality of coal, low productivity levels of existing plants and focus to reduce greenhouse emissions are some of the factors which are resulting in decreasing share of fossil fuels. At the same time, building up renewable energy plants has now become imperative in order to meet the domestic demand. International Energy Agency (IEA) data for 2008 indicates that electrification rates for India were nearly 65%. In urban areas, 93% had access to electricity while the same figure barely touched 50% for rural areas. About 400 million people do not have access to electricity in India. Due to a huge demand-supply gap, nearly 30% of India's total energy demand has to be met through imports. At 720 KWh, India's annual per capita power consumption is less than 20% of that in China, and is about 30% of the world average.

The per capita energy demand in India is expected to rise sharply due to high economic growth and rapid industrialization. The past three decades have seen the demand for energy rise at an average rate of 3.6% per annum. According to an analysis by The Energy and Resources Institute (TERI), the annual primary energy and electricity growth rates are expected to be between 3.7-4.4% and 5.1-5.7%, respectively. The energy demand is expected to grow even further to 5.2%, to incorporate the GDP growth rate of 8-10% in the coming years.

Chart 29: FDI in renewable energy in India



Foreign Direct Investment (FDI) in India has been on the rise in recent years. In the financial year (FY) 2009-10, FDI in the renewable energy sector alone was USD 497.91 million.

MARKET SEGMENTS

The energy sector comprises of two main segments namely renewable and non-renewable sources of energy with non-renewable segment occupying the major share of the current production. Although coal is expected to continue to be the dominant energy source in the next decade, the depleting coal reserves and the growing environmental concerns are forcing the Indian government to actively develop non-coal sources. Renewable energy currently contributes a small fraction but it is expected to grow very rapidly especially in areas like wind and solar power. The government as well as private sector has been shifting their focus from fossil based fuels to nuclear energy and other renewable sources.

NON-RENEWABLE SOURCES

Non-renewable sources of energy production include nuclear power and fossil fuels like coal, oil and natural gas. These sources are not sustainable sources of energy as their rate of consumption far exceeds their formation in nature.

a. **Coal:** India is both the third-largest producer and consumer of coal in the world. EIA reports show that the coal production and consumption in India in 2009 were 613.4 million tons and 680.9 million tons, respectively. The total installed coal-based capacity in India in 2010 was 89,778 MW.

b. **Oil:** In 2009, India was the fourth largest consumer and the sixth largest net importer of oil in the world, importing nearly 2.1 million barrels per day (bbl/d), or about 70 percent, of its oil demand. According to EIA, the oil consumption in India through 2011 is expected to grow at 100,000 bbl/d. The total installed oil-based capacity in India in 2010 was 1,199 MW.

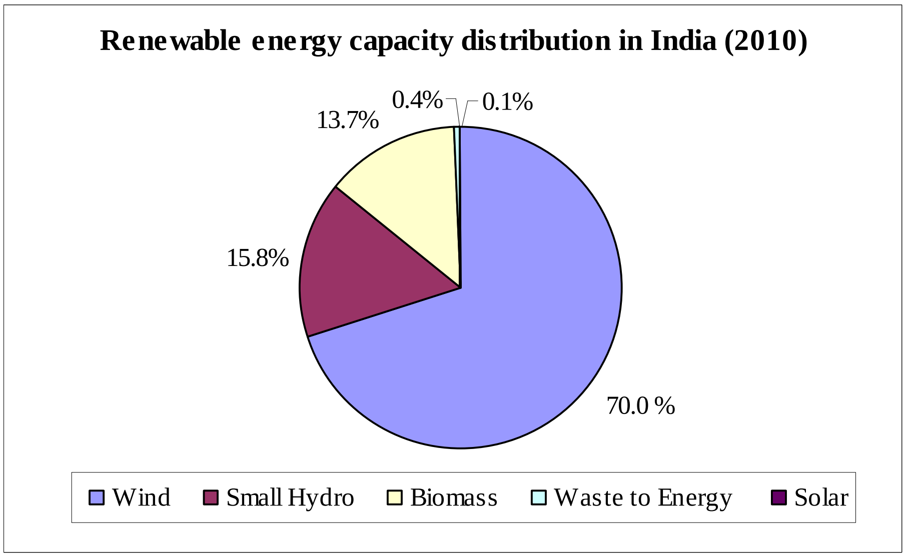
c. **Natural Gas:** The production of natural gas in India in 2009 was approximately 1.4 trillion cubic feet (Tcf), with a consumption of about 1.8 Tcf. The net imports of natural gas were 445 Bcf in 2009. The total installed gas-based capacity in India in 2010 was 17,374 MW.

d. **Nuclear Power:** As of 2010, India has 20 nuclear power plants in operation generating 4,780 MW, while 5 other upcoming ones are expected to generate an additional 3,900 MW. India's nuclear power industry is undergoing rapid expansion with plans to increase nuclear power output to 63,000 MW by 2032.

RENEWABLE SOURCES

Renewable energy sector growth in India during the last four years has been significant. According to a report by Institute for Financial Management and Research (IFMR), the potential annual market demand for clean energy in India is expected to be worth USD 2.2 billion. India's renewable energy power generation capacity now stands at 18,654 MW. The installed capacity distribution is presented in the following chart.

Chart 30: Renewable energy capacity distribution in India, 2010



a. **Hydropower**: The potential for hydro-electric potential in terms of installed capacity in India is estimated to be about 148,700 MW out of which a capacity of 30,164 MW (20.3%) has been developed, and 13,616 MW (9.2 %) of capacity is under construction.

b. **Solar:** India is the world's second largest consumer of solar photovoltaic (PV) energy and solar hot water products, behind only China, with a forecast annual installed PV growth rate of 134%.

c. **Wind:** India now ranks as a "wind superpower" with an installed wind power capacity of 1167 MW, and a net potential of about 45000 MW from 13 identified states. Wind resource assessment program, wind monitoring and wind mapping are currently in progress, covering 800 stations in 24 states with 193 wind monitoring stations in operations.

d. **Biomass:** India's total ethanol production for the year 2007 was 53 million gallons of fuel ethanol. While ethanol production in India is expected to increase with a CAGR of about 2% during the period 2008-2017, the consumption is projected to expand at a CAGR of around 6.5%. India's total biodiesel requirement is projected to grow to 3.6 Million Metric Tons in 2011-12, with the positive performance of the domestic automobile industry.

e. **Geothermal:** India has around 10.6 GW of untapped geothermal potential. However, geothermal power projects have not been exploited at all.

f. **Waste-to-Energy:** The waste-to-energy installed capacity in India is 17 MW from municipal solid waste and 29.5 MW from industrial waste. Every year there is an estimated 30 million tonnes of solid waste and 4,400 million cubic meters of liquid waste generated in the urban areas of India. The municipal solid waste (MSW) generation ranges from 0.25 to 0.66 kg/person/day with an average of 0.45 kg/person/day.

Apart from the conventional energy sources, another emerging area is the decentralized energy generation which addresses the environmental concerns and remote transmission issues prevalent in centralized power systems. Decentralized energy systems are small-scale power generation technologies, typically in the range of 3 kW to 10,000 kW. These systems reduce the need to develop elaborate infrastructure like power lines.

ELECTRICITY

In 2007, India had approximately 159 GW of installed electric capacity and generated 761 billion kWh. Conventional thermal energy sources like coal, petroleum and natural gas produced over 80% of electricity in 2007 in India. Of these, coal is the most important source of energy, producing about 70% of the electricity in 2007. Hydroelectricity, a seasonally dependent power source in India, accounted for nearly 16% of power generated in 2007. At present, nuclear power accounts for only 2% of electricity generation in India and is planned to increase to about 5% by 2020 and 25% by 2050.

The principal demand for electricity arises from the agriculture, transport and domestic sectors. However, India suffers from a critical shortage of electricity generation capacity. According to the World Bank, about 40% of Indian homes have no access to electricity. In addition, there are also electricity efficiency issues, with about transmission and distribution losses amounting to about 30-45%. In order to improve efficiency standards, the Energy Conservation Act was passed in 2002, which established the Bureau of Energy Efficiency and has sought to promote efficient use of energy and labeling of energy-intensive products.

R&D ACTIVITIES[29]

[29] Governmental Energy Innovation Investements, Policies and Institutes in the Major Emerging Economies: Brazil, Russia, India, Mexico, China, and South Africa
Belfer Center (Harvard Kennedy School), November 2010

In India, state-owned enterprises are the most heavily involved in coordinating R&D activities, with the Ministry of Science & Technology (MST) in charge of R&D programs, along with the Department of Science and Technology (DST) and the Department of Scientific and Industrial Research (DSIR).

The execution of India's energy policy and energy research and development activities (R&D) activities takes place in five different ministries:

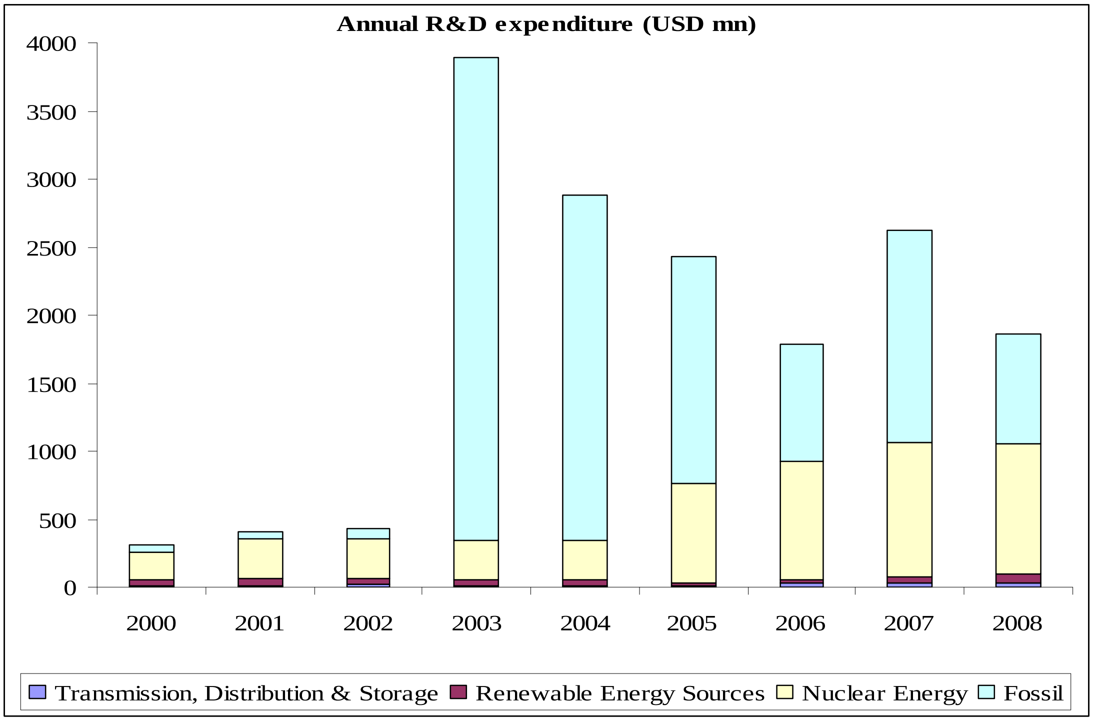
- Ministry of Power (MOP)
- Ministry of Coal (MOC)
- Ministry of Petroleum and Natural Gas (MPNG)
- Ministry of New and Renewable Energy (MNRE)
- Department of Atomic Energy (DAE)

Indigenous energy-related R&D in India has been increasing substantially in the past years. The Planning Commission, the central institution for formulating policies in India, has developed an "Integrated Energy Policy" that spells out the targeted R&D goals and supports research institutions and universities. The Energy ministry has recommended that the Planning Commission include large funding for renewable energy in the 11th National Five Year Plan (2007-12). Proposed activities include increasing the share of hydro, nuclear, and renewable sources in the energy mix; developing more efficient coal technologies; improving energy efficiency in industry and transport; and exploring hydrogen (production, storage, and end-use) technologies.

R&D SPEND

At USD 1.9 billion in 2008, in terms of PPP, R&D expenditure in India in the field of energy currently stands at about 8% of India's overall spending on research and technology. The majority of research expenditure has been on fossil and nuclear energy, but recent years have witnessed increased focus on renewable energy and energy storage, distribution and transmission. The following graphs represent the distribution of total annual R&D expenditure spent in the energy sector in India.

Chart 31: Annual R&D expenditure



The amount spent for nuclear energy research in India has been on the rise in the recent years, and forms the second highest portion of the total expenditure. India's three-stage nuclear plan, envisioned by Homi Bhabha, is designed to counter India's uranium deficit by utilizing the vast reserves of thorium. The first stage of India's nuclear plan is based around pressurized heavy water reactors (PHWRs) and state-of-the-art research facilities. Stage two, which seeks to plug India's energy deficit by 2050, involves using reprocessed plutonium to fuel reactors that breed further uranium-233 and plutonium from thorium and uranium. In stage three, advanced heavy-water reactors will burn uranium-233 while converting India's thorium reserves into further uranium in a sustainable cycle. All three stages are running parallel and each has been demonstrated on a laboratory scale.

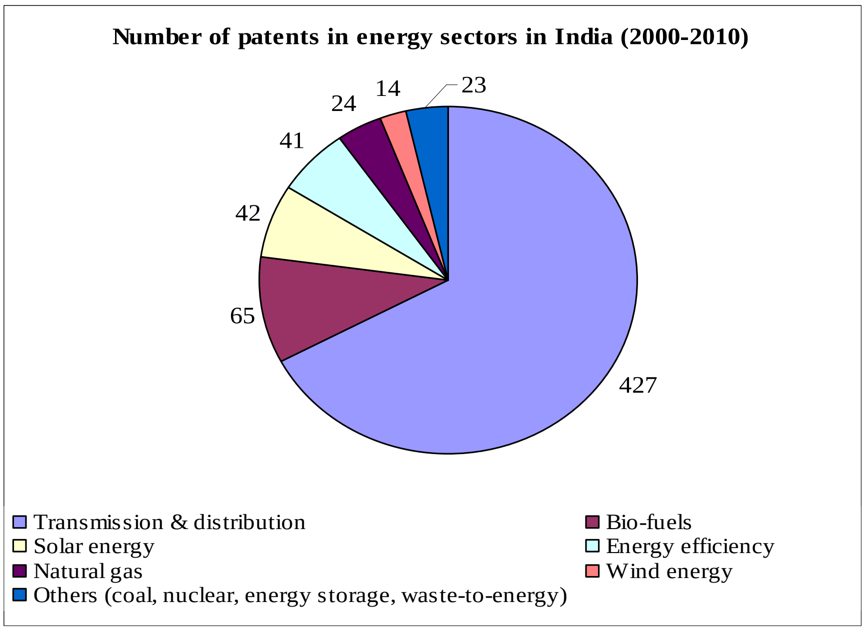
There has also been increased focus on research on renewable energy and energy storage, distribution and transmission in India in recent years. While bio-fuels and solar energy have been the major focus of research in both the public and private sectors, the government has also been making efforts to identify new sources of energy like oil shale and hydrogen. The focus of research in the private sector has predominantly been in transmission and distribution; Larsen & Toubro, Crompton Greaves and Schneider Electric India being the major players in the arena.

Surprisingly, the private investment in the bio-fuel sector declined in the year 2008. On the other hand, the private investments in the solar, wind and small-hydro based projects in India escalated. The Central and State governments, however, continue to fund research projects for generating bio-diesel and ethanol from crops. Overall, the energy R&D landscape in India seems promising as the investments in renewable energy in India have multiplied in the recent years.

INNOVATION AREAS[30]

The last decade has witnessed an increased focus on non-conventional energy sources. There have been more than 600 patents filed in the energy sector in India during the period 2000-2010, of which about 70% have been in the arena of energy transmission and distribution.

Chart 32: Number of patents in energy sector in India, 2000-2010



There have been four major focus areas for innovations in the energy sector.

Electricity transmission & distribution: Riddled with huge transmission and distribution losses, the primary objective of research activities in this sector has been to minimize these losses. The major thrust areas of research are to develop efficient and low-maintenance power grids. Research activities are also aimed at integrated power distribution automation system. Smart grids have been the focus of government as well as private research institutes.

Bio-fuels: Traditional bio-fuel technologies involve the production of bio-diesel and ethanol from food feedstock. However, due to its huge population, increasing demand-supply gap of food and limited

[30]Netscribes Analysis

expansion scope of agricultural land, the Indian government cannot implement this model. Hence, the government has been promoting research on developing alternative technologies for bio-fuel production.

Bio-diesel research efforts in India are focused on developing non-edible oils from plants and animal fats like fish oil. The plants of special interest are Jatropha curcas and Pongamia pinnata. A major area of research also revolves around developing sustainable methods of mass cultivation of these varieties of crops. The end-objective of these efforts is to encourage the use of wastelands and other unproductive land for the cultivation of these relatively hardy crops. The Indian government policy is also driven by the fact that bio-fuel crop cultivation in wastelands would provide additional employment to the vast rural population in India. Another recent area of focus has been on studying algae as a source of bio-diesel. Likewise, research initiatives for ethanol production in India are also directed for identifying and developing alternative sources like algae and molasses. Efforts are also being made to develop methods to convert cellulose to ethanol. These activities aim to achieve ethanol-blended fuels with increasing ethanol content.

Energy efficiency: The energy efficiency R&D in India can be segregated in three major categories:

- Energy efficiency in end-use: This constitutes efficient usage of energy by households, lighting, etc.
- Energy efficiency in transportation: This constitutes fuel-efficient vehicles and transport systems.
- Energy efficiency in power generation: This constitutes efficient usage of fuel sources for mass-scale energy generation, especially thermal power sources.

Research in these areas is encouraged by the government as it is expected to save about 19% of India's energy requirements by 2031-32.

Solar energy: In the field of solar energy research, the major objectives have been to achieve lower capital and maintenance costs associated with solar panels. Although the government subsidizes the cost of solar panels, the operating costs are currently too high for this technology to be economical in the long run. Research activities focus on both solar thermal and photovoltaic areas. For solar photovoltaic applications, the primary focus has been on efficient usage of single crystal silicon. Development of solar energy based equipment also aids in decentralizing the energy generation, thereby limiting transmission and distribution losses. At the same time, these projects help remote areas become self-sufficient.

Although relatively less significant, research activities have also been happening in natural gas, wind energy and clean coal technologies. Research for developing wind energy is expensive, due to which most of the wind turbine generator manufacturers in India have to license technologies. However, given India's huge potential in the area, investment in wind research will help India in the long run. In coal, the emphasis of research has been on developing super-critical technologies for boilers. This technology helps make more efficient use of coal, while reducing the carbon emissions significantly.

INNOVATION ECOSYSTEM IN INDIA

The innovation ecosystem in the energy industry mainly comprises of the following factors:

- **Government regulations:** The Government of India, through MNRE, has introduced a number of fiscal incentives as well as promotional measures in order to hasten the development of alternative energy sources in India. The incentives include tax concessions, loans from IREDA, customs and excise duty relief and liberalized foreign investment procedures. Andhra Pradesh, Madhya Pradesh and Maharashtra have introduced promotional policies through their respective State Electricity Regulatory Commissions (SERCs). Further, the Government has also launched Jawaharlal Nehru National Solar Mission (JNNSM) with the objective to create conditions through rapid scale-up of capacity and technological innovation to drive down costs towards grid parity. The Electricity Act of 2003 provides that co- generation and generation of electricity for renewable sources would be promoted by the SERCs by providing suitable measures for connectivity with grid and sale of electricity. These measures have seen a large amount of investments in the energy industry for both, research and infrastructure, by the private sector in recent years.

- **Supporting institutes**: India has a wide network of government bodies, industry associations, and private R&D institutes which are involved in innovation related activities in the country. The government bodies and industry association provide the base framework for innovation activities. These programs also encourage interaction between academia, industries and research bodies which provides a good innovation environment. The major government institutes involved are CSIR, and Bhabha Atomic Research Center (BARC).

- **Academia:** India has a good network of academic institutes, many of which are focused on research and innovation activities. Among these the prominent ones are Indian Institutes of Technology (IITs), Foundation for Innovation and Technology Transfer (FITT) and University of Punjab Agriculture which are also focusing their research activities on solar energy, bio-fuels and other alternative sources. Apart from these institutes, there are also a number of agricultural universities spread across the country. The government is making efforts to set up institutes and promote R&D activities in the country.

LEADING ORGANIZATIONS INVOLVED IN INNOVATION

The energy industry is dominated by public sector enterprises which constitute more than 82% of the installed capacity. Of India's total R&D budget, 8% goes to various CSIR labs and 9% to agricultural and medical research. With the 11th five year plan, the Indian government has been encouraging research and development activities for alternative sources of energy. The major government bodies funding research activities are MNRE, Department of Science & Technology, Department of Atomic Energy, Ministry of Power and Department of Bio-technology. The major government research institutes are:

- Indian Institute of Petroleum (IIP), Dehradun
- Mechanical Engineering Research & Development Organization (MERADO), Ludhiana
- The Solar Energy Centre (SEC), Gurgaon
- Central Salt & Marine Chemicals Research Institute (CSMCRI), Bhavnagar
- Central Mechanical Engineering Research Institute (CMERI), Durgapur

Most of the aforementioned institutes are a part of the CSIR labs, which speaks volumes about their importance in the energy research landscape in India. Further, the major academic institutes involved in R&D activities are funded by the central and/or state governments.

Energy research in the private sector, has witnessed a huge growth of late, the key companies involved in research activities being Larsen & Toubro, Crompton Greaves, Schneider Electric India, Moser Baer, Suzlon and Vestas. While L&T, Crompton Greaves and Schneider Electric India have already established research centers in India, Vestas has recently setup a research center in Chennai for wind energy research.

Table 17: Key players by patents filed (2000 onwards)

Top five patent filers & no. of patents families filed			
Transmission & Distribution	**Bio-fuels**	**Solar Energy**	**Energy efficiency**
Larsen & Toubro – 113	CSIR – 11	Moser Baer India – 6	CSIR – 11
Bharat Heavy Electricals Ltd – 35	Indian Institutes of Technology – 4	Bharat Heavy Electricals Ltd – 4	Taiwan Oasis Technology – 9
Crompton Greaves – 30	Kirloskar Integrated Technologies – 4	CSIR – 3	Gangotree Eco Technologies – 4

Schneider Electric India – 18	Gangotree Eco Technologies – 4	Seven Stars Worldwide Ltd – 2	Kirloskar Integrated Technologies – 4
CSIR – 12	Punjab Agricultural University – 2	Bina Metal Way – 2	DRDO – 3

DRIVERS[31]

DEPLETION OF CONVENTIONAL RESOURCES

Coal, oil and natural gas, together form the most important energy sources in India. Although India is the world's third largest producer of coal, its reserves are perishable and are not expected to last more than 50 years. Similarly, surging oil and gas demand has made India increasingly dependent on foreign countries. Nuclear energy, too, accounts only for a miniscule portion of India's energy demand.

With the conventional resources becoming increasingly scarce, there is a need to tap into and develop other sources. India stands seventh in the world in solar photovoltaic, and ninth in solar thermal systems, but the initial high cost of equipment has made it unattractive to end-users. Another issue to be addressed, especially for the Indian market, is to develop alternatives of food feedstock for generation of bio-fuels. Focused R&D on alternative energy sources like bio-fuels, solar and wind energy can help reduce their costs make these technologies commercially viable.

INCREASING POWER DEMAND

Spurred by sustained economic growth, rise in income levels and increased availability of goods and services, India's incremental energy demand for the next decade is projected to be among the highest in the world. With a projected commercial energy requirement of 665 million tons of oil equivalent (MTOE) by 2017, India's energy demand is set to grow at a rate of about 8% per annum. The overall energy deficit was 11% in FY 2009-10, while the peak-hour deficit was 12%. A TERI report states that in order to meet the electricity demand, supply has to increase six fold, to about 900 GW by 2031. This would trigger a similar increase in consumption of fossil energy sources. A huge part of the current demand for energy is currently being met through imports of direct energy resources; the import of oil alone is expected to

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[31] Power to the People
Centre for Development Finance at the Institute for Financial Management and Research (CDF-IFMR) and the World Resources Institute(WRI), September 2010

increase to 90-93% by 2030 from the current level of 73%, making India vulnerable to global supply shocks.

Non-conventional energy sources offer viable potential options to address India's energy demand concerns, and have been the focus area for research activities in India. Devising energy efficient systems and slashing transmission and distribution losses also promise to answer to India's energy shortage.

ENVIRONMENTAL CONCERNS

Coal-based power forms the mainstay of India's energy sector. With increasing energy and power demands, both domestic production and import levels are set to multiply. However, using coal in the longer term is neither economical nor environment-friendly as the quality of Indian coal is poor and there a lack of infrastructure to clean it. As the world moves closer to a consensus on climate change, using coal at this growing rate may become untenable. To work around these problems, India will need to develop alternatives to coal. **Foreign collaborations will be the key over here to develop and install clean coal technologies and technologies to improve efficiency of existing power plants.**

Almost half of India's rural households do not have access to grid electricity, and over 85% rely on traditional, polluting fuels such as kerosene, firewood and dung for their cooking and lighting needs. These fuel sources are inefficient, often unreliable, and create health risks as well as contributing to environmental degradation. There is an urgent need for cleaner, safer affordable energy services in this underserved consumer segment.

With improving average standard of living, it has become important for India to engage in research activities to address technology issues as well as formulate strategies to allow for appropriate development of clean technologies.

EFFICIENT RESOURCE UTILIZATION

Not only is there a need for India to enhance its overall energy production capacity, but minimization of transmission and distribution losses of electricity is also a pressing need. With transmission and distribution losses accounting for more than 50% of the energy production, it becomes a critical issue for India. The problem only intensifies if India is to achieve its goal of supplying electricity to remote areas. In the 11th 5-year plan proposed by the Government of India, the power grid is expected to transfer 60% of the power generated in the country as compared to only 45% today.

There also exists a significant scope for the development of decentralized renewable energy generation (DRE) and energy efficient cooking stoves. Community level biomass, small hydro power plants, solar home systems and solar lanterns have the potential to significantly reduce losses in transmission by localizing energy generation.

GOVERNMENT SUPPORT

Government support has played a vital role in boosting the research activities currently taking place in India. Fueled by the government's policies and funds, premier research institutes like CSIR and BARC and academia like IITs and IISc have been leading the way. The Union Budget of India for 2010-2011 increased the grant to MNRE to USD 223.5 million.

In 2009, the government of India launched the Nehru National Solar Mission with a budget of USD 932 million, to develop solar power infrastructure. The government also launched an Accelerated Program on Energy Recovery from Urban Wastes, which aims to develop waste-to-energy technology through MNRE's financial support. The government has also been promoting grassroots innovations through NIF and GIAN.

CHALLENGES[32]

PUBLIC SECTOR R&D SPEND POLICIES

In the developed countries, industries generally spend more than 2% of their turnover on R&D. In India, however, the total expenditure on R&D was only about USD 1,857 million in 2008, which is about 0.2% of the turnover. There is, thus, a strong case for funding by the government either directly or through fiscal incentives. The latter accounts for the bulk of government support in the developed countries. Fiscal incentives, however, have not resulted in significant expenditure on R&D by Indian industry.

R&D in the energy sector in India is critical to increase energy supply and energy efficiency. For this, the role of the public sector in research related activities is extremely important. Although more funds for alternative fuel and renewable energy research have been allotted in the 11th Five Year Plan, the total R&D expenditure in the energy sector in India is still quite low.

Further, the R&D spend by the Indian government is heavily skewed. Although coal accounts for a major portion of the energy supply in India, the clean and efficient coal technology sector does not get much in terms of R&D spend. Nuclear energy, on the other hand, receives a substantial portion of the overall energy R&D expenditure even though its share in energy production is only a tenth of that of coal. This

[32] India's Energy And Energy-R&D Landscape: A Brief Overview
Belfer Center (Harvard Kennedy School), February 2002

may be due to the fact that India's nuclear energy program has historically been self-sustaining. The changing scenario in the form of nuclear deals between India and the United States of America is likely to reflect on the R&D spend in the upcoming years. In 2004-05, about 90% of the total energy R&D expenditure went to research in nuclear energy.

INVESTMENT BY PRIVATE SECTOR

The rising cost of energy and the growing concern over climate change and global warming has led industries to carry out R&D for new technologies aimed at achieving energy efficient transmission and distribution systems. The privatization of electricity in India has been another important driver for these research activities. The government also has been formulating policies to encourage investments in wind, solar and bio-fuels research. However, there has not been much activity in the private sector in fields other than electricity transmission and distribution. The major exceptions to this general rule are PRAJ, Moser Baer Solar and Vestas.

Private companies still spend a miniscule percentage of their turnover in energy R&D. Within the last ten years the expenditure on R&D has remained nearly constant. This may stem straight from the fact that the government is more than forthcoming in funding research projects for clean and renewable technologies.

INNOVATION SUCCESSES

World's Largest Solar Steam Cooking System

Location: Tirumala, Andhra Pradesh

The world's largest solar steam cooking system has been installed by the Tirumala Tirupathi Devasthanam (TTD) at Tirumala in Andhra Pradesh. The system is modular, and has a capacity to prepare two meals per day for 15,000 people. It employs automatic tracking solar dish concentrators, which convert water into high pressure steam for cooking. The coupling of the system with a diesel-based boiler enables it to work under all climatic conditions.

The system was inaugurated on 11th October 2002, and is expected to save around 1,18,000 litres of diesel per year, valued at USD 52,000. The total cost of the system is about USD 2.5 million, which includes back up boiler, utensils and annual maintenance contract for five years. The system has been installed by M/s Gadhia Solar Energy Systems, Valsad under a demonstration scheme of Ministry of Non-conventional Energy Sources (MNES) with 50% financial support. Balance of the cost has been borne by the TTD trust. A total of 6 such systems have been installed in the country.

BIOTECH

Location: Kerala

BIOTECH, a Kerala based NGO, has developed biogas digesters for managing food waste and other organic waste in more than 20,000 households, 220 institutions and 19 municipal sites, serving about 80,000 people.. The digesters are made of ferro-cement and gas collectors of fibreglass reinforced plastic (FRP), enabling them to be installed quickly and easily.

These systems are capable of handling waste from toilets and kitchens, as well as markets and municipal sites. The larger systems use the generated biogas to run small engines to generate electricity for lighting. The largest system is an integrated energy-from-waste plant that processes nearly three tonnes of organic waste per day, including sorted municipal waste and effluent from an abattoir.

The cost of the plant is about USD 400 and about half the cost is subsidized by grants from both the Ministry of New and Renewable Energy (MNRE) and the local body government. The payback period for the system is less than 3 years.

Ecolibrium

Location: Gandhinagar, Gujarat

Incubated by Center for Innovation, Incubation, and Entrepreneurship (CIIE) at Indian Institute of Management, Ahmadabad (IIMA) and supported by Ministry of New and Renewable Energy (MNRE), under Renewable Energy Search program, Ecolibrium is a smart-grid startup aimed at enabling consumers to manage power consumption in real-time.

Smart grid is essentially an addition of communication and application layers on top of the existing power transmission layer. At present, smart meters in India use GSM and GPRS based data acquisition systems, which increase the cost of each node, as each node requires a SIM card and GSM network access. Ecolibrium has reduced the cost of each node by developing Zigbee, a free radio frequency network-based proprietary device, which tracks real-time energy consumption and can also control the switch on/off function from an online portal or from a cell phone.

The company's pilot project was commissioned in October 2010, and is coming up in Gandhinagar, Gujarat. The company focuses on the following:

- Demand side management and Demand response management
- Automated Meter Reading
- Providing a platform for consumers to participate energy grid awareness
- And efficient grid integration of renewable sources

GLOBAL PARTNERSHIPS

In 2009, there was a private investment of USD 2.3 billion in Indian clean-tech. The market's five-year growth rate was 72%. The venture capital investment, at USD 190 million, was down 13% from the previous year. **The sector that attracts the most investment is energy production from biomass and waste. On the other hand, India's relatively subsidized domestic solar energy, wind and hydropower sectors may provide a challenge for foreign firms who will have to directly compete with local firms**. BHEL and NTPC are collaborating on a 100 MW clean coal thermal plant based on the integrated gasification combined cycle (IGCC) technology at Dadri near Delhi.

An Indo-US Joint Clean Energy Research and Development Center (JCERDC) is proposed to be established under a joint initiative between the Government of India and the US Department of Energy.

The objective of the JCERDC is to provide a platform for collaborative R&D on clean energy, initial priority being solar energy, second generation bio-fuels and energy efficiency of buildings. India has also joined a USD 1 billion FutureGen program initiated by US for development of clean coal technology. The project will be operational by 2012, and aims at building a coal-based electricity and hydrogen production plant. Following a 2008 agreement with the US on civil nuclear co-operation, India can now import fuel and reactors, while building more of its own.

Apart from the US, France, Japan and Germany have been willing to invest in the Indian energy sector research through Indian Renewable Energy Development Agency (IREDA). The major investment areas have been biomass, solar energy and wind energy.

Indian-Foreign University Collaboration: In an effort to develop more efficient and environment-friendly solutions for energy generation, **there have been a lot of collaborations between India and foreign universities, principally in the field of solar energy and bio-fuels**. The major institutions involved have been Duke University (USA), University of Stuttgart (Germany), Technische Universitat Braunschweig (Germany), Delft University (Netherlands), University of Manitoba (Canada) and Loughborough University (UK).

CSIR, in collaboration with Commonwealth Scientific and Industrial Research Organization (CSIRO) - Australia and Chinese Academy of Sciences (CAS), has been crucial in promoting related research efforts. TERI, with its Energy-Environment Technology Development (EETD) Division, has also been fostering a partnership with the Technical University of Denmark to develop technologies for decentralized power generation applications in India. EETD, together with CSIRO Australia, has also been developing solar-biomass hybrid systems for combined, decentralized cold storage, and power generation application in rural areas.

Although, a number of universities in India have been emphasizing on research programs on bio-fuels and solar energy, none have witnessed any international collaboration, the exceptions being IITs and IISc.

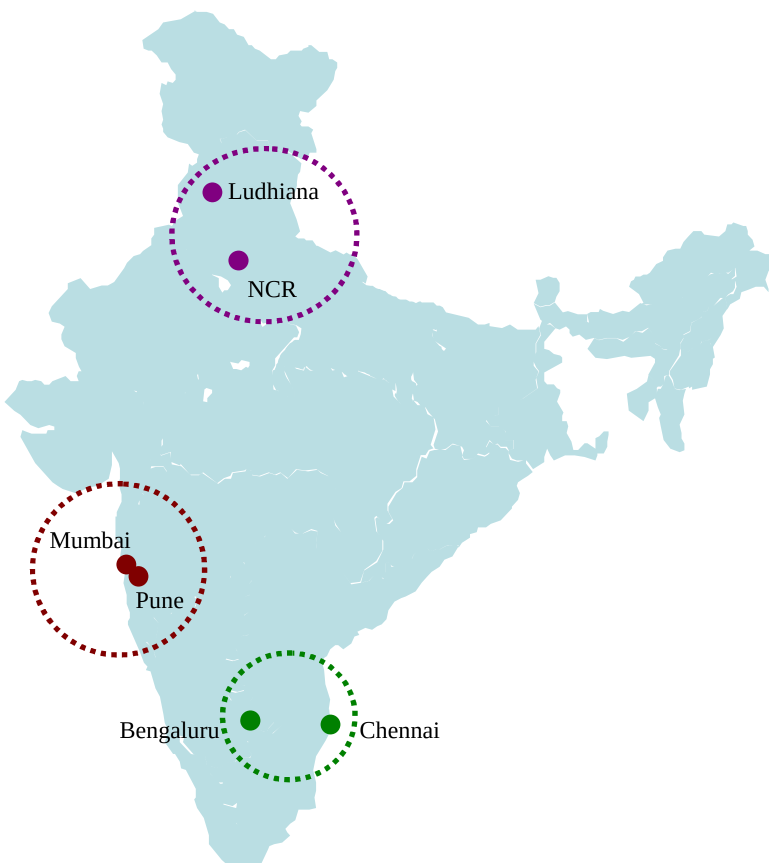
Indian-Foreign Company Collaboration: The field of bio-fuels, especially the development of Jatropha to produce bio-diesel, has witnessed a lot of interest in India. The major companies involved in collaborating on R&D efforts for bio-fuels have been UOP (US), Daimler Chrysler (Germany), General Motors (US) and British Petroleum (UK). Other major companies involved in collaborative R&D efforts have been Applied Materials Inc (US) for solar energy, IBM (US) for efficient power grids and Alcoa (US) for energy efficiency. Again, the major research institutes involved in international collaborations appear to be CSIR, TERI and IITs.

Foreign collaborations in India have predominantly been in the areas of solar energy and bio-fuel related research activities. **Foreign companies not only bring in monetary support, but also their technical expertise in specific areas. The objective of these collaborations varies from testing and adapting existing technologies to Indian conditions to developing better and more efficient methods for energy generation. As India continues to build its power generation capacity, foreign collaborations will continue to play an important role in research and manufacturing activities.**

MAJOR INNOVATION HUBS

India, as a whole, possesses a relatively high abundance of solar radiation, moderate wind speeds, hydro and biomass energy resources. Coupled with the presence of academia and government support, the innovation centers in India are evenly spread throughout the country. However, these can be divided into three main clusters: northern, western and southern cluster.

Figure 28: Innovation clusters



Northern Cluster

Ludhiana	Punjab Agricultural University, Mechanical Engineering Research & Development Organization (MERADO)
NCR (New Delhi, Gurgaon, Noida, Faridabad)	Indian Institute of Technology Bombay Delhi, Moser Baer Solar, Solar Energy Centre (SEC), The Energy & Resources Institute (TERI), Indian Oil Corporation Ltd (IOCL) R&D Center
Western Cluster	
Mumbai	Bhabha Atomic Research Centre (BARC), Tata Institute of Fundamental Research (TIFR), Indian Institute of Technology Bombay, Bombay Textile Research Association (BTRA), The Energy and Resources Institute (TERI), Crompton Greaves
Pune	PRAJ-Matrix - The Innovation Center, Kirloskar Integrated Technologies, Tata Research Development and Design Centre (TRDDC), Suzlon
Southern Cluster	
Bengaluru	Siemens Corporate Research and Technologies (CT), Indian Institute of Science (IISc), The Energy and Resources Institute (TERI), John F Welch Technology Center, Schneider Electric India
Chennai	Larsen & Toubro Engineering, Design & Research Centre (L&T EDRC), Centre for Wind Energy Technology (C-WET), Vestas Technology R&D Center, Indian Institute of Technology Madras

NORTHERN CLUSTER

The northern cluster is a major hub for energy related research activities in the country, NCR and Ludhiana being home to some important research centers. The major focus of R&D in the institutes and companies in this cluster is in the fields of solar energy and bio-fuels.

PUNJAB[33]

Punjab is an agricultural state with fertile land, plenty of water resources, livestock, and agricultural residues. This makes it an ideal hub for research activities in the field of Jatropha cultivation, with Ludhiana forming a major R&D center. This is due to the presence of Punjab Agricultural University and Mechanical Engineering Research & Development Organization (MERADO).

- **Academic infrastructure:** The Punjab Agricultural University has been actively researching ways to cultivate and develop crops required for the production of bio-diesel. Funded by the Petroleum Conservation Research Association (PCRA), the Punjab Agricultural University has been working on a project to develop cultural practices for Jatropha. PCRA has also been sponsoring MERADO to design and develop energy efficient oil expellers for Jatropha.
- **Government policies:** The state government of Punjab has been focusing on the thrust areas of power generation from biomass/agro residues and urban/municipal/industrial waste. Moreover, the government has also been promoting research in the field of solar, wind and small hydro energy. The government of Punjab has also set attractive prices for power generated from renewable energy projects within the entire "Northern Regional Power System".
- **Government initiatives:** The government of Punjab has started a "New & Renewable Energy Program" under the Punjab Energy Development Agency (PEDA). The New & Renewable Energy Program is designed specifically to evaluate, develop and encourage the commercialization of renewable energy technologies and other novel energy sources. One of the principal aims of the program is to assist industry to identify and evaluate business opportunities in the national and international markets. The program is a collaborative exercise, involving government, industry and the energy supply sector. The state government and has laid down a number of targets in the new and renewable energy sector, which include:
  - Generation capacity of 1000 MW by the year 2020 bringing the share of renewable energy resources to the level of 10% of conventional power
  - To motivate all sectors of the economy to ensure conservation of energy to the extent of 20% by the year 2020

NATIONAL CAPITAL REGION (NCR)

[33] Power Generation Policy 2010
Government of Punjab, Department Of Power

NCR forms a major research hub owing to the presence of academia, research institutes and companies. The most important of these are Indian Institute of Technology Delhi The major share of research activities in the NCR is on solar energy.

- **Academic infrastructure:** Indian Institute of Technology Delhi leads the way with research activities going on primarily in the field of solar energy. In collaboration with SEC, IIT Delhi has been working on designing cost efficient solar thermal cookers and solar hybrid absorption refrigeration plants. Collaborating with Duke University, IIT Delhi has also been researching methods of developing clean and efficient hybrid solar biomass cook stoves and developing petrol-alcohol-water micro emulsion fuel as substitute for petrol & ethanol-blended petrol.

- **Government initiatives:** The National Solar Mission is a major initiative of the Government of India and other state governments to promote ecologically sustainable growth while addressing India's energy security challenge. The Solar Energy Center (SEC), set up by the government of India under the MNRE for the development of solar energy technologies and to promote their applications through product development, has been vital in promoting collaborations in solar energy related research. The SEC has been working jointly on a number of projects with National Institutions such as the IITs, the NPL, the Indian Agricultural Research Institute, the Energy & Resources Institute (TERI), etc. It is also collaborating with reputed international institutions such as the National Renewable Energy Laboratories (NREL) of USA in the photovoltaic area; University of Stuttgart, Germany in the area of solar thermal testing; and with Inter-solar Centre of Moscow in the area of solar energy.

WESTERN CLUSTER

The western cluster is a major hub for energy related research activities in the country. This cluster shows the most diversity, with research areas varying from wind energy to energy efficiency to atomic energy. Apart from the presence of premier research institutes, a number of companies have their R&D centers in this cluster as well.

MAHARASTHRA[34]

[34] Seminar on Implementation of Renewable Technologies
Mr. S P Mayabhate, General Manager, Maharashtra Energy Development Agency (MEDA)

The western cluster is concentrated in Mumbai and Pune, both of them in Maharashtra. There are two major reasons for the same:

- **Academic infrastructure:** The state of Maharashtra has a strong academic infrastructure. Mumbai, with institutes like Indian Institute of Technology Bombay, The Energy and Resources Institute (TERI), Tata Institute of Fundamental Research (TIFR) and Bhabha Atomic Research Center (BARC), forms an important innovation hotspot. The presence of companies like Crompton Greaves further adds to its standing as a research hub. Pune, on the other hand, is led by companies such as PRAJ, Kirloskar and Suzlon.

- **Government policies:** State level incentive structures provided by the state policies for the promotion of the renewable based energy attracted number of private investors into the sector. States like Maharashtra have been progressed a lot in attracting renewable energy investors and stimulating innovations in this field.

  Maharashtra has a financial solution that, the fund collected through levying a cess on the consumption of electricity should be deposited in Green Power Development Fund, which should be used for promoting the development of the green or renewable power generation in the state. The key objectives of the fund are to provide support to set up renewable power units and to provide incentives for the operation of the renewable power plants. The state regulator in Maharashtra has also been imposing financial penalty for not adhering to the allocated quota for procurement.

  Government initiatives: The Maharashtra Energy Development Agency (MEDA) was formed under the government of Maharashtra to promote and develop non-conventional energy sources and technologies. To attain this, MEDA has been promoting the use of standalone systems for solar thermal, biomass and wind energy. MEDA has also established a bio-fuel park near Pune. MEDA has also been working in collaboration with International Institute for Energy Conservation to reduce the energy demand.

SOUTHERN CLUSTER[35]

[35] Environmental Innovation in Electricity Sector in India: Role of Electricity Regulators
Gopal K Sarangi, Arabinda Mishra

The southern cluster forms another important hub for research activities. The two major cities that emerge in this cluster are Bengaluru and Chennai belonging to the states of Karnataka and Tamil Nadu respectively. Both these states have renewable energy promoting policies in place which have seen a number of private investors in the area.

The state of Karnataka does not have any fossil fuel reserves, due to which it had to rely on other states to meet its energy demand. Recently, renewable energy, especially solar, has seen a lot of investments by both the government of Karnataka and the private sector. In June 2010, India's biggest solar photovoltaic plant was inaugurated near Bengaluru. The plant has a 3 MW capacity and costs about USD 3.4 million. The government of Karnataka has also been planning to set up similar plants across the state.

Bengaluru is a global hub for research and development in the area of energy transmission & distribution and energy efficiency. The presence of Indian Institute of Science and companies alike make it an important contributor in the field of energy related R&D. Tata BP Solar is planning to invest USD 100 million in a solar photovoltaic plant of 128 MW in Bengaluru. Wipro, too, plans to enter the green energy technology business in the city with custom-designed solar and other renewable energy plants.

Chennai is a major research center for wind energy and electricity transmission & distribution. The presence of Indian Institute of Technology Madras is an important reason for the same. Adding to this factor is the presence of major companies like Vestas R&D Center and Larsen & Toubro Engineering Design and Research Center. The Centre for Wind Energy Technology (C-WET), established by MNRE at Chennai as an autonomous R&D institution of Government of India, has also helped securing Chennai's position in the area of wind energy research. Apart from these research centers, there are a number of companies willing to invest in the wind energy technology, the major ones being NEPC India, Auro Mira Energy Company Pvt Ltd, RRB Energy Ltd and Regen Powertech.

GOVERNMENT REGULATIONS AND INCENTIVES[36]

A comprehensive RE Policy for all-round development of the sector, encompassing all the key aspects, has been formulated by MNES. The broad objectives envisaged in the draft policy are:

- Meeting the minimum energy needs through RE;
- Providing decentralised energy supply in agriculture, industry, commercial and household sectors in rural and urban areas, and

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[36] Renewable Energy Policy - India
National Resources Institute

- Providing grid quality power.

Policy for All-round Development of Renewable Energy: Policy measures aim at overall development and promotion of renewable energy technologies (RETs) and applications. Policy initiatives encourage private as well as FDI including provision of fiscal and financial incentives for a wide range of RE programs. Further, the procedures have been simplified, and provide excellent opportunities for increased investment in technology up-gradation, induction of new technologies, market-development and export promotion.

Foreign Investment Policy:

- Foreign investors can enter into a joint venture with an Indian partner for financial and/or technical collaboration and for setting up of RE-based power generation projects
- Proposals for up to 100 per cent foreign equity participation in a joint venture qualify for automatic approval.
- 100% foreign investment as equity is permissible with the approval of the Foreign Investment Promotion Board (FIPB).
- Foreign investors can also set up a liaison office in India
- The Government of India also encourages foreign investors to set up RE-based power generation projects on Build, Own and Operate (BOO) basis. Various Chambers of Commerce and industry associations in India provide guidance to the investors in finding appropriate partners
- The Government of India encourages foreign investors to set up power projects on BOO basis. Investors are required to enter into a power purchase agreement with the concerned state government
- No prior approval of the government is required to set up an industrial undertaking with Foreign Direct Investment (FDI) by Non-Resident Indians (NRIs) or Overseas Corporate Bodies (OCBS)
- The Reserve Bank of India (RBI) has permitted Indian companies to accept investment under the 'automatic route' without obtaining prior approval from RBI. Investors are required to notify the regional office of RBI, of receipt of inward remittances within 30 days of such receipt and file required documentation within 30 days of issue of shares to foreign investors

Industrial Policy

- MNES is promoting medium, small, mini and micro enterprises for manufacturing and servicing of various types of RE systems and devices.

- Industrial clearances are not required for setting-up of an RE industry
- No clearance is required from Central Electricity Authority (CEA) for power generation projects up to INR 1 billion
- A five-year tax holiday is allowed for RE power generation projects
- Soft loans are available through IREDA for RE equipment manufacturing
- Facilities for promotion of Export Oriented Units (EOUS) are available for the RE industry
- Financial support is available to RE industries for R&D projects in association with technical institutions
- Import of power projects are allowed
- Private sector companies can set up enterprises to operate as licensee or generating companies
- Customs duty concession is available for RE spares and equipment, including those for machinery required for renovation and modernization of power plants. Excise duty on a number of capital goods and instruments in the RE sector has been reduced or exempted

Joint Ventures

- Joint ventures are the commonly used mode by foreign investors as it provides maximum visibility and presence in the country
- A joint venture is generally a financial as well as technical collaboration. Various Chambers of Commerce or the public accountants in India could guide the investor in finding an appropriate partner
- A foreign investor can enter into a joint venture not only for manufacturing RE products and systems, but also in setting up RE-based power generation projects
- A foreign investor can enter into a joint venture with an Indian partner who understands the local environment and can exploit the business opportunities. A feasibility study of the project should be done before entering into such a venture
- Joint ventures could be in the following forms:
    - Takeovers or strategic alliances with existing Indian companies: usually joint ventures are in the form of takeovers or strategic alliances with the existing reputed companies with a niche market

  - A Greenfield project is the one that is set up with new manufacturing facilities and new plant and machinery. For this purpose, an Indian joint venture company could be formed with up to 100 per cent equity being held by the foreign investor
  - Whether it is a Greenfield project, takeover or a strategic alliance, an Indian company is required to be formed for this purpose
- A foreign investor can set up a liaison office as an intermediate step before entering into a joint venture

Policies by State Governments

- A number of states have announced policy packages including banking, third party sale and buy-back, which have been outlined in the respective technology or program areas in this publication
- Some states are providing concessions or exemption in state sales tax. These rates vary widely from state to state and between different technologies.
- Fourteen states have so far announced policies for the purchase and support of electrical energy generated from various RE sources

OUTLOOK

The growth trajectory of the Indian economy is highly dependant on the infrastructure with power being a very critical component. With the demand for power rising rapidly and the current scenario of acute power shortages, there is high focus on improving self reliance. Further, the focus on global warming also requires the replacement of old coal power plants with newer efficient ones. This in turn necessitates the development of efficient and clean power generation technologies both in the renewable and non-renewable power sector.

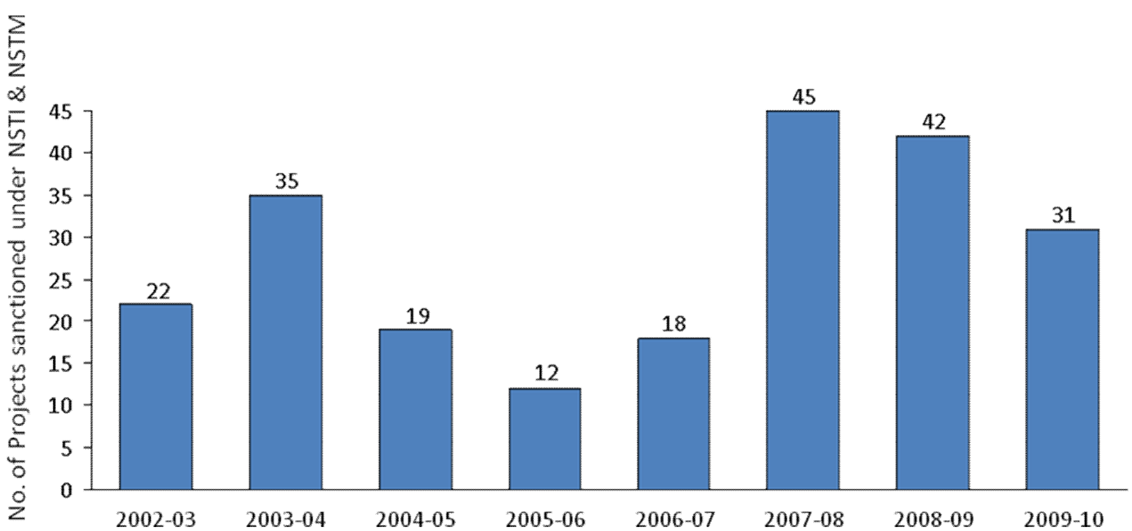
Currently, most of the energy R&D effort in India could be characterized as incremental innovation. The focal areas of research related activities have been to improve existing manufacturing methods and to adapt acquired technologies to suit the conditions. However, this scenario has been improving of late with new research initiatives by the government in the thrust areas of alternative feedstock for bio-fuels and efficient polysilicon crystals for solar energy. The government is also making a lot of efforts to promote research activities in universities and other institutes. Along with the government bodies, the private sector is also ramping up its investment in the power sector. A number of companies are now undertaking research projects to develop technologies for power.

As India aims to bridge the huge gap between power demand and supply, most of these projects will be undertaken with foreign collaborations. Currently also, most of the companies and research bodies are working with foreign counterparts to access and develop new technologies. These projects would work on mutual sharing of skills and technologies. Along with expertise, the Indian companies would also look at foreign bodies to bring in funding to the projects. Improving efficiency of the existing plants and development of new projects in renewable and alternate energy sources (especially solar and biofuel) will be the key focus.

10. NANOTECHNOLOGY

Mankind has seen number of revolutions in the past particularly in the field of science and technology in areas such as Agriculture, Industry, Medicine and Information Technology. Currently, we are on the verge of another such development, Nanotechnology. Its introduction has opened the doors for enormous opportunities as this technology deals with matter at the atomic and molecular level. In India, Nanotechnology R&D is at a nascent stage with concerted initiatives from different government agencies such as DST, DBT, and DIT etc. However, with its gradual development and expansion in scope, private industry participants and investors have started taking keen interest. In order to propagate nanotechnology, a common platform for these agencies along with academia is necessary for commercialization. Like all sunrise industry, funding of the nanotechnology research a partially answered question and more so in India. **According to an expert at the DST, "The Nanomission, promoted by the government looks after the R&D in this field and its growth expected to be high with foreign collaborations on a project to project basis".**

Chart 33: Number of sanctioned projects by DST, year wise



Source: http:/nanomission.gov.in

In India, though Nanotechnology is still in its infancy, the progress made has been appreciable fields such as medicine, bioscience, environment, electronics, cosmetics, materials and security etc.

Table 18: Distribution of Nanotechnology related R&D projects (2002-2009)

Sector	DST/SERC	DIT	DBT	CSIR	DRDO	ICMR	DAE	MNRE
Agriculture	✓		✓					
Chemical	✓			✓			✓	✓
Health	✓		✓	✓	✓	✓		
Electronics	✓	✓						
Energy	✓							
Environmental	✓		✓					
Textiles	✓							
Material Sciences	✓	✓	✓	✓	✓	✓	✓	✓

MAJOR AREAS OF R&D

Nanotechnology has created a platform for a series of innovations across different application areas pertaining to various sectors. The scale of R&D has gained a momentum in the recent years with involvement of academia, industry, investor community as well as different state governments. However, as per a Senior Research Scientist from Department of Biotechnology**, "The collaborations with foreign universities are a priority for advancement of nanotechnology. Funding and other related modalities is an issue but are taken care by the Centre of Excellences. Till date not many collaboration have been made due to reasons such as regulations and decisions by the Centre of Excellences. However, it is imperative that knowledge exchanges with international universities and agencies for different subjects will help development of nanotechnology for different streams"**.

The major areas of activities of nanotechnology R&D in different sectors are mentioned below:

Table 19: Major areas of Nanotechnology R&D

Sectors	Area of focus
Agriculture &	- Detecting contamination in raw agriculture products

Fertilizers	- Development of nano tubes devices to diagnose diseases in agriculture crops - Photo-catalysis applications using nano particles - To detect carcinogenic pathogens and bio sensors for improved and contamination free agriculture products - Use of nano partials capped with bio compatible Chitosan - Developing nano scale particles for use of less fertilizer - Development of nano based fertilizers and nano engineering - Nano sized membrane made from organic wastes for conserving of water in crop production
Chemicals	- Bioactive nanoparticles - Chemical processing for example sol-gel, combustion synthesis - Chemical vapour synthesis with electrical pyretic deposition - Computational nanotechnology - Development of a low pressure plasma system to generate and coat nanoparticles - Development of Nanophosphors - Development of a low pressure plasma system to generate and coat nanoparticles - Electron and Photon energy spectra of nanostructured materials linear and non-linear optical properties of nanostructured materials - Equal Channel Angular Pressing of coarse grained bulk materials for the synthesis of bulk - Nanocrystalline alloys - Formation of nano particles in surfactant aggregates - Formation of superstructural phases and self-assembled nano structures by heteroepitaxial growth - Fullerene/metal doped fullerene based solar cell - Hydrogen storage inside carbon nano-tubes/coiled structures - Hydrophobic coating using nano particles - Hydrothermal/sol gel route silver iodide based crystalline glasses for various engineering properties - Micro magnetic simulations in magnetic nano systems - Myelin structures as reactors to produce nanoparticles - Nano-cellular toxicity, Nano-genotoxicity, Nanoprobes, Nanomaterial safety and toxicity - Polymer layered silicate nano composites - Synthesis and characterization of carbon, metals and polymers based nanostructures, Modification of electrodes with nanomaterials and nanostructuring of electrode nanostructures - Synthesis and characterization and application of tagline metal oxide leg., ZnO MgO, V2O5 etc. - Synthesis of Carbon Nanotubes (CNTs) using CVD and DC Arc Discharge, Boron Nitride Nanotubes (BNNTs), SiC nanomaterials, etc

	- Water soluble carbon nanotube, drug delivery, reverse osmosis, global warming - Synthesis of Nanometric inorganic powders, Nano fluid, Nanometric Electrolyte for oxide fuel cells, Nano materials for catalysts, Single electron & dots
Healthcare (including water purification system)	- Bioactive nanoparticles - Development of a mesoporous tin oxide by template technique for advanced gas sensors and devices - Development of nano crystalline diamond and silicon thin films by microwave plasma enhanced chemical vapour deposition technique - Effect of silver nano particles on biological systems - Hydrophobic coating using nano particles - Inorganic nano particles (titanic alumina, silica mixed oxides) organic-inorganic hybrids, composites, functional nano coatings, ultra and nano ceramic membranes - Nano-cellular toxicity, Nano-genotoxicity, Nanoprobes, Nanomaterial safety and toxicity - Nano coatings by sol-gel route - Nano technology for biosensors in Healthcare and Environmental applications - Nanotubes Environmental remediation, Nano chemistry, Nano biology, Optical limiting - Reverse Osmosis
Pharmaceuticals	- Computational nanotechnology - Formation of nano particles in surfactant aggregates - Hydrophobic coating using nano particles - Micro magnetic simulations in magnetic nanosystems - Myelin structures as reactors to produce nanoparticles - Nano-cellular toxicity, Nano-genotoxicity, Nanoprobes, Nanomaterial safety and toxicity - Nanotechnology for biosensors in Health care and Environmental applications - Polymer layered silicate nano composites
Drug Delivery	- Bioactive nanoparticles - Computational nanotechnology - Drug delivery & reverse osmosis - Formation of nano particles in surfactant aggregates - Hydrophobic coating using nano particles - Myelin structures as reactors to produce nano particles - Nanotechnology for biosensors in Health care and Environmental applications
Electronics	- Bulk Nano Applications, optical coatings, superhydrophobic surfaces, smart adhesives and composites; Nanofluidics, MEMS, sensors polymer and organic opto-electronics; Nanoparticle embedded dielectrics & conductors; Printable Electronics Nanofabrication - Characterization of nano particles in the exhaust of diesel engines - CNTs, BNNTs, SiC nanomaterials

	- Computational nanotechnology - Deposition of Nanocomposite - Development of a low pressure plasma system to generate and coat nanoparticles - Development of a mesoporous tin oxide by template technique for advanced gas sensors and devices - Development of nanocrystalline diamond and silicon thin films by microwave plasma enhanced chemical vapour deposition technique - Development of nanophosphors - Electron and phonon energy spectra of nanostructured materials Linear and non linear optical properties of nanostructured materials - Formation of superstructural phases and self-assembled nanostructures by heteroepitaxial growth - Hydrogen leak sensors - Mechano chemical synthesis of Ferro electrics and crystalline glasses. Nano barium bismuth tantalite, lithium tantalite. - Micro magnetic simulations in magnetic nanosystems - Nanoscale physics - Nanotechnology for biosensors in Healthcare and Environmental applications - Plasma route for preparation of Nanomaterials - Silicon based Nanoelectronic devices and fabrication Technology - Synthesis and characterization of Nano-crystalline materials related to solid oxide fuel cell (SAFE) and Lion battery technology development - Synthesis of carbon nanotubes (CNTs) using CVD and DC Arc Discharge, Boron Nitride Nanotubes (BNNTs), SiC nanomaterials, etc - Synthesis of Nano metric inorganic powders, nanofluid, Nano super paramagnets, Nanometric electrolyte for oxide fuel cells, Nano materials for catalysis, Single electron and dots - Thin films by sputtering & Plasma Polymerisation - Zd based skin fraction sensors
Energy (including Solar Cells)	- Carbon nanotubes based super-capacitor - CNTs, BNNTs, SiC Nanomaterials - Coiled carbon networks and their applications in sensor, light weight composites etc. - Computational nanotechnology - Development of nano crystalline diamond and silicon thin films by microwave plasma enhanced chemical vapour deposition technique - Fullerene/metal doped fullerene based solar cell - Hydrogen leak sensors

	- Hydrogen storage inside carbon nano-tubes/coiled structures - Nanocrystalline silicon and silicon quantum dots - Nanomaterials for hydrogen storage and analysis - Nanostructured carbon e.g.nano-diamond and carbon nano tubes - Synthesis and characterization of Nano-crystalline materials related to solid oxide fuel cell (SAFE) and Lion battery technology development - Synthesis of Nano metric inorganic powders, nanofluid, Nano super paramagnets, Nanometric electrolyte for oxide fuel cells, Nano materials for catalysis, Single electron and dots - Water soluble carbon nanotube, global warming - Zd based skin fraction sensors
Textiles	- Chemical processing for example sol-gel, combustion synthesis - Chemical vapour deposition for carbon nanotube - Chemical vapour synthesis with electrical pyretic deposition - Condensation from electrical explosion of wire - Consolidation of powders - Hydrogen storage inside carbon nano-tubes/coiled structures - Mechanical alloying/milling for nanocrystalline materials - Nano coating by sol-gel route - Nano metrology, Micro fluids, two phase flow and heat exchangers - Nanofinishes, Nanocapsules, Nanofibers, Nanocarbon fiber composites, Plasma assisted nanofinishes - Nanomaterials based EM absorber coatings, nanoparticles/Nanotubes based composite fibers and their application in textiles - Polymer Nanocomposites, Nano Coatings and various nanotechnology applications in textiles - Synthesis of nanomaterials
Metallurgy and Materials	- Arc discharge for carbon nano tube - Bioactive nanoparticles - Bulk nanocrystalline lightweight metallic materials employing mechanical alloying followed by HI Ping and extrusion - Chemical processing for example sol-gel, combustion synthesis - Chemical vapour deposition for carbon nanotube - Chemical vapour synthesis with electrical pyretic deposition - CNTs, BNNTs, SiC Nanomaterials - Coiled carbon networks and their applications, light weight composites etc. - Computational nanotechnology

	- Condensation from electrical explosion of wire - Consolidation of powders - Deposition of Nanocomposites - Development of a low pressure plasma system to generate and coat nanoparticles - Development of nano filter materials - Fullerene/ metal doped fullerene - Hydrophobic coating using nano particles - Hydrothermal/sol gel route silver iodide based crystalline glasses for various engineering properties - Inorganic nano particles (titanic alumina, silica mixed oxides) organic-inorganic hybrids, composites, functional nano coatings, ultra and nano ceramic membranes - Ion beam induced nanostructure formation - Ion implantation studies on nanomaterials - Mechano chemical synthesis of ferro electrics and crystalline glasses. Nano barium bismuth tantalite, lithium tantalite - Micro magnetic simulations in magnetic nano systems - Microwave Sintering -Myelin structures as reactors to produce nano particles - Nano coatings by sol-gel route - Nano mechanical systems, Nano manufacturing - Nano structured metals/alloy/composites for structure application - Nanomaterial based EM absorber coatings, nanoparticles/nanotubes based composites fibers and their application in textiles - Nanomaterials for hydrogen storage and analysis - Nanostructured films - Photoconductivity and Photoluminescence of Nano stuctured materials - Plasma route for preparation of Nanomaterials - Polymer based nano composites with 'Metal Oxides', 'MMTCLAY', Acetylene black and carbon Nanotubes - Polymer layered silicate nano composites - Sinterink resactory metals by nano structuring for difference - Spark plasma sintering (SPS) - Spray Pyrolysis - Synthesis and characterization of carbon, metals and polymers based nanostructures, modifications of electrodes with nanomaterials and naostructuring of electrodes nanostructures - Synthesis and characterization of Nano-crystalline materials related to solid oxide fuel cell

	(SAFE) and Lion battery technology development - Synthesis of Carbon Nanotubes (CNTs) using CVD and DC Arc Discharge, Boron Nitride Nanotubes (BNNTs), SiC nanomaterials, etc - Synthesis of Nano metric inorganic powders, nanofluid, Nano super paramagnets, Nanometric electrolyte for oxide fuel cells, Nano materials for catalysis, Single electron and dots - Synthesis of nanomaterials - Thin films by Sputtering & Plasma Polymerization - Vapor condensation
Food Technology	- Development of new polymers Nanocomposites - Nano tech food synthesizer - R&D in anti-counterfeit developing nano technology based anti-counterfeit technology - Sensors and signaling micro biological and biochemical changes - To detect carcinogenic pathogens and biosensors for improved and contamination free food products - Uses of nano particles in food packaging for enhance preservation time (Shelf life), food safety and supply chain tracking
Communication	- Computational nanotechnology - Development of low pressure plasma system to generate and coat nanoparticles - Electron and Photon energy spectra of nanostructured materials linear and non-linear optical properties of nanostructured materials - Micro magnetic simulations in magnetic nano systems
Paints	- Formation of nano particles in surfactant aggregates - Hydrophobic Coating using nano particles - Polymer layered silicate nano composites
Security	- Basic research in Nanomaterials, Chemical sensors, MEMS, Squids, Development of Nanometric hard coating
Bio-Defense	- Nano-biotechnology
Biotechnology	- Bioactive nanoparticles - Bulk nanocrystalline lightweight metallic materials employing mechanical alloying followed by HI Ping and extrusion - CNTs, BNNTs, SiC Nanomaterials - Computational nanotechnology - Deposition of Nanocomposite - Effect of silver nanoparticles on biological system - Formation of nanoparticles in surfactant aggregates

	- Formation of superstructural phases and self-assembled nanostructures by heteroepitaxial growth - Nanotechnology for biosensors in Health care and Environmental applications - Nanotubes Environmental remediation, Nanochemistry, nanobiology, Optical limiting - Polymer based nano composites with 'Metal Oxides', 'MMTCLAY', Acetylene black and carbon Nanotubes. - Polymer layered silicate nano composites - Thin films by Sputttering and Plasma Polymerization - Water soluble carbon nanotube, drug delivery, reverse osmosis, global warming

Source: Teri" Nanotechnology developments in India",2010; National Foundation of Indian Engineers "Status of Nanotechnology"

INVESTMENTS IN NANOSCIENCE AND TECHNOLOGY

DST funded Nanoscience and Technology Initiative (NSTI) which functioned from 2001-06 was the nanotechnology related initiative in regard to funding and implementation. Launched in year 2001, NTSI was initialized with an initial budget of USD 25 million. In the year 2006-2007, the government approved the launch of Nanoscience and Technology Mission with USD 250 million for five years (2007-2012).

Apart from the expenditure spent on R&D, the NSTI allocated budget have been utilized on building Centres of excellence (CoEs) and other related infrastructure. However, significant share of the budget allocated for NSTM have been invested in the development of human resources related to this domain.

On the other hand, DIT has spent around USD 10 million from 2004-2006 and USD 9 million in 2006-2007 on its programs for Microelectronics and Nanotechnology Development respectively.

CSIR also has invested around USD 10 million in the field of Nanotechnology. Similarly, other agencies such as ICMR, DBT, DAE, MNRE and DRDO have expended significant amounts on development of nanotechnology in their respective profiles.

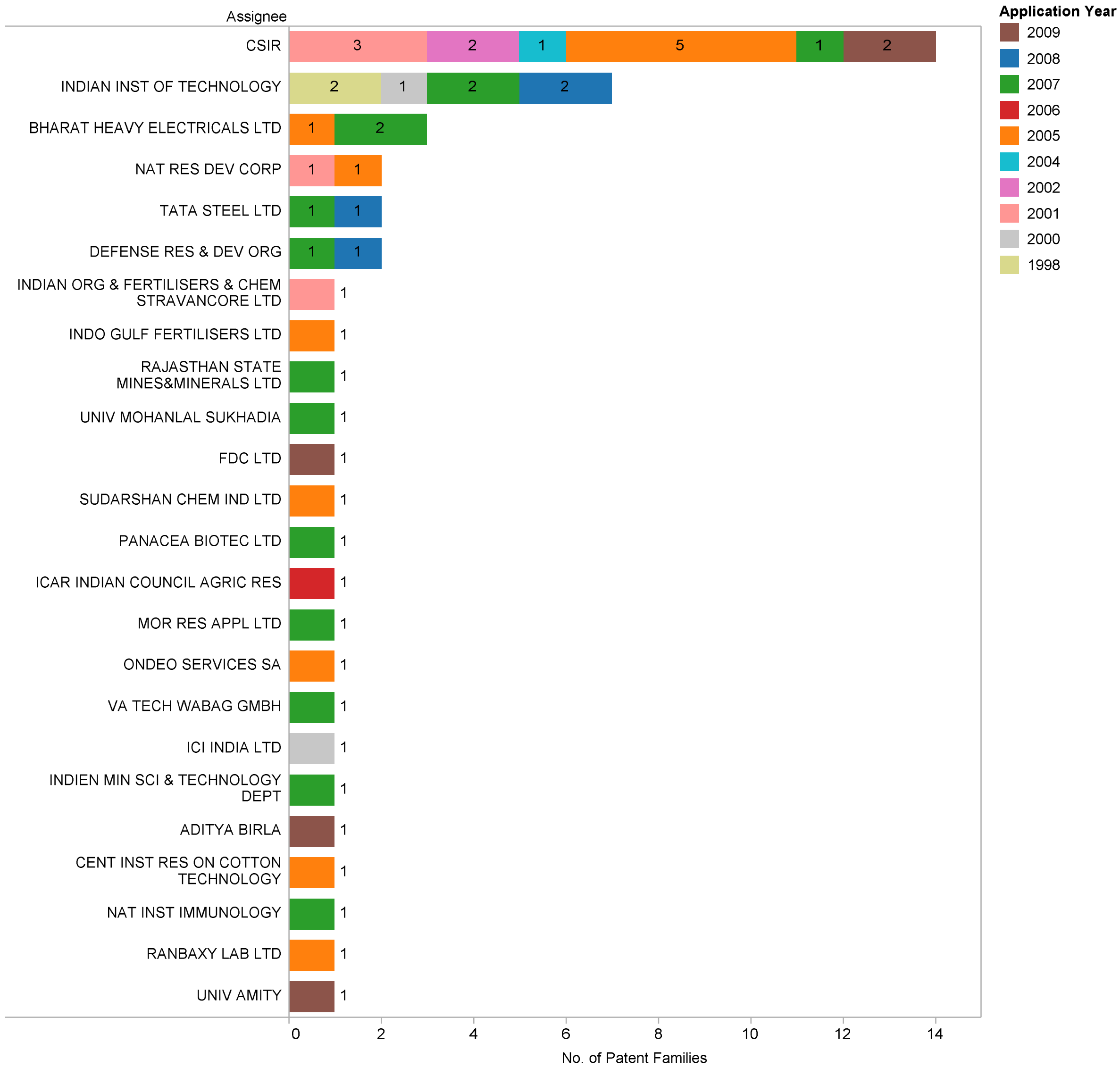
Source: Nanotech Now "Reaching the critical mass in Indian nanotechnology industry", 2007; Government of India "Department of Atomic Energy"; Teri "Nanotechnology Development in India", 2010

NANOTECHNOLOGY PATENTS DISTRIBUTION

Over the past decade, there has been considerable progress made on the front of IP generation from various stake holders from the scientific community involved with Nanotechnology. The charts below depict sector wise patent filings by different entities.

AGRICULTURE

Chart 34: Number of patent families-48



CHEMICALS

Chart 35: Number of patent families-81

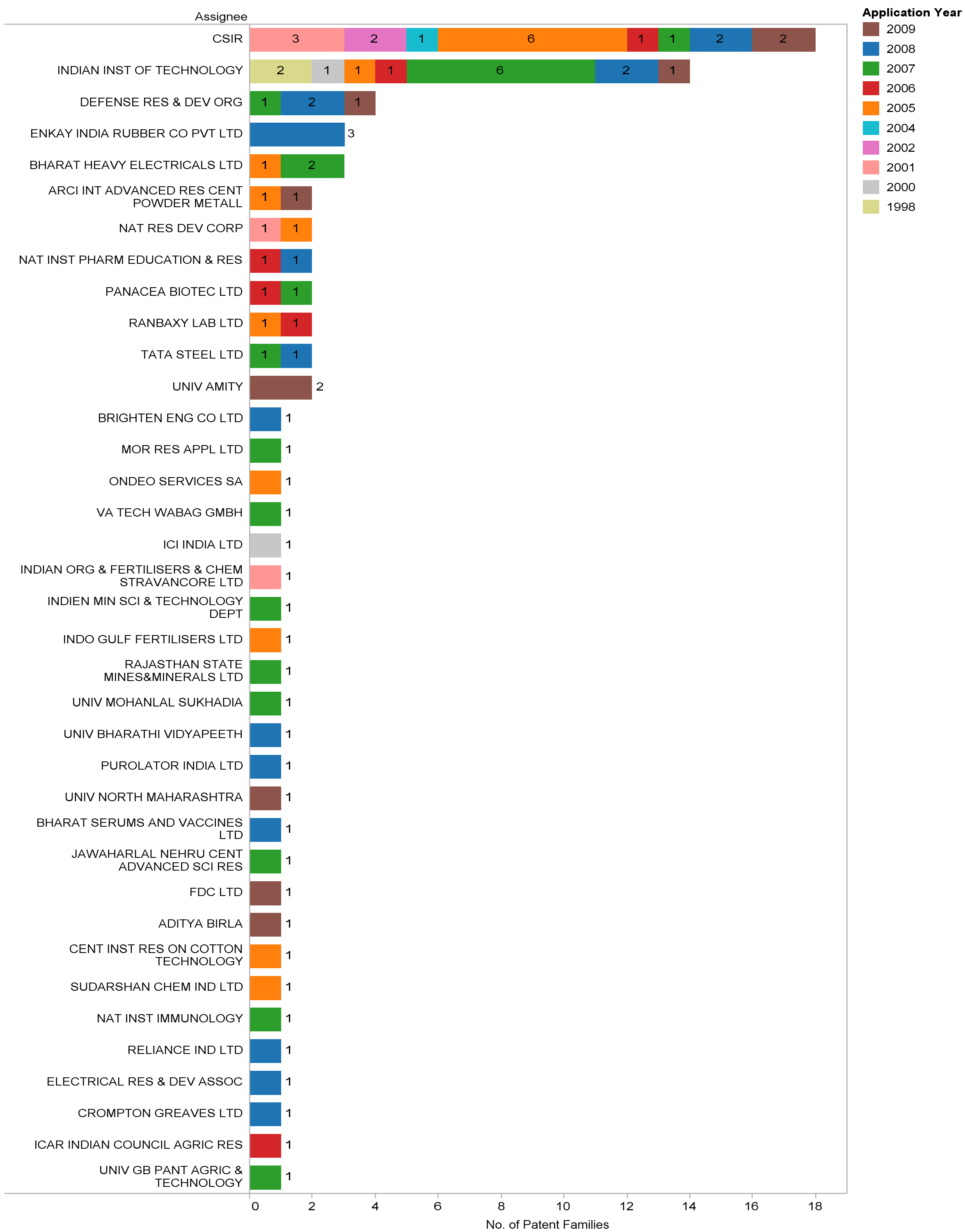

Assignee
CSIR
INDIAN INST OF TECHNOLOGY
DEFENSE RES & DEV ORG
ENKAY INDIA RUBBER CO PVT LTD
BHARAT HEAVY ELECTRICALS LTD
ARCI INT ADVANCED RES CENT POWDER METALL
NAT RES DEV CORP
NAT INST PHARM EDUCATION & RES
PANACEA BIOTEC LTD
RANBAXY LAB LTD
TATA STEEL LTD
UNIV AMITY
BRIGHTEN ENG CO LTD
MOR RES APPL LTD
ONDEO SERVICES SA
VA TECH WABAG GMBH
ICI INDIA LTD
INDIAN ORG & FERTILISERS & CHEM STRAVANCORE LTD
INDIEN MIN SCI & TECHNOLOGY DEPT
INDO GULF FERTILISERS LTD
RAJASTHAN STATE MINES&MINERALS LTD
UNIV MOHANLAL SUKHADIA
UNIV BHARATHI VIDYAPEETH
PUROLATOR INDIA LTD
UNIV NORTH MAHARASHTRA
BHARAT SERUMS AND VACCINES LTD
JAWAHARLAL NEHRU CENT ADVANCED SCI RES
FDC LTD
ADITYA BIRLA
CENT INST RES ON COTTON TECHNOLOGY
SUDARSHAN CHEM IND LTD
NAT INST IMMUNOLOGY
RELIANCE IND LTD
ELECTRICAL RES & DEV ASSOC
CROMPTON GREAVES LTD
ICAR INDIAN COUNCIL AGRIC RES
UNIV GB PANT AGRIC & TECHNOLOGY
0 2 4 6 8 10 12 14 16 18
No. of Patent Families
Application Year
2009
2008
2007
2006
2005
2004
2002
2001
2000
1998

Chart 36: Number of patent families-42

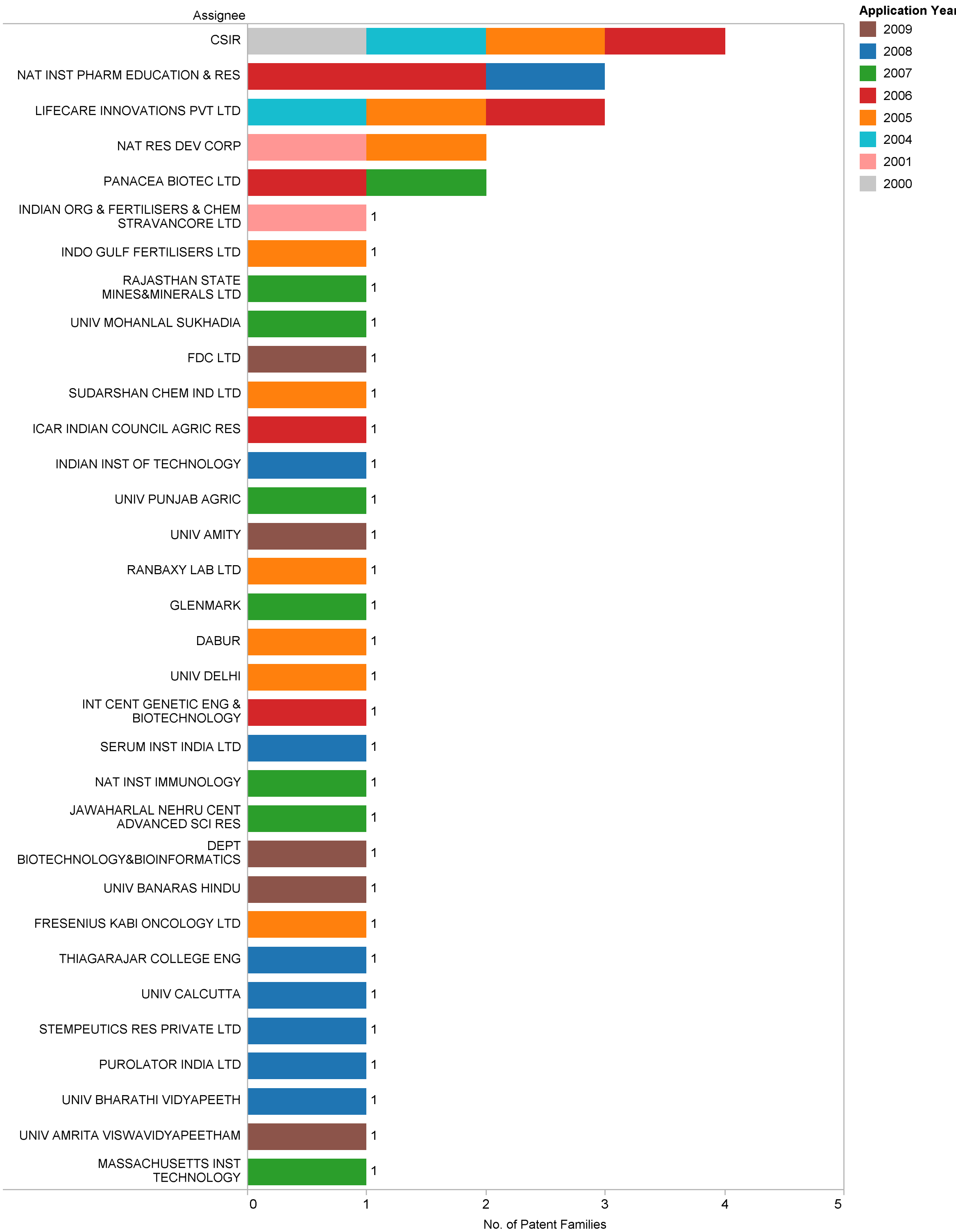
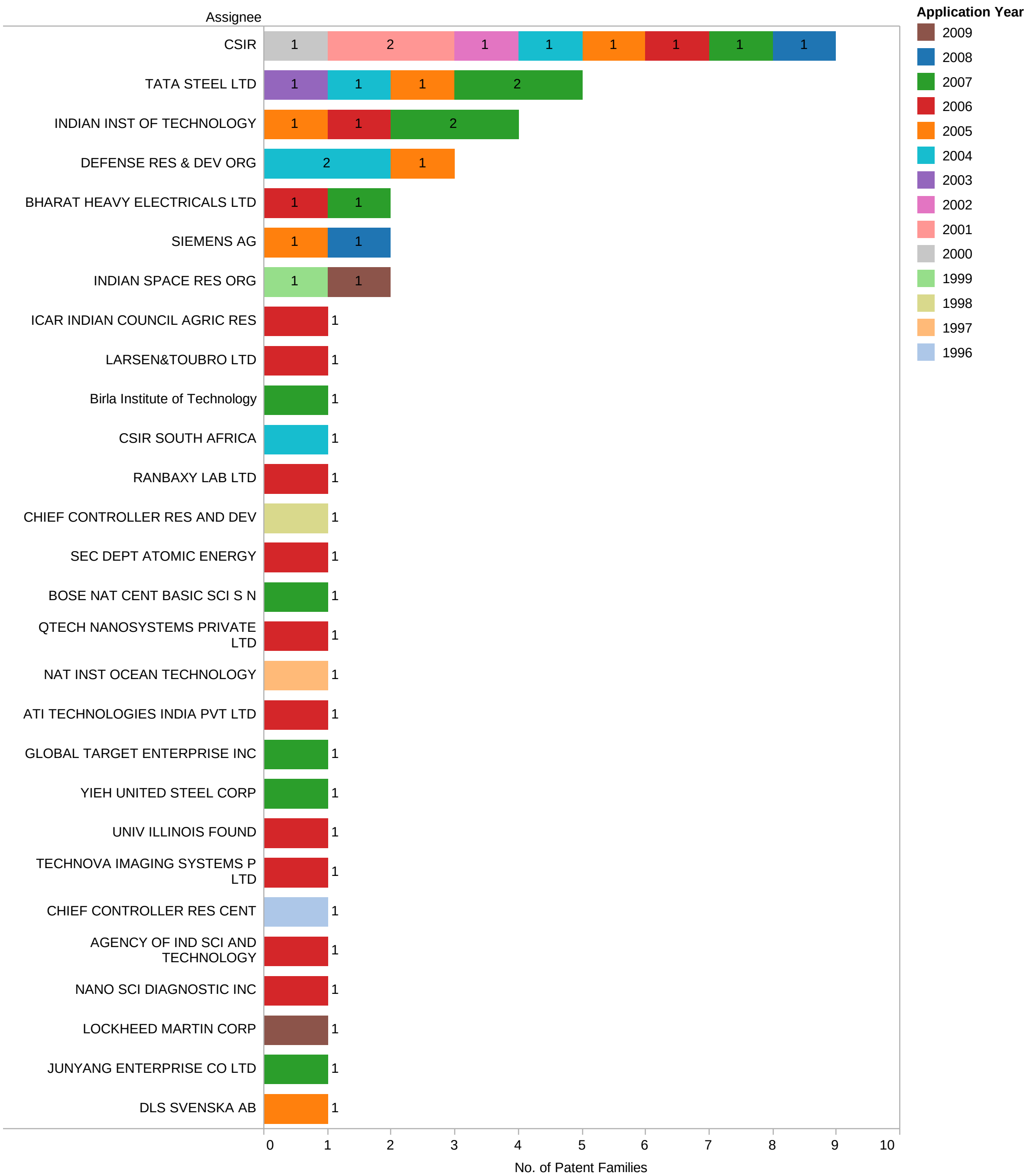
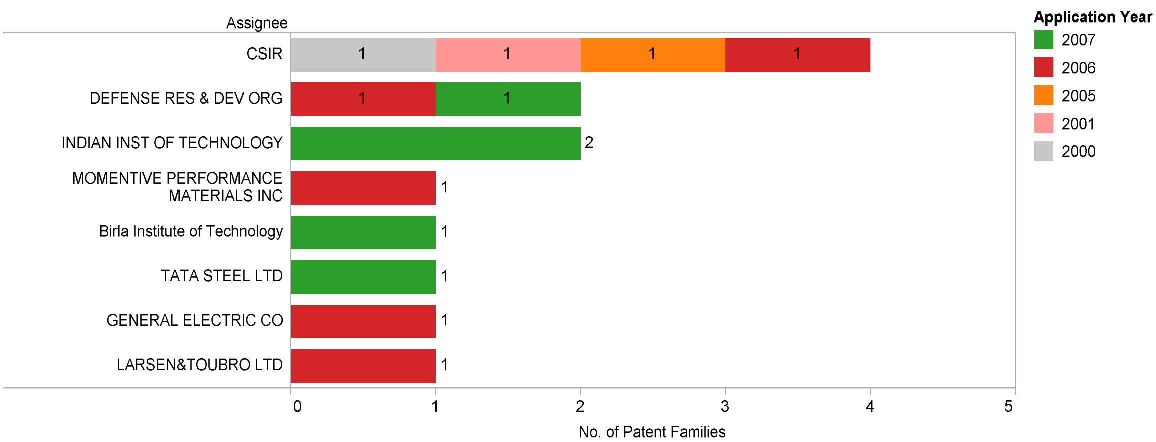


Chart 37: Number of patent families- 48



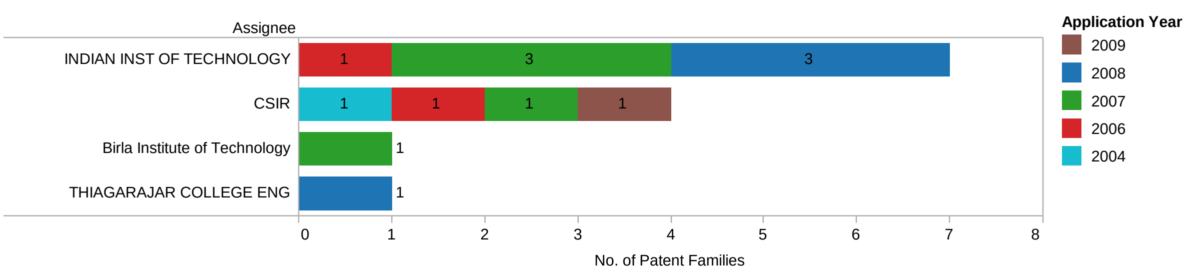
ENERGY

Chart 38: Number of patent families- 13



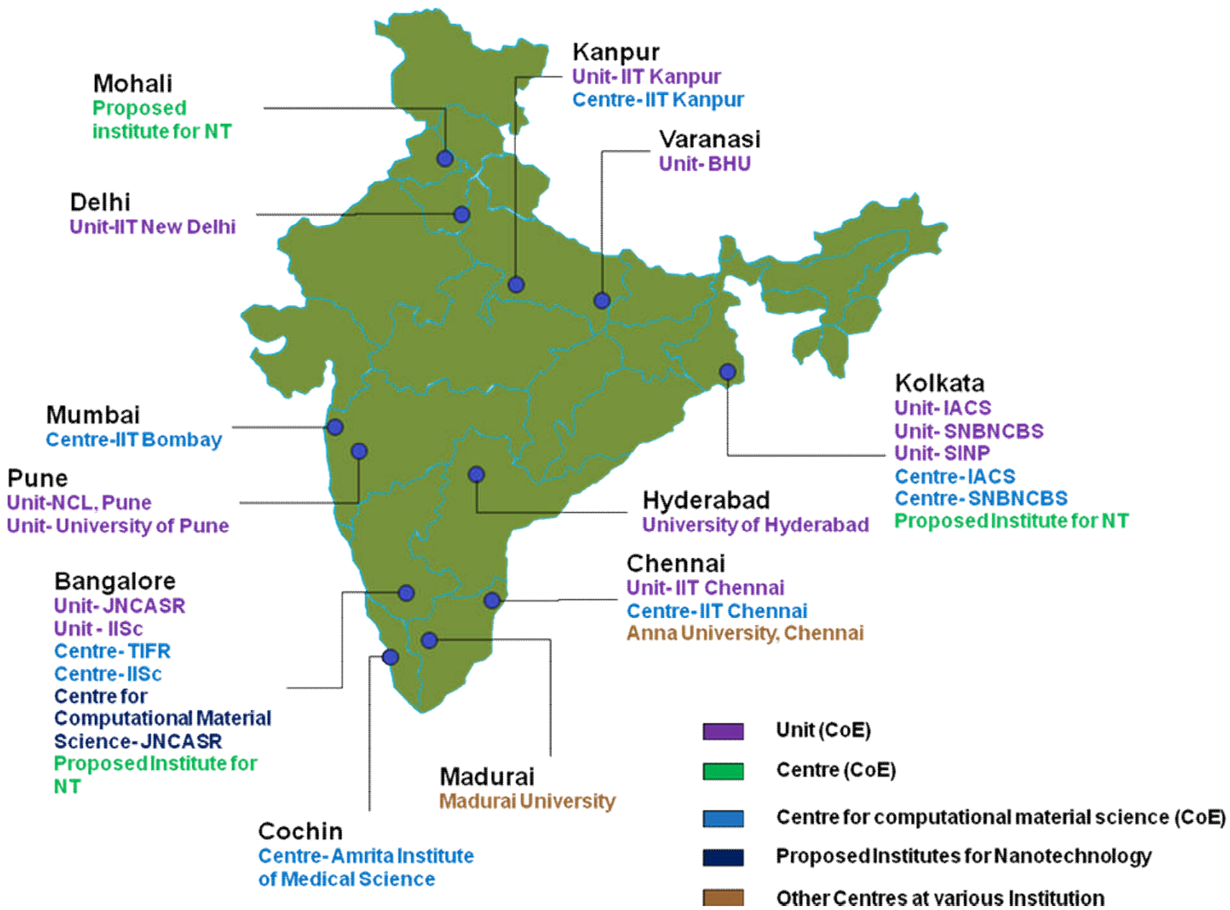
MATERIALS

Chart 39: Number of patent families-13



LOCATION OF NANOTECHNOLOGY RESEARCH CENTRES

Figure 29: Nanotechnology research centers



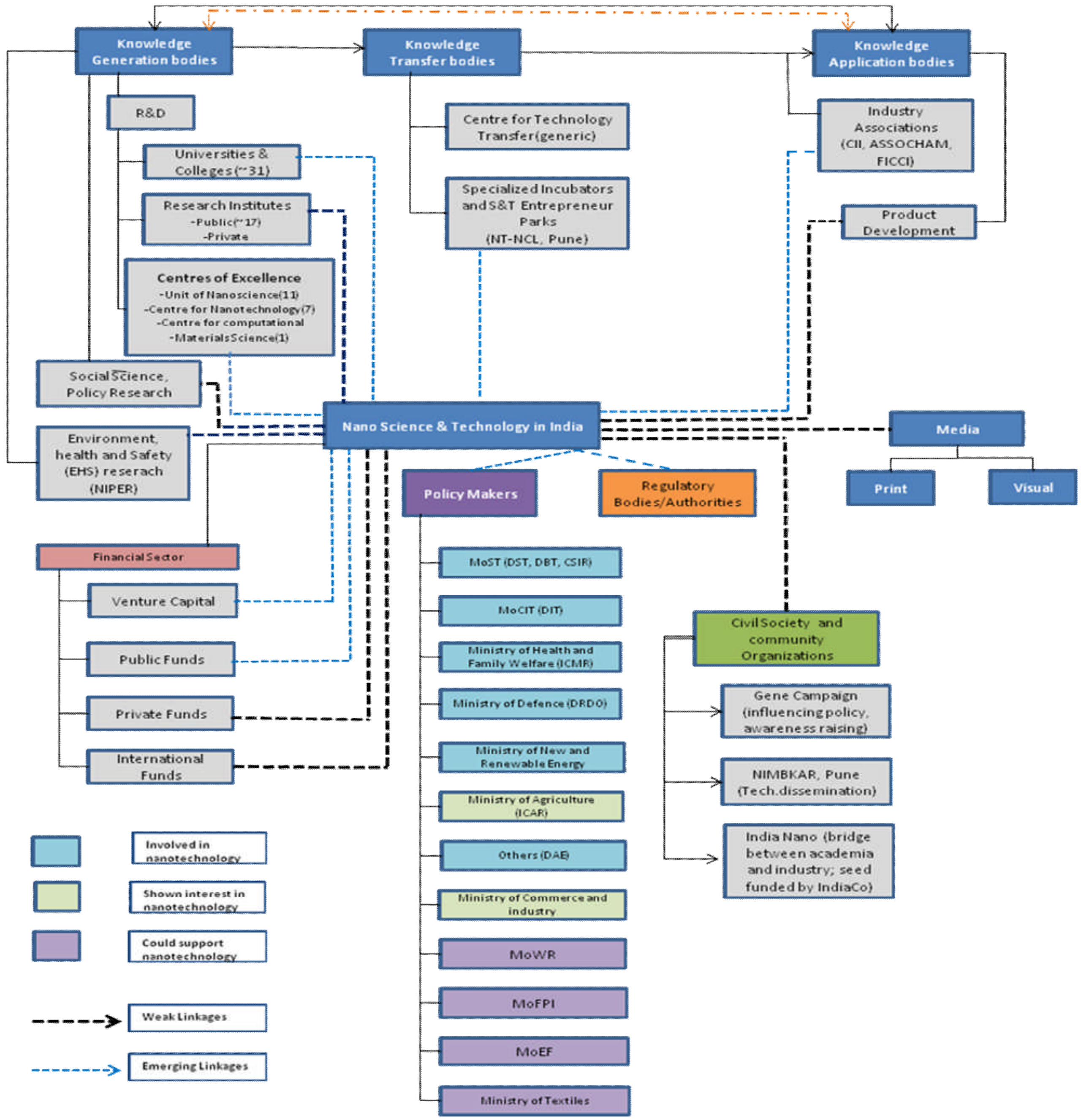
Source: Teri" Nanotechnology developments in India", 2010

With five Center of Excellences (CoE's) and a proposed Institute for Nanotechnology, both Bengaluru and Kolkata are apparently the most promising hubs. Known for IT and Biotechnology, Bengaluru, with its involvement in nanotechnology might trigger multidisciplinary R&D and innovation enabling a convergence among these emerging technologies. Also, with the increasing involvement in the field of nanotechnology, the other southern cities like Chennai, Cochin and Madurai might come up as a larger hub for the development of this technology in the future.

KEY PLAYERS

The emergence of Nanotechnology has attracted a number of players from diverse fields even though it is primarily a state driven initiative. Over the years, participation from the private industries has increased considerably. However, most of the R&D activities are being carried out in publically funded universities and research institutes.

Figure 30: Map of stakeholders



Source: Teri "Nanotechnology developments in India"; 2010

GOVERNMENT AGENCIES

Department of Science and Technology (DST) is the nodal department responsible for organizing, coordinating and promoting development of Nanoscience and Nanotechnology. In year 2001, Nano Science and Technology Initiative (NSTI), an initiative by DST was started with the aim to develop India as one of the major player in this area under its principal program, the Nanoscience and Technology Mission (NSTM). Over the five years NSTI has provided funding worth USD15 million.

Apart from the DST, because of the multidisciplinary nature of Nanotechnology, various other agencies have started active participation. Department of Biotechnology (DBT), involved in the development and support of Biotechnology, has initiated the research in Life science and Nanotechnology intersections. CSIR, with its wide network of 38 laboratories dedicated in scientific and industrial R&D has also initiated its R&D in various fields of Nanotechnology. SERC is an apex body of DST through which it promotes R&D programmes in new areas of science and engineering has also stepped up its efforts.

Further, Indian Council of Medical Research (ICMR) under the Ministry of Family Health & Welfare along with Department of Information technology (DIT), under are promoting Nanotechnology applications in the fields of health and electronics respectively.

In order to unleash the potential of nanotechnology in the field of renewable energy sources such as fuel cells and photovoltaic etc., the Ministry of New and Renewable energy (MNRE) has also joined hands for supporting and developing nanoscience and technology.

Department of Atomic Energy (DAE), under the Government of India and with the wide network of 50 laboratories, DRDO, under the Ministry of Defense are now contributing to the expansion of this technology in India.

In addition to the above mentioned agencies, various others such as Ministry of Commerce and Industry as well as Indian Council of Agricultural Research (ICAR) under the Ministry of Agriculture have started taking interests in this field of nanotechnology. However, their active involvement is still awaited.

Other prospective agencies:

- Ministry of Water Resources
- Ministry of Food Processing Industries
- Ministry of Rural Development

R&D INSTITUTIONS: PUBLIC SECTOR

With Nanotechnology becoming a buzzword in the technology market, various scientific and academic institutions are involved in the field. DST, under NSTI has established 19 Centers of Excellence (CoE) for Nanoscience and Technology across 14 institutions. As mentioned in the figure below, the "11 Units of nanoscience" conduct basic research in various fields of nanoscience/ nanoscale systems and technology. The seven "Centers for nanotechnology" focus on R&D in niche fields such as nanoscale phenomena in biological systems and materials pursued in institutes like Tata Institute of Fundamental Research-TIFR or nanoelectronics in IIT Bombay.

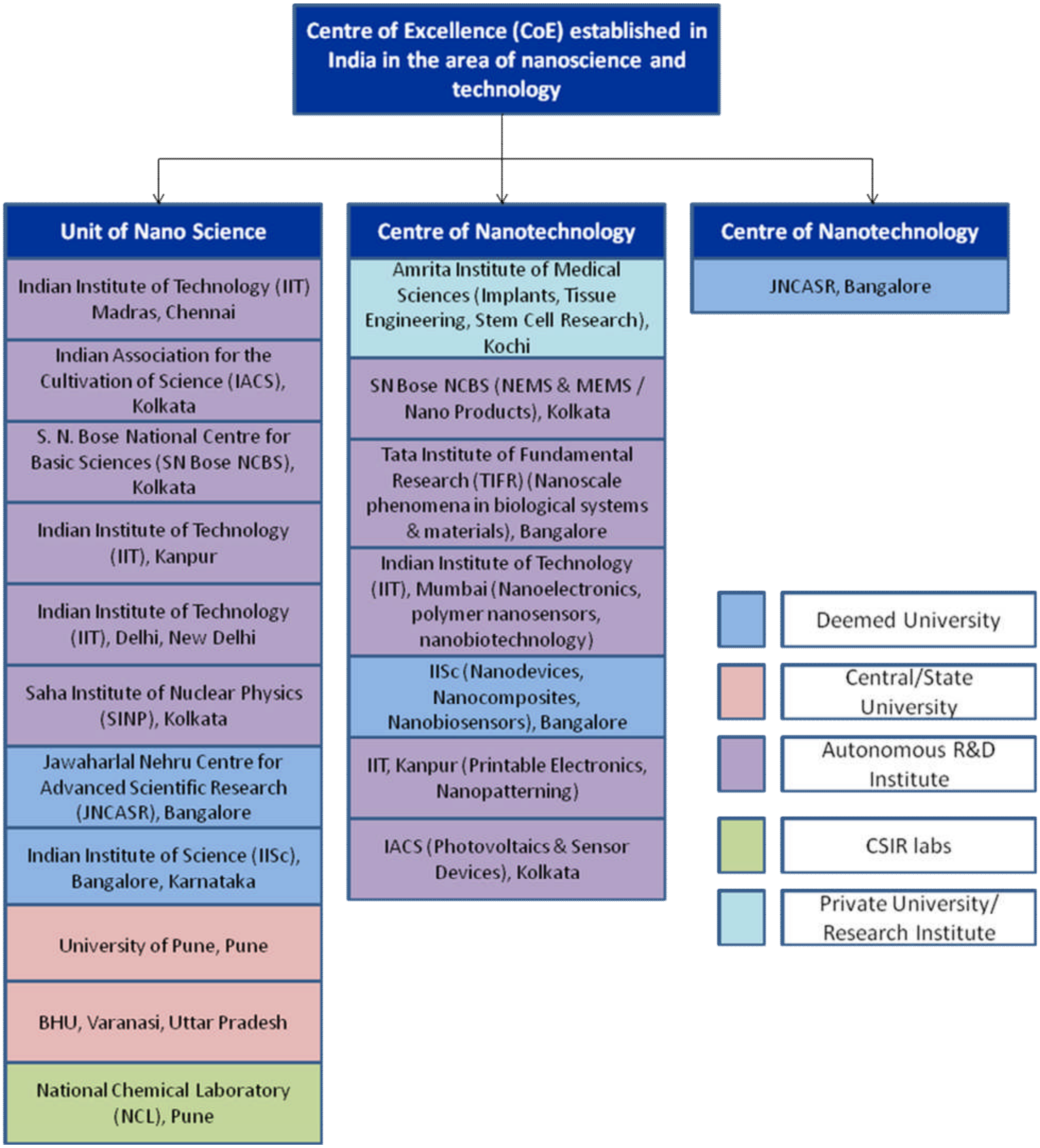
Table 20: Distribution of "Centres of Excellence" across R&D institutes

Centers	Units	Centre	Others
Central/State Universities	2	0	-
Deemed Universities	2	1	1
CSIR Laboratories	1	-	-
Autonomous Institutes	6	5	-
Private University/Research Institutes	-	1	-

Source: Teri" Nanotechnology developments in India";2010

These "Centers" aim to pursue R&D for specific applications in a given time period. In addition, the "Center for Computational Materials Science" has now been established. The CoEs are comprised of universities (central, state, deemed and private), autonomous institutes and CSIR institutes. These CoEs along with those at IIT Chennai, Mumbai and Delhi lead the research projects in nanoscience and nanotechnology.

Figure 31: 'Centre of Excellences' in India



Source: http:/nanomission.gov.in

There are several universities and research centers involved in the development of Nanotechnology based applications.

Table 21: Universities

S.No	Institute Name, Location	Research Area/Center
1	Alagappa University, Karaikudi, Tamil Nadu	1. Synthesis & preparation of nanoparticles secondary cell materials of spinel structure and their compatibility to intercalation process
2	Amity Institute of nanotechnology, Noida, UP	1. Synthesizing of Carbon Nanomaterials 2. Development of Nanophosphors Drug/vaccine Delivery, Water Purifications 3.Development of nano-oxides-Al2O3, TiO2 etc.
3	Amrita Institute of Medical Sciences, Kochi	1.Center for Nanotechnology in stem cell research
4	Anna University, Chennai	1.White Light emitting diode Systems 2.Single molecule and interfacial processes in nanobiology
5	Banaras Hindu University, Varanasi	1.Unit on NanoSciences and Technology
6	Bengaluru University, Bengaluru	Nanostructure materials synthesized by hydrothermal and combustion/microwave routes and their application
7	Barkatullah University, Bhopal	Investigation of electronic and Phonon Properties of nanostructured materials
8	Delhi University, New Delhi	Development and characterization of Cdse, Cds and CdTe nanocrystalline embedded in borosilicate glass Matrix
9	Department of Physics, VisvaBharati, Shantiniketan	Synthesis and Characterization of transition metal doped BaTiO3 nanoparticles
10	Hyderabad University, Hyderabad	Linear and Non Linear optical studies or metal/organic nanoparticles and ultrathin films
11	Indian Institute of Sciences, Bengaluru	
12	Indian Institute of technology, Kanpur	1. Nanomaterials: Nanoparticles, Porous Materials, nanotubes, Thin Films 2. Colloid and Interfacial Science: Self Assembly, Surfactants 3. Nanocomposites: Silica Polymer, Polymer Nanotube, Silica-nanoparticle

13	Indian Institute of Technology, Bombay	1. Centre for Research in Nanotechnology & Science 2. Centre for Excellence in nanoelectronics
14	Indian Institute of Technology, Chennai	Nano Fluidics
15	Indian Institute of Technology, Delhi	Unit on NanoSciences and Technology
16	Indian Institute of Technology, Guwahati	Engineering nanoscale materials and their application in Nanotechnology
17	Indian Institute of Technology, Kharagpur	1. Nano-composites 2. Nano-materials 3. Nano-cermets 4.Nano-polymer composites 5. Nano-Ceramics 6. Nanomechanics
18	Indian Institute of Technology, Roorkee	Synthesis and Photochemistry of composite metal semiconductor nanostructured materials
19	IT-BHU	
20	Jadhavpur University	1. M.Tech courses in Nanosciences and Nanotechnology 2. Collaboration with HP for information transfer 3. Carbon Nanotubes and their field emission properties 4. Nanodiamonds, Diamond like nanocomposites
21	Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Jakkar, Bengaluru	1. Nanomaterials, Crystal growth 2. Veeco India Nanotechnology Laboratory
22	Jawaharlal Nehru University, New Delhi	1. Preparation and Characterization of bio-polymeric nano Particles
23	Kerala University, Thiruvannanthapuram	Study of photoconductivity and photoluminescence of nanostructured materials
24	Madras University, Chennai	1. Nanostructured materials 2. Consultancy in nanoparticles (ultra fine) technology
25	Mahatma Gandhi University, Kottayam	Nanomaterials: Synthesis characterization and Applications

26	Osmania University, Hyderabad	Development of nanowires and nanostructural thin films
27	Presidency College, Kolkata	Conducting polymer/binary polymer- Inorganic hybrid nanocomposite material
28	Punjab University	M.Tech in Nanosciences and Nanotechnology
29	Sardar Patel University, Vallabh Vidyanagar, Gujarat	Studies on development, microstructural and analysis and physical properties of aligned carbon nanotubes and composites by CVD method
30	Thapar University, Patiala	1. Preparation & Characterization of Nano-Dispersed liquid crystal polymer composite materials 2. Preparation & Characterization of Electro ceramic-Polymer Nano-Composite materials 3. Fabrication of Cds nanowires & their characterization 4. Synthesis Characterization and application of chalcogenide nano/Microstructures
31	University of Mumbai	Nanomaterials
32	University of Poona, Pune	1. Investigation of nanoparticles using SPM and optical microscope 2. SPM group

Table 22: Research centres

	Research Center Name	Research Area/Facilities
1	Bhabha Atomic Research Center	
2	Center of Materials for Electronics Technology	Nanosized Powder Synthesis
3	Central Electronics Research Institutes	MEMS and Microsensor
4	Central Glass and Ceramic Research Institute, Kolkata	Characterization
5	Central Scientific Instruments Organization	Study of molecular motors for targeted drug delivery and nanomolecular switching

6	Defense Research an development Establishment, Gwalior	
7	Indian Association for the cultivation of Sciences, Kolkata (IACS), Kolkata	Spectroscopy
8	Institute of fundamental research, Mumbai	1. Thin Films and nano-materials 2. Nanoscale interactions in cells
9	National Center for biological Sciences, Bengaluru	Probing nanometer scale dynamics of chromation fluidity using single molecule force and fluorescence microscopy/spectroscopy
10	National Chemical Laboratories, Pune	1. Synthesis and shape, size control of Nanomaterials 2. Surface Analysis of polymer thin films, nanomaterials, biomaterials, nanolithography using Scanning probe microscopy (AFM, STM etc)
11	National Metallurgical Laboratory, Jamshedpur	Nanocomposite thin films of Si-C-N system for wear resistance and functional application by magnetron sputtering
12	National Physical Laboratories	Synthesis of carbon composites
13	Raman Research Institute, Bengaluru	Micro/nano machines in fluids
14	Regional Research Laboratories, Trivandrum	Investigation on the liquid crystalline phases of cation induced compacted and nanostructured DNA
15	S.N.Bose National Center for Basic Sciences (DST)	Physics of mesoscopic & nanoscopic systems
16	Saha Institute of Nuclear Physics	1. Surface Physics Division 2. Fabrication of nano-patterns
17	Solid State Physics Laboratory, Delhi	1. MEMs Components 2. Materials Development & Characterization

Source: Indiananotechnology.com “Nanotechnology in India: Universities & Research Centres”

INDUSTRY PARTICIPATION

In addition to the public sector, few private industry houses are also involved in the R&D of Nanotechnology. Leading companies such as Reliance, Mahindra & Mahindra and Tata Group are considering this field as an important opportunity and has pledged significant investments.

Table 23: Major companies

Company	**Area of research**
Cranes Software International Limited	Has its research set up for nanotechnology and MEMS at IISc, Bengaluru
Velbionanotech	Involved in the designing of drugs pertaining to various diseases such as Cancer, heart related diseases, Kidney stones, AIDS and cosmetic generic products. These drugs are aimed to be delivered to human body through nanoparticles.
Monad Nanotech	Engaged in the commercial production of carbon nano materials at low cost in technical association with IIT Mumbai. The company is also engaged in the supply of nano materials to research organizations in the country.
Innovations Unified Technologies	Involved in the supply of small and bulk quantities of MWNT/SWNT of different grades.
Qtech Nanosystems	Focusing on nanotechnology based products. The company is engaged in the product development and commercialization for nanotechnology.
Auto Fibre Craft	Engaged in manufacturing of specialized nanomaterials.
Bee Chems	Focusing on the manufacturing of different grades of Nano Silica products for alumina and silica industries.

Yashnanotech	Engaged in providing business intelligence and consulting services in nanotechnology globally

Source: Nanowerk "Nanotech companies in India"

NON-GOVERNMENT ORGANIZATIONS

Various NGO's are also playing an important role in the field of nanotechnology development by acting as a bridge between industry and academia. For instance, the Nanotechnology Research and Innovation Foundation (IndiaNano), a non-profit organization aims at developing a podium for strategic collaboration among the diverse groups with the expectation to harness technological advancements. This initiative is being supported by Girvan Institute of Technology, National Chemical Laboratory and The Centre for Materials for Electronics Technology, and has been seed funded by private equity firm, IndiaCo.

The IndianNano operates through its "Innovation Acceleration Network (IAN)" and provides the realistic assistance to the technical entrepreneurs in various fields such as Intellectual Property Management, Operations, Technology Transfer and Business Development to enable them to compete in international markets.

Another such organization acting as a facilitator for nano development is 'Nano Science and Technology Consortium'. It is helping in creating a ecosystem for the growth, promotion and partnering in the field industries, academics and government agencies. The organization assists these entities by providing advisory, consultative and educative services.

CHALLENGES FACING NANOTECHNOLOGY DEVELOPMENT

LACK OF COORDINATION

Owing to the multidisciplinary nature of Nanotechnology and its wide scope, there is a significant degree of overlap in the various R&D activities amongst various agencies. Such overlaps have led to human resource and financial waste along with the duplication of time intensive efforts. This overlaps have further highlighted the concern about poor coordination among different agencies leading to a vicious circle at such a critical stage of growth. Through the establishment of 'Nanomission', DST has attempted to mitigate this risk.

In order to nourish this technology, major efforts in this field need to be notified and made clear to the policy makers and scientific community. The flow of information necessary and the level of transparency in the initiatives is hindered because of limited accessibility of information.

HUMAN RESOURCE

As with most sunrise sectors, propagation of R&D efforts depend on the availability of capable human resource. Given the complexity involved in Nanotechnology research, India has a shortage of scientists and researchers capable of furthering cutting edge applications. The government being aware of the situation has invested significantly in upgrading skills and capabilities of the existing pool of people. But to take the next step in its evolution in Nanotechnology, the country needs a lot more effort both from the government and industries with respect to human resource development to be able to bridge the gap.

SLOW INDUSTRY ORIENTED DEVELOPMENT

As with most technology driven sectors, public R&D efforts in nanotechnology in India are more concentrated towards basic research which leads to a gap between research outcomes and industrial requirements. At its present state, efforts in R&D are being aligned towards product development which has attracted industry participation and (Public Private Partnerships) PPPs.

Given the high costs and risks associated with the development of nanotechnology, industry participation is significantly less. However, for its growth industry participation is essential at this stage as funding is a basic requirement for the propagation of any technology.

LESS EMPHASIS ON TOXICOLOGICAL STUDIES

With the expansion in the scope of nanotechnology, many researchers in India are focused on development of applications for sectors such as health, materials, textiles and water but not much is being done for toxicological studies, necessary to check the level of EHS risks associated with these application developments.

LIMITED ACCESSIBILITY TO R&D FACILITIES

Financial restrictions for R&D activities in Nanotechnology are a serious impediment for its growth. Even after the establishment of Centre of Excellences with requisite infrastructure support, accessibility of these facilities remain negligible to most academic institutes and universities because of their locations. Hence the scientific community at large is unable to leverage on benefits of these facilities present in India.

NATIONAL/ INTERNATIONAL COLLABORATIONS

Over the years, collaborations in the field of nanotechnology have added to the momentum of development in India. The collaboration is generally through the mode of funding, participation of universities in terms of knowledge exchange.

According to a senior scientist at Department of Information Technology, "The level of International collaboration has experienced an increase over the past few years. The agencies pass on the collaboration to their affiliated Institutes/research centers working on specific subjects. India is seeking out for more collaboration in this field. Subject matter developments with different universities and industries are what the agencies are looking for eagerly, funding, as criteria, is not on the top priority."

Table 24: List of collaborations

Sr. No.	Respondent	National	International
1	Advanced Material & Processes Research Institute (AMPRI), Bhopal		University of Hertfordshire, UK
2	Bengal Engineering and Science University Howrah	National Metallurgical Laboratory (NML), Jamshedpur	University of New South Wales, Australia
			University of Trento, Abo Akedemi, Finland
3	Central Glass & Ceramic Research Institute Kolkata		University of Padova, Italy
4	Central Salt & Marine		Center for the study of Industrial

	Chemicals Research Institute Bhavnagar		Organization (CSIO), Australia
			Inha University, South Korea
5	Centre for cellular and Molecular Biology Hyderabad	Council of Scientific and Industrial Research (CSIR) Labs	Kumamoto University, South Korea
			Australian University
			Purdue University
6	Central Electrochemical Research Institute, Karaikudi	Central Electronics Engineering Research Institute (CEERI), Pilani	
		Council of Scientific and Industrial Research (CSIR) Labs	
		National Chemical Laboratory (NCL), Pune	
7	Centre for Materials for Electronics Technology, Pune	Bhabha Atomic Research Centre (BARC), Mumbai	Korea Research Institute of Chemical Technology, Daejeon, South Korea
			University of St.Andrews, Scotland, UK
8	Defense Bioengineering and Electro medical Laboratory, Bengaluru	Advanced Systems Laboratory (ASL), DRDO, Hyderabad	Oxford University, UK
		Defence Materials and stores Research & Development Establishment (DMSRDE), Kanpur	
		Defence Research and Development Organization (DRDO) Labs	
		Solid State Physics Laboratory (SSPL), Delhi	
9	Defence Institute of	Jawaharlal Nehru Centre	

	Advance Technology, Pune	for Advanced Scientific Research (JNCASR), Bengaluru	
10	Delhi University, Delhi		Himeji University, Japan
			Tohoku University, Japan
11	DMSRDE (DRDO), Kanpur	Advanced Systems Laboratory (ASL), DRDO, Hyderabad	University of Arkansas, USA
		Defence Research and Development Organization (DRDO) Labs, Pune	
12	Hyderabad University, Hyderabad	Bhabha Atomic Research Centre (BARC), Mumbai	Longmuir-Blodgett (LB) Films, Japan
13	Indian Agricultural Research Institute, New Delhi		Nano Science and Technology Institute, Cambridge, USA
			University of Massachusetts, Lowell (USA)
			Institute of Nanoscience of Engineers Technology (INSET), Northern Illinois University, DeKalb
14	Indian Institute of Science Bengaluru	Indian Space Research Organization (ISRO), Bengaluru	Multinational Automobile company, US
			The Institute of Medical Science, Tokyo
			University of Colorado, USA
			University of Durham, UK
			Federal Institute of technology, Zurich, Switzerland
15	Indian Institute of Technology, Chennai	Defence Research and Development Organization (DRDO)	Helmut Schmidt University, Hamburg, Germany
			Institute of Physics, Academia Sinica,

		Labs	Taiwan
			Massachusetts Institute of Technology (MIT), Cambridge, USA
			Nagoba University, Japan
			Technical University, Germany
			The Leibniz Institute of Polymer Research, Germany
16	Indian Institute of Technology, Delhi	Aditya Birla Group	
		Aerial Delivery Research & Development Establishment Advanced System Lab (ADRDE), Agra	
		All India Institute of Medical Science (AIIMS), Delhi	
		Anand Group	
		Defence Bioengineering and Electromedical Laboratory (DEBEL), Bengaluru	
		Defence Laboratory (DL), Jodhpur	
		Defence Materials and stores Research & Development Establishment (DMSRDE), Kanpur	University of Singapore, Singapore
		Indira Gandhi Centre of Atomic Research (IGCAR), kalpakkam	
		International Advanced	

		Research Centre for Powder Metallurgy and New Materials (ARCI), Hyderabad	
		National Chemical Laboratory (NCL), Pune	
		National Physical Lab (NPL), New Delhi	
		Reliance Group	
		Resil Chemicals Private Limited, Bengaluru	
		SRF Limited	
17	Indian Institute of Technology, Kanpur	Saha Institute for Nuclear Science, Kolkata	
18	Indian Institute of Technology, Kharagpur	Defence Metallurgical Research Laboratory (DMRL), Hyderabad	Forschungszentrum Karlsruhe FZK, Germany
		Facilitation Centre for Industrial Plasma Technologies (FCIPT), Gandhinagar	Technical University, Clausathal
		Institute of Material Science, Bhubaneshwar	UNIPRESS, Poland
		National Metallurgical Laboratory (NML), Jamshedpur	University of Tennessee, US
		National Physical Lab (NPL), New Delhi	University of UIM, Germany
		Vikram Sarabhai Space Centre (VSSC), Trivandrum	University Sains, Malaysia
19	Indian Institute of	Bhabha Atomic	Agere Systems Inc, USA

	Technology, Mumbai	Research Centre (BARC), Mumbai	
		High Energy Materials Research Laboratory (HEMRL), Pune	Applied Materials Inc, USA
		Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam	Institute of Technology, Japan
		Tata Institute of Fundamental Research (TIFR), Mumbai	Intel, USA
			International Rectifier Corporation , USA
			Laboratory for Advanced Research in
			Microelectronics (IMEC), Belgium
			Nanyang Technological University, Singapore
			National University of Singapore (NUS),
			Singapore
			Universitaet der Bundeswehr Munich, Germany
			University of California, Los Angeles
			University of Krisorsbateru, Germany
			Yale University , USA
20	Indian Institute of Technology, Roorkee	Tata Institute of Fundamental Research (TIFR), Mumbai	
21	Industrial Toxicology Research Centre	National Chemical Laboratory (NCL), Pune	Michigan Nanofabrication Facility, USA
22	Institute of Minerals and Materials Technology Bhubaneshwar	Central Food Technological Research Institute, Mysore	Nagoya Institute of Technology, Japan

		Indian Institute of Chemical Technology (IICT), Hyderabad	
		Institute for Plasma Research (IPR), Gandhinagar	Georgia Institute of Technology, USA
		Naval Materials Research Laboratory (NMRL), Mumbai	
		The Centre for Cellular and Molecular Biology (CCBM), Hyderabad	
23	Institute of Physics Bhubaneshwar	Bhabha Atomic Research Centre (BARC), Mumbai	University of Electro Communication Japan
		Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam	University of Hawaii at Manoa, USA
24	International Advanced Research Centre for Powder Metallurgy & Material, Hyderabad		Engineered nanoProducts Germany AG, Germany
25	International Centre for Genetic Engineering and Biotechnology, New Delhi	National Institute of Virology (NIV), Pune	
26	Inter-University Accelerator Centre New Delhi		Institute of Nuclear Studies, Rosendorc, Germany
			Centre Interdisciplinaire de Recherche

			Ions Lasers (CIRIL) Lab., France
27	Jadavpur University, Kolkata	Balmer Lawrie & Co. Ltd, Kolkata	York University, USA
		Central Glass & Ceramic Research Institute,Kolkata	Solid-State Electronics Laboratory, USA
		Indian Association for the Cultivation of Science (IACS), Kolkata	Italian University
		Rashtriya Ispat Nigam Ltd., Visakhapatnam	Mie University, Japan
		Saha Institute for Nuclear Science, Kolkata	Virginia Tech University, USA
		Shalimar Paints Limited, Mumbai	Han Yang University, South Korea
		SN Bose Centre for Basic Sciences, Kolkata	
		Variable Energy Cyclotron Center, Kolkata	
28	Jawaharlal Nehru Centre for Advanced Scientific Research, Bengaluru	National Chemical Laboratory (NCL), Pune	Institute for Materials Research (IMR), Japan
29	Jawaharlal Nehru University, New Delhi		Material Science and Engineering, UNSW Australia
			University of Amherst ,USA
30	Kerala University	Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam	
31	Madras University,	National Chemical	

	Chennai	Laboratory (NCL), Pune	
32	Mahatma Gandhi University Kottayam	Rubber Research Institute of India, Kottayam	University of Paris, France
			University Peruga, Italy
33	National Chemical Laboratory, Pune	Jawaharlal Nehru Centre for Advanced Scientific Research, Bengaluru	University of Liverpool, UK
		National Centre For Cell Science (NCCS), Pune	
34	National Metallurgical Laboratory,Jamshedpur	The Centre for Cellular and Molecular Biology(CCBM), Hyderabad	
35	Pune University	Bhabha Atomic Research Centre (BARC), Mumbai	
		Indian Space Research Organization (ISRO), Bengaluru	
		National Chemical Laboratory (NCL), Pune	
36	Raman Research Institute, Bengaluru	Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bengaluru	
37	Saha Institute of Nuclear Physics, Kolkata		Hiden Analytical Ltd., UK
38	Sardar Patel University Vallabh Vidya Nagar		Tokyo Institute of Technology, Japan

Source: National Foundation of Indian Engineers “Status of Nanotechnology”

Speaking on the various modes of collaborations happening in India in nanotechnology, a senior scientist from IIT Kanpur stated, "The level and type of collaboration depends on the subject and in each stream there are a number of subjects. However, the most common types of collaboration one can see is funding and expertise exchange. At IIT Kanpur, knowledge exchange with foreign universities is the key and it is also happening with other institutes as well".

EU-INDIA NANOTECHNOLOGY COLLABORATION

The joint India-EU S&T steering committee decided that science and technological collaborations were a top priority. Natural disasters, climate change, ICT, nanotechnology, multifunctional materials, surface transport and health were concluded as the high priority areas of focus.

The areas of cooperation in the field of nanotechnology and functional materials were deduced in the EU-India workshop held at S.N. Bose National Centre for Basic Sciences, Kolkata in year 2005. It includes:

1. Nanometrology
2. Interfacial phenomena in materials
3. Interaction of engineered nanoparticles with the living world and the environment
4. Basic materials for fuel cells
5. Nanostructures other than carbon
6. Hydrogen storage
7. Multi functional organic materials and materials by design

Further, after the review by 2nd India-EC S&T Steering Committee Meeting held in the same year, the recommendations were made in order to boost the nanotechnology for stimulating collaborations.

1. An Indian Scientific mission to Europe in the domain of nanolithography
2. Indian participation in EC's international consultation on ethical aspects of nanotechnology
3. EU-India workshop on computational materials science
4. European participation in international conferences on nanotechnology in India

The first funded project, EuroIndiaNet project, in the field of Nanoscience and technology is considered to build a platform for sustainable partnership between the two. It plans to develop a Nanotechnology strategy through the inputs and discussions from researchers, government and industries along with the opportunities to interact and network within.

BILATERAL COLLABORATIONS WITH EU NATIONS

Within the EU; UK, Germany and France are highly active in the field of Nanotechnology. The key features of bilateral collaboration between India and these EU countries are discussed below:

UK-INDIAN BILATERAL COLLABORATION

The UK-India Education and Research Initiative acts as a main vehicle for the collaboration between these two countries. However, it is not limited to Nanoscience only. It covers a wide array of activities including research, higher education, schools, technical and professional skills enhancement etc.

The collaboration aims to fund 40 UK awarded programmes delivered in collaboration with India and 50 new research projects by 2011. In regards with nanotechnology, this collaboration consists of visits of scientists between UK and India. Such visits are supported by British Council, the United Kingdom (Office of Science and Innovation), the Royal Society and the Department of Science and Technology.

FRENCH-INDIAN BILATERAL COLLABORATION

The scientific collaboration among the two countries, France and India is managed by Indo-French Centre in order to promote the advanced research. This collaboration includes industrial research projects and seminars. The research projects application can jointly be made from France and India with a submission deadline of 6 months. These applications then undergo a thorough peer review in both countries before approval by a scientific council. The projects fall under the following categories mentioned below and have duration of 3 years tenure;

1. Pure and Applied Mathematics
2. Life and Health Sciences
3. Computer and Health Sciences
4. Pure and Applied Physics
5. Pure and Applied Chemistry

6. Earth and Planetary Sciences
7. Instrumentation
8. Material Sciences
9. Earth and Planetary Sciences
10. Environmental Sciences
11. Others

Though, Nanoscience and technology permeates different areas, these projects are funded under Pure and Applied Chemistry, Pure and Applied Physics and Material Sciences categories.

GERMANY-INDIA BILATERAL COLLABORATION

The Indo-German collaboration in Science and Technology includes personnel exchange, application and project based collaboration. In addition to this, there are few bilateral institutional arrangements with Germany such as Helmholtz network of research institutions and the Max Planck Society.

India's collaboration with German Ministry for Research & Education) funds up to 25 projects in pre-defined areas every year including;

1. Advanced materials, with special emphasis on nano-materials and polymers
2. Biotechnology
3. Aeronautics, space science, technology & applications
4. Environmental research
5. Medical & Health Research
6. Information technology
7. Technologies for newer renewable energy strategies
8. Synchrotron & Accelerator technologies and applications

Nanotechnology projects are undertaken as a part of these areas of priorities. Previously held Nanotechnology projects included diverse fields such as nano hydro gels for biomedical applications and thin films for solar cells. In addition, every year around 50 projects are benefited from exchange of personnel through German Academic Exchange Service (DAAD).

Apart from the projects, workshop such as Indo-German Workshop on “Nano-Materials and Technologies” held in 2001 at Berlin further enhance the collaborative efforts in this field.

INDO-DUTCH BILATERAL COLLABORATION

The Indo-Dutch Programme on Alternatives in Development has kindled collaborations between the two countries. The social science research collaborations among India and the Netherlands were stimulated by the lndo-Dutch Programme on Alternatives in Development (1986-2006). This programme of was implemented by the Netherlands Foundation for the Advancement of Tropical Research (WOTRO) and Indian Council of Social Science Research (ICSSR). This programme is expected to also include natural sciences in many other fields such as Nanotechnology.

Though, there is formal Science and Technology collaboration between India and Netherlands, many universities, with the help of the Netherlands Organization for International Cooperation in Higher Education (NUFFIC), are engaged in exchange programmes with India independently.

INDO-BELGIAN SCIENCE AND TECHNOLOGY COOPERATION

In 2006, the Science and Technology cooperation between the two countries was signed by the Belgian research centre IMEC with an Indian company, SemIndia for collaboration in semiconductor fabrication facility located at Hyderabad. The Belgian research centre also has collaborations with Indian Institute of Science, Bengaluru for conducting joint research on steps of Nano-electronics process.

STATE GOVERNMENT INITIATIVES

Apart from the various central departments under different ministries, state governments have also geared up with their initiatives to leverage capabilities in technology infrastructure available in their states. State governments of Karnataka, Tamil Nadu and Haryana have taken keen interest for the development of Nanoscience in their states.

KARNATAKA

Karnataka is known as an IT and Biotech hub. Its highly reputed science and technology institutes like JNCASR and IISc, infrastructure and qualified human resource provides a ready platform to expand and become a Nanotechnology hub. The state government has been keen in creating and promoting an environment for the advancement of Nanotechnology related research. A recent venture with instrument supplier, Vecco Instruments, in Bengaluru to partner with JNCASR for the work ahead in the field of nanotechnology shows its intent.

Karnataka as a technologically progressive state accounts for a significant share of research in Nanotechnology and is well and truly striding ahead to become a "Nano City" in the future. The state is also to receive a grant of around USD 25 million from the Central government for further strengthening its position as a preferred destination for Nanotechnology in the country. Further, initiatives are being taken for downstream activities like translation of R&D into commercial opportunities by hosting events such as "Research-Industry-Collaboration hub" (RICH) conference in Bengaluru with an aim to create a strong platform for scientists, industry and investors.

TAMIL NADU

The state government of Tamil Nadu is turning every possible stone to promote the state as a potential Nanotechnology hub. The government is planning to develop a scheme worth around USD 25 million for technical transfer from the University of Arkansas. Also the government has provided seed funds to institutes such as "Centre of Life sciences" at Bharathiar University and Anna University for R&D in Nanotechnology. It is also promoting Nano-capabilities to foreign investors like the Taiwan's 'Science Park' in order to attract private investments for the proposed Nanotechnology parks in the state.

HARYANA

The state government plans to make the state as a technology centre which includes Nanotechnology and foresees it as a future silicon valley in India. Few projects are planned to attract private partnership and investments to the tune of USD 2 billion. The state government also has plans for partnerships with premier institutes across the country in order to build a strong pool of researchers with advanced capabilities in the areas of software products, biosciences, materials and nanotechnology. Further the government of Haryana also has plans to set up Nanotechnology parks in the state.

OUTLOOK

Nanotechnology is being keenly looked at by market observers as the next big revolution, though public opinion is still polarized to an extent of its efficacy. The Indian government is keen to capitalize on the opportunities presented by this new technology and is taking proactive steps in that direction. As said, the government does not want India to miss out like it did with the semi conductor revolution. Accordingly, the scientific community, industry and investors are gearing up to be part of this space particularly for sectors like chemicals, healthcare, electronics, material sciences and textiles.

There are however, many roadblocks that face India in its quest to be at the forefront of this revolution. First, with many agencies, institutes and research centers involved in R&D there are distinct overlaps and hence redundancies. The need of the hour is to improve coordination amongst different stakeholders to be able to streamline research and technology development. Second, given the wide scope of Nanotechnology, the country faces shortage of qualified professionals and with time this gap is like to widen further. The government cognizant of this fact has started investing significantly in human resource development but it alone cannot provide the necessary scale of changes and improvements required. The private sector needs to step in with more vigor. Finally, in its present state, Nanotechnology is at its infancy in the country. To harness its potential, India needs strong technical collaborations with advanced countries.

Given the buzz around the globe and the multidisciplinary nature of Nanotechnology, the future looks promising for India. Many state governments have pledged investments in related infrastructure in their respective states. In a way, there is now a rush amongst many stakeholders to be seen as the vanguard in Nanotechnology advancement in the country. As the ecosystem builds up with more participants and stakeholders, there is going to be positive spill over’s to the nation’s economy and to the overall development of the country.

11. DEFENCE

In the year 1801, the base for India's defence production industry was laid with the establishment of Gun Carriage Agency in Kolkata. Since then the industry has grown manifold with a strong network of Defence Public Sector Undertakings (DPSUs), other defence focused labs and R&D institutions. Despite such growth India still imports almost 70% of its defence equipment requirements. For the period 2006-10, India was the largest importer of arms, accounting for 9.1% of the worldwide import market, surpassing China and South Korea at 6.3% and 6% respectively. More than 75% of India's import comes from Russia. This trend is due to the fact that India has not been able to fully develop its capabilities for defence equipment production. In spite of the Indian governments stressing on the need for self reliance, the domestic defence industry has not been able to achieve it because of complete government control.

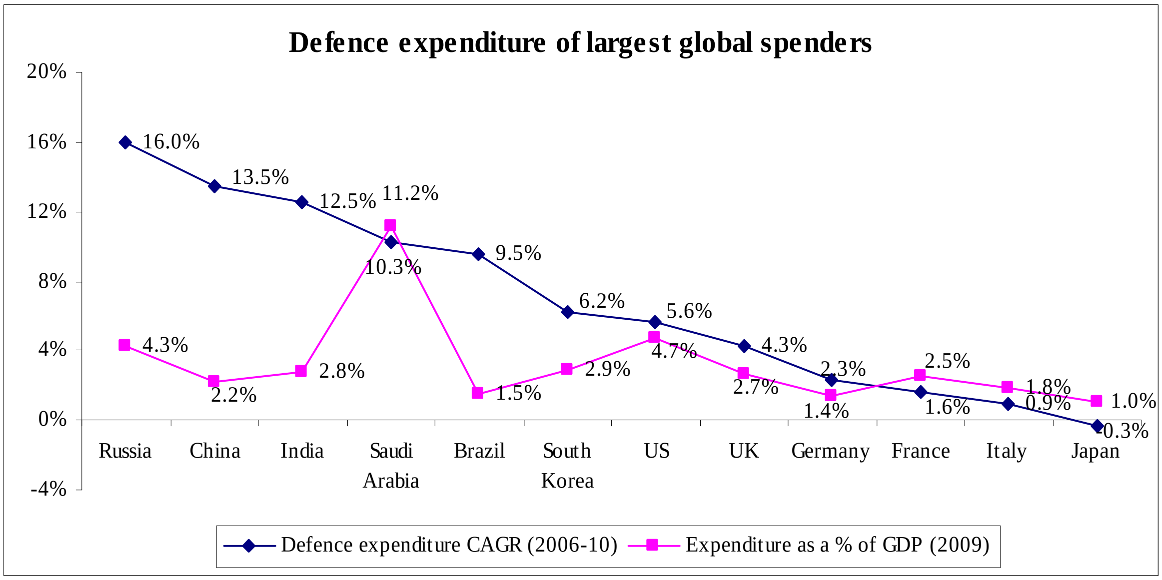
However, the continued focus on self reliance coupled with attention from the global majors, has made India a major hub for defence activities in the recent years. Several large defence companies have looked at India for low-cost manufacturing options, R&D capabilities and acquisition of specific engineering talent making the relationship more of co-development than just export-import. A readymade local base in the country has helped the international companies in optimizing the supply chain and strengthening its ties with potential customers.

DEFENCE EXPENDITURE[37]

With the increased focus of government on defence spending, India is among the top ten defence spenders globally. For the period of 2005-09, India also had the third highest CAGR of 12.5% in defence spending after Russia and China. However, in terms of defence expenditure as a percentage of GDP, India does not rank very high. In terms of GDP share, Saudi Arabia is the largest spender at 11.2% of GDP followed by US and Russia at 4.7% and 4.3% respectively.

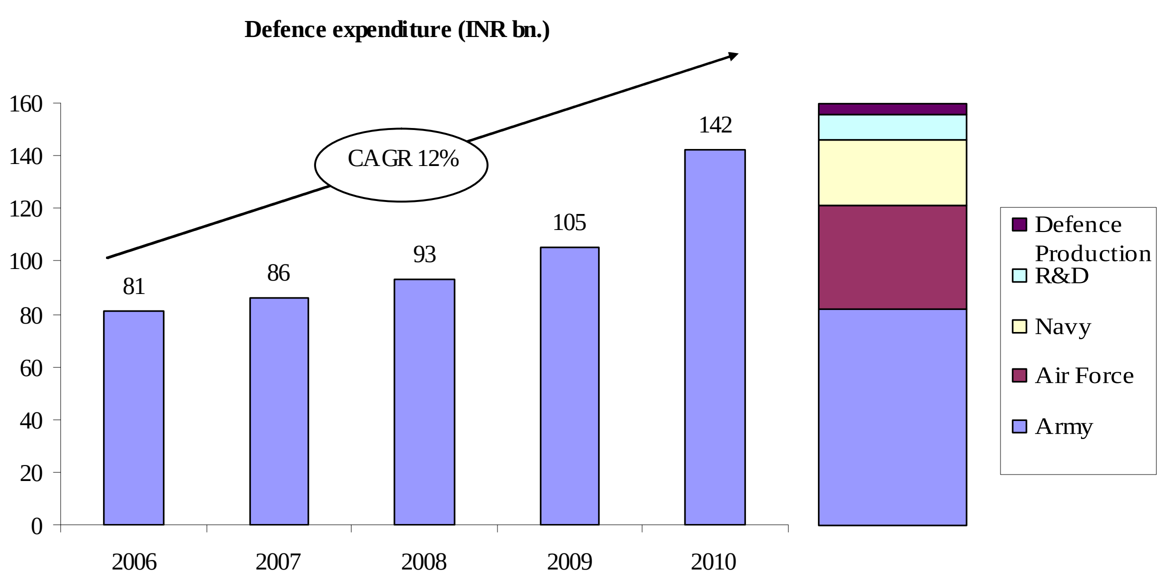
Chart 40: Defense expenditure of largest global spenders

[37] Stockholm International Peace Research Institute (SIPRI) military database



In absolute terms though, India has been increasing its defence expenditure through the past decade. Majority of this expenditure goes to the army, followed by air force and navy. Expenditure on R&D only accounts for around 6-7% of the total defence spending in the country.

Chart 41: India's defense expenditure

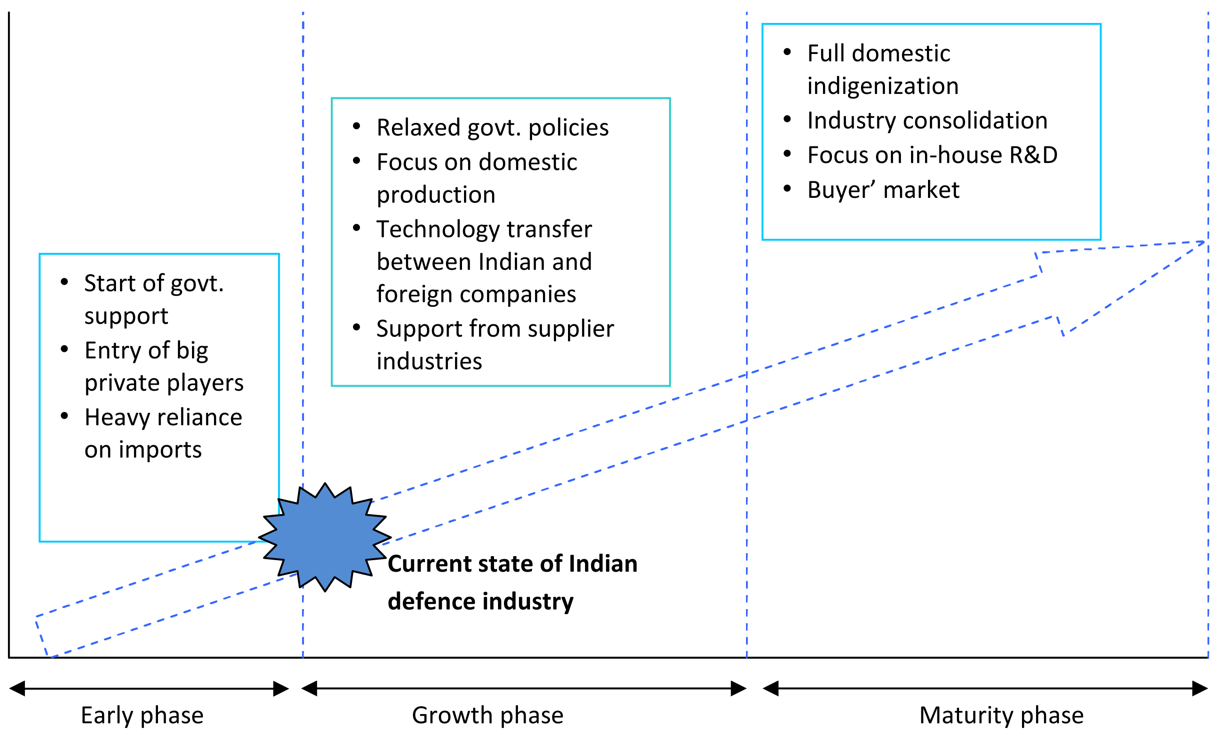


During the period 2006-10, revenue expenditure (which includes everyday operating expenses) has accounted for around 60-70% of the total expense while capital expenditure (which includes creation of assets and expenditure on procurement of new equipment) accounted for the remaining 30-40%. As per the plans of the defence ministry, capital expenditure is expected to grow at a CAGR of 10% from 2011-15, depicting the focus of the government in strengthening its defence equipment base.

RESEARCH AND INNOVATION

The Ministry of Defence is the nodal body for the planning and policy framework of the defence industry in India with a number of departments responsible for different activities. Under this the Defence Research and Development Organization (DRDO) is the main organisation responsible for all defence related R&D activities which have been in the concentrated within several government institutes. Though India has long focused its efforts on development of indigenous capabilities there exists a large gap between the technical capabilities and industry demand.

Figure 32: Defence industry growth curve



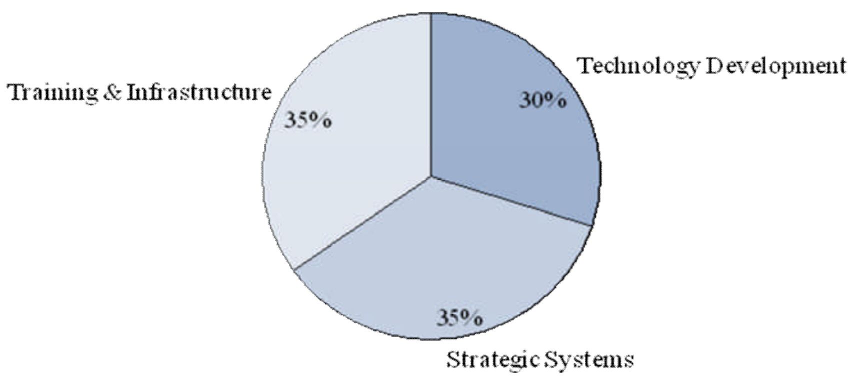
Currently, India has limited capabilities in defence research and production. The government has opened the private sector recently for entry into defence related activities and is also relaxing norms with an aim to develop indigenous capabilities. The industry is considered to be entering the growth phase and is expected to see a lot of development especially with foreign collaborations. However, there is still a long way to go to reach a stage of full domestic indigenization.

DEFENCE RESEARCH AND DEVELOPMENT ORGANIZATION[38]

DRDO's mission is to design and develop state-of-art defence systems and technologies and has been involved in identification of critical technologies, technology development and identifying partners for technology acquisition. It is the nodal agency responsible for providing technology solutions and also develop infrastructure and committed quality manpower. Established in 1958, DRDO has now grown to a network of 52 laboratories and is one of the most versatile defence organizations in the world. These laboratories are engaged in a wide variety of disciplines ranging from equipments for army, navy and air force, to development of materials and life sciences products. These laboratories are spread all across the country and have been reasonably successful in developing military hardware and equipments.

DRDO gets its funding from the government of India. Currently, it has a financial backup of about 6 per cent of the Indian Defence budget. About one-third of this budget is utilized for projects and technology development, another third for strategic systems development and the remaining for manpower, training and infrastructure.

Chart 42: DRDO expenditure



All of DRDO’s programs are a planned process which are determined by the Services Long Term Integrated Perspective Plan (LTIPP) and its own technology forecasting based on global developments.

Figure 33: Types of DRDO projects

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[38] DRDO- Nabanita R Krishnan, Critical Defence Technologies and National Security - The DRDO Perspective

DRDO Programs

Mission Mode projects

- Driven by user demand – army wings
- Time bound
- Dependant on technologies which are proven and easily accessible either
    - Within DRDO
    - Can be procured from abroad

Technology Demonstration projects

- Funded & controlled by DRDO – minimal user inputs
- Development & testing of technology for future
- May be developed and designed in collaboration with industry and academia respectively

Science and Technology projects

- Minimal funding at lab level
- Loose alignment to future needs
- Undertaken with academia involvement
- Involves analysis and simulation modules

The Services Long Term Integrated Perspective Plan (LTIPP)

A combination of the above three project types determines the five year plans of the organization. Over the years, DRDO has designed and developed a wide range of products and technologies in each of the disciplines it operates in. The table below provides a summary of the key products and technologies which have been developed by DRDO.

Table 25: DRDO – key products and technologies

Discipline	Product	Technology
Aeronautics	Combat aircrafts: LCA, Tejas UAV: Lakshya, Nishant Aerostat Avionics	Control laws for unstable aircraft, open architecture avionics, composite structure, mobile launch & recovery, jam resistant data links, image processing
Missiles	Strategicc: Agni, Prithvi, Dhanush Tactic: Akash, Nag, Trishul Cruise: Brahmos	Re entry vehicle structure, liquid propulsion, autonomous navigation, stabilization/launch from moving platform, command guidance, folding fin mechanism
Navy	Sonar: Humsa, Nagan, Ushus,	Transducer arrays, Signal Processing, Homing, On board computer fire control, propulsion system,

	Mihir Torpedoes Processor based mines Naval Paints	platform interface, corrosion protection paints
Electronics	EW system: Samyukta, Sangraha Radar: BFSR, 3D CAR, Rajendra C41, Lasers	Direction finding, jamming techniques, voice recognition, secrecy system, network centric information fusion, High Accuracy Trx/Rx modules
Armaments & combat engineering	Combat vehicle: MBT Arjun, Bhim, Tank Ex MBRL Pinaka, Sarvatra Bridging System	Hydro gas suspension, Composite armor, flow formed rocket motor, launcher mechanism, propellants, warheads
Materials	Composites, rare earth magnets, special steels, carbon nanotubes, nano composites	Titanium sponge extraction, Aerofoil & super alloy castings, Multi walled carbon nanotubes, thermal protection for structure, conducting polymer
Life sciences	Selection, protection & nutrition packages for soldier, bio-waste management, agro-tech & NBC systems	Psychometric test, Hapo management, NBC sense/detect technologies, life support systems, diagnostic kits, food pre-processing for extreme conditions

Along with the above products and technologies, DRDO has also developed its infrastructure to support the defence industry requirements. Some of the key infrastructure developed by DRDO includes integrated test range at Balasore for missiles, structural dynamic vibration test facilities for aircraft structures, electronic warfare test ranges, propulsion test facilities, test tracks for land based combat systems, underwater weapon test ranges and EMI/EMC test rigs among others.

However, DRDO still needs to develop its capabilities in a number of products and technologies. There is a need to develop advanced surveillance platforms, extended reach next generation combat aircraft, expanded air defence and ballistic missile defence capability and autonomous unmanned systems for land and water. Some of the breakthrough technologies which will be required to be developed include

Hypersonic Vehicle Technology, Network Centric Warfare Components, Directed Energy Weapons, Nanotechnology and advanced materials.

OTHER ORGANIZATIONS INOLVED IN INNOVATION[39]

Apart from DRDO, there are other organizations both pubic and private, which are also investing in defence research and production activities. **Historically, defence activities have been under the realm of public sector only, which accounts for 86% of the domestic market. Currently India has a good base of eight defence public sector units (DPSUs) and forty ordnance factories which are engaged in defence research and production activities. These together, account for over 65% of the public sector production**. The DPSUs have been given a number of benefits like tax exemptions & concessions, funding from Government to develop R&D and manufacturing capabilities, and preferential treatment for government projects.

Table 26: List of DPSUs

DPSU	Major products and activities
Hindustan Aernonautics Ltd. (HAL)	• With 19 production units and 9 research centers HAL is one of the major designer and manufacturer of aircraft, helicopter and related accessory • It has had several successful R&D programs. Key projects under development are Dhruv (Advanced Light Helicopter), Tejas (Light Combat Aircraft), and Intermediate Jet Trainer (IJT) among others
Bharat Electronics Ltd. (BEL)	• Engaged in design, development and manufacture of sophisticated state-or-the-art electronic equipment components for the use of the defence services and other government users
Bharat Earth Movers Ltd. (BEML)	• One of the largest manufacturers of defence equipment, BEML provides sophisticated defence equipment, and vehicles for all terrain operations • It also launched an Aero Space Manufacturing Division in 2008-09
Bharat Dynamics	• Missiles, torpedo counter measure system, counter measures dispensing

[39] Deloitte, Prospects for Global Defence Export Industry in Indian Defence Market, 2010

Ltd. (BDL)	system
Mazagon Dock Ltd (MDL)	• Key organization for manufacture and repair of warships, submarines, missile boats, destroyers, frigates and corvettes for Indian Navy
Garden Reach Shipbuilders & Engineers Ltd (GRSE)	• Builds and repairs warships and auxiliary vessels for the Indian Navy and the Coast Guard
Goa Shipyard Ltd (GSL)	• Design, construction and commissioning of sophisticated vessels for the defence and commercial sectors • It has world class CAD/CAM facility for basic design, simulation and advanced outfitting to enhance productivity

Private players: The relaxation of norms in 2001, which entailed 100% ownership of private sector defence production and FDI upto 26%, has given a boost to the private sector participation. A number of private sector firms including SMEs are now venturing into defence research and production activities. Some of the key private players in the sector are:

- Tata Group: Develops missile & rockets launchers, electronics, composite components and provides software and intermediate services for aerospace and defence applications
- Mahindra Defence Systems: Provides light vehicles, simulators for weapons and weapons systems, mines and small arms
- Larsen and Toubro: Designs, develops and manufactures missile systems, electronics and naval engineering systems
- Samtel: Manufactures wide range of displays for avionics and engineering services.

Along with these private players some other companies like Ashok Leyland, Bharat Forge, Godrej & Boyce, HCL Technologies, Infosys Technologies, Kirloskar Brothers, and Wipro are in the list of prospective Raksha Udyog Ratnas (RURs). If approved, these RURs will get privileges similar to those of DPSUs. However, due to protests from industry, the appointment of RURs is currently uncertain. Several industry players are uncertain on introducing an additional class of defence companies. Further, many also oppose the requirements for RUR eligibility. Factors like prior experience and minimum turnover act as deterrents for smaller companies to enter the market.

Role of SMEs: Apart from the big corporations, SMEs are also gearing up in defence research and production activities. One of the key roles played by SMEs is the design and development of sub-systems and components. Technology collaboration would be the primary method for ensuring the growth of SMEs in the sector. According to Confederation of Indian Industry (CII) estimates, the Indian defence sector currently comprises over 6,000 SMEs, which supply around 20%-25% of components and sub-assemblies to the DPSUs, DRDO, ordnance factories, Defence Research and Development and the armed forces. Further, with the requirement of defence offsets, the role of SMEs is expected to grow. As a result of the offset requirements more and more international companies will seek to work with SMEs. In order to leverage this, the SMEs will also need to develop their capabilities in order to align themselves with the global requirements.

For European agencies, there exists good opportunity in participating with the private players and SME's particularly in the technology co-development area.

GROWTH DRIVERS[40]

INCREASED GOVERNMENT FOCUS

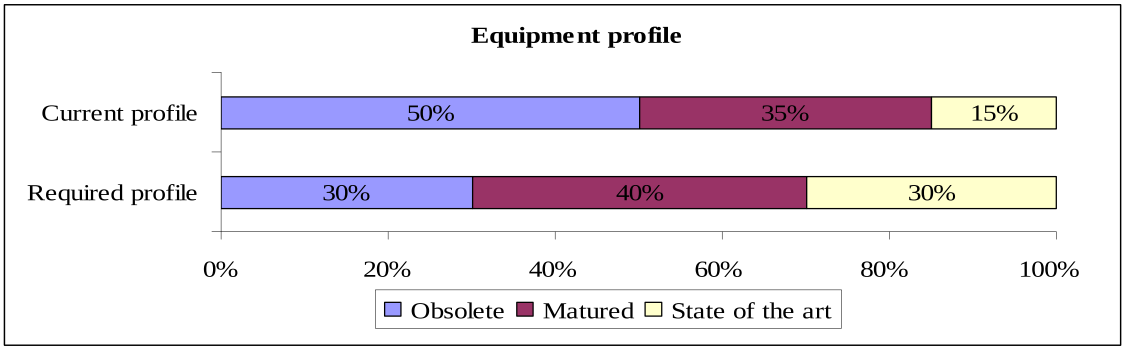
Considering the regional dynamics with occasional border skirmishes and intrusions, continued threat of terror attacks, defence will continue to remain a priority sector for the government. All sections of defence including army, navy and air force are expected to invest heavily in procurement of new equipment and technology for future capability building for the next 20-25 years. This presents tremendous opportunities for the industry to meet the domestic demand and also for the government to strengthen indigenous capabilities. The relaxation in the government regulations will also be a major driver for both domestic and foreign companies to invest in the sector.

OBSOLETE EQUIPMENT

[40] The Hindu, India's growth opportunity in defence, February 2010
KPMG, CII, Opportunities in the Indian Defence sector

The current equipment profile of the Indian defence industry is far behind its necessary requirements. More than 50% of the equipment is obsolete which needs to be brought down to a level of 30% quickly.

Chart 43: India's defense equipment profile



This highlights the need for modernization which will facilitate stronger R&D activities in the industry. The government and the industry have realized this need and have stepped up their efforts towards technology development for equipment and systems production.

OFFSET POLICY

The offset policy by the government is expected to be a major factor driving the growth of the domestic defence industry. The offset policy would result in lot of investment flow in the Indian defence industry and the figure estimated is to be USD 9 billion by 2012. However, there are also a lot of concerns in the industry regarding the offset policies. Some experts are of the view that India may not have the requisite capacity to meet the offset requirements. There is also a need to make the offset policies more clear in order to reap their full benefits. For eg: it needs to be ensured that offsets result in value-addition and do not result in outsourcing of minor components. Once the provisions are put in place, offsets would be a major driver for the defence industry.

SYNERGY BETWEEN INDUSTRIES

The defence industry is closely related to other manufacturing industries like automotive and discreet manufacturing due to the similarity in operations and processes. As a result, many private sector companies are now expanding their operations in the defence sector. Indian companies are now developing their competitiveness in engineering, quality and technology at par with global standards. A number of global companies are looking at India for collaboration opportunities and the strength of the local companies will provide them a competitive edge to reap benefits from this emerging scenario.

CHALLENGES[41]

INSUFFICIENT REGULATORY SUPPORT

Though the government has made changes to the existing policies for the defence sector, the provisions are not sufficient enough to meet the industry requirements.

- Restrictions on foreign investment: The foreign defence companies consider 26% FDI limit as a major drawback. FDI limit of 26% does not give adequate management control to the foreign companies in the JVs. There have been proposals to increase this limit to 49%, however again there are varied views on this. **According to some experts increasing FDI limit would increase foreign control and would go against the objective of self-reliance. Further security and secrecy of data will be a concern. However, MSMEs and large corporate who are eager to diversify into defence propagate increased investment.** FDI limits restrict MSMEs to source funding and technologies from foreign players. Considering many MSMEs are coming up with breakthrough technologies, this becomes a major impediment. If FDI limits are increased, it will provide tremendous opportunities for European companies keen on entering in the Indian defence market.
- All JVs which are formed for offset clauses are governed under the indirect tax regime as applicable to Indian companies. As such, they are required to pay all indirect taxes as per regulations.
- R&D cess is charged at the rate of 5% on import of technology in India under a foreign collaboration
- According to the industry the current weighted deduction for scientific research is not sufficient and there is demand to introduce additional incentives to reduce the burden of R&D costs. However, policy makers differ on this, and according to them granting special incentives for such research would lead to distortions.

LIMITED BENEFITS TO PRIVATE SECTOR

[41] KPMG, CII, Opportunities in the Indian Defence sector

The defence sector has historically been promoted by public institutions. As a result there are a number of benefits which are available only to DPSUs and not to the private sector. For example, DPSUs enjoy exemption from excise duty on all goods supplied by them to Ministry of Defence for official purposes. On the other hand this benefit is restricted to the private sector except for some cases which receive specific notifications. This reduces the competitiveness of private sector firms at the time of bidding for projects. Further there are a number of technologies which are available only to DPSUs and not to private companies. This also acts as an inhibitor to the growth and development of the private sector in this sector.

SUPPLY CHAIN ISSUES

Even though India has a fairly well developed wide supply chain network, it needs to be further developed to improve efficiencies in the defence sector. Considering the large share of supply chain in the cost structure of the defence industry, bringing in efficiencies in the supply chain becomes imperative. Also, the industry is expected to have different category of players operating synchronously, hence it is imperative that the industry to make use of the competitive strengths of each stakeholder to enhance efficiencies and overall effectiveness.

COLLABORATIONS

Foreign collaborations: India is quickly emerging as a key player in defence industry globally. As a result, US and European companies are now recognizing India both as a potential research and manufacturing partner as well as a key market. DRDO has a number of joint programs ongoing for research in armament, avionics and life sciences with Britain, France, Italy, Russia, Spain, Ukraine and the United States. The focus is to build defense technologies for the future through joint intellectual property rights with international partnerships.

- **Russia**: Russia has been a long standing partner for India for defence research and manufacturing activities. **More than 75% of India's defence equipment is procured from Russia**. However over the years, the relation between India and Russia has moved from a buyer – seller equation to collaboration for defence research and development. One of the biggest deals here is the proposal for joint development and production of the fifth-generation fighter aircraft (FGFA) valued at USD 30 billion

- **United States**: DRDO has been taken out of the "Entity List" in US which marks a major break for US-India defence relationships. Currently DRDO has partnership with US companies in about 30 programs. These programs are related to materials, services, manufacturing technologies and advanced communications systems. However, India and USA are yet to develop a trust factor for collaboration in defence R&D which will determine the growth path of collaborations in the long term. European agencies can step in here and capitalize on the opportunities if the situation does not improve in India-USA bilateral relations.
- **Europe**: India has numerous collaborations and partnerships with a number of European countries like Ukraine, Sweden, France, Israel and Germany. These partnerships are aimed towards joint development and manufacturing projects as well as possibility of technology transfers.

However, there are certain roadblocks with international collaboration in strategic sectors like defence. **Generally countries do not collaborate on critical technologies, which they would like to retain for themselves. Further, collaborations are also withdrawn several times due to restrictions imposed by foreign policies. DRDO undertakes International Collaboration on "equal partners with complementary skills" model, which also helps in easier access to technology. The Mission Mode projects also necessitate international help in a number of cases, due to their time constraints.**

Table 27: List of collaborations

Indian company	Foreign company	Collaboration details
Mahindra Defence system	BAE system	Manufacture of land combat vehicles based on BAEs RG 31 mine protected vehicles
Mazagon Dock Ltd	Direction des Constructions Navales, Navantia	Development of Scorpene Submarine, which is incorporated with the SUBTICS integrated combat system
Larsen & Toubro	EADS	Setting a facility in Pune for design, development and manufacturing of electronic warfare, radar, military avionics & mobile systems
Larsen & Toubro	Raytheon, Boeing	MoU for joint business in defence industry

Larsen & Toubro	RAC, SAAB	Manufacture of structures on which MMRC aircrafts are built
TATA advanced systems	Israel Aerospace Industries Ltd.	Develop & manufacture missiles, UAVs, electronic warfare, radar and security systems
Hindustan Aeronautics Ltd	Israel Aerospace Industries (IAI)	IAI will help Hindustan Aeronautics in converting the 'Dhruv' ALH into an unmanned maritime rotorcraft
DRDO	Israel Aerospace Industries (IAI)	A USD 2 billion partnership to co-develop an anti-aircraft missile
DRDO	Ukrspecexport	Agreement for possibility of technology transfer, and joint designing and production of military equipment
DRDO	MBDA missiles	Co-development of a new range of Short Range Surface to Air Missiles (SRSAM) for the Indian Army

Industry – academia collaboration: In order to tap the intellectual capabilities of academia and speeding up developmental projects, DRDO has initiated a number of projects with academic institutes. Currently more than 100 academic institutes across the country are part of the DRDO academia network

- To bridge the technology gaps, DRDO has set up five Centers of Excellence (CoE) across key academic institutes. They include computational fluid dynamics centre at IISc, composite manufacturing at NAL and IIT Kanpur, aerospace design at IIT Mumbai, life sciences at Bharathiyar University, milimetric devices at University of Calcutta and high energy materials at University of Hyderabad.
- Setting up a research and innovation centre at IIT Madras, Research Park. This research center is another step towards increased industry-academia collaboration for research activities where the institute is expected to enable cost efficiency while developing innovative products and technology.
- Another initiative is the setting up of National Center of Aerospace and Innovation Research (NCAIR) at IIT Mumbai. It will work towards building an ecosystem for manufacture of aerospace components, with an aim to get 5-6 patents in 3 years. NCAIR is being sponsored by

the Department of Science and Technology (DST) and Boeing, with DST investing around USD 4.3 billion. Hindustan Aeronautics Ltd. (HAL), National Aerospace Laboratory (NAL), Tata and Larsen & Toubro are other companies involved with the project.

- DRDO will collaborate with National Institute of Technology Calicut (NITC) to carry out defence related futuristic frontline researches. The initiative is to develop new technologies and machine for defence, and will receive a funding of USD 0.5 million from DRDO for the projects under Extramural Research Scheme.
- It has established a practice of independent research boards to be chaired by experts in their respective fields. Focusing in the areas of aeronautics, armaments, naval sciences and life sciences, the boards will invite research proposals from independent and academic researchers.

GOVERNMENT INITIATIVES[42]

- **Policy implementation:**
  - Government has launched the Defence Production Policy 2010, which lays stress on reducing dependence on imports and enhancing domestic manufacturing. The policy aims to develop a strong indigenous base for defence. Some of the key parameters are:
    - Enhanced role of private sector for the first time to engage in R&D and manufacturing in the field.
    - Only those equipment will be imported which can't be developed indigenously in requisite timelines and are essential for meeting critical requirements
    - Separate fund for the public and private sectors including SMEs, to not only support innovation activities but also enhance cutting edge technologies in the defence sector.
  - To boost the defence R&D activities, the Government is setting up a new Defence Technology Commission

[42] New defence production policy to promote domestic industry, Deccan Herald, April 15, 2011;
Deloitte, Prospects for Global Defence Export Industry in Indian Defence Market, 2010;
KPMG, Unlocking the potential The Indian Aerospace and Defence Sector, 2011

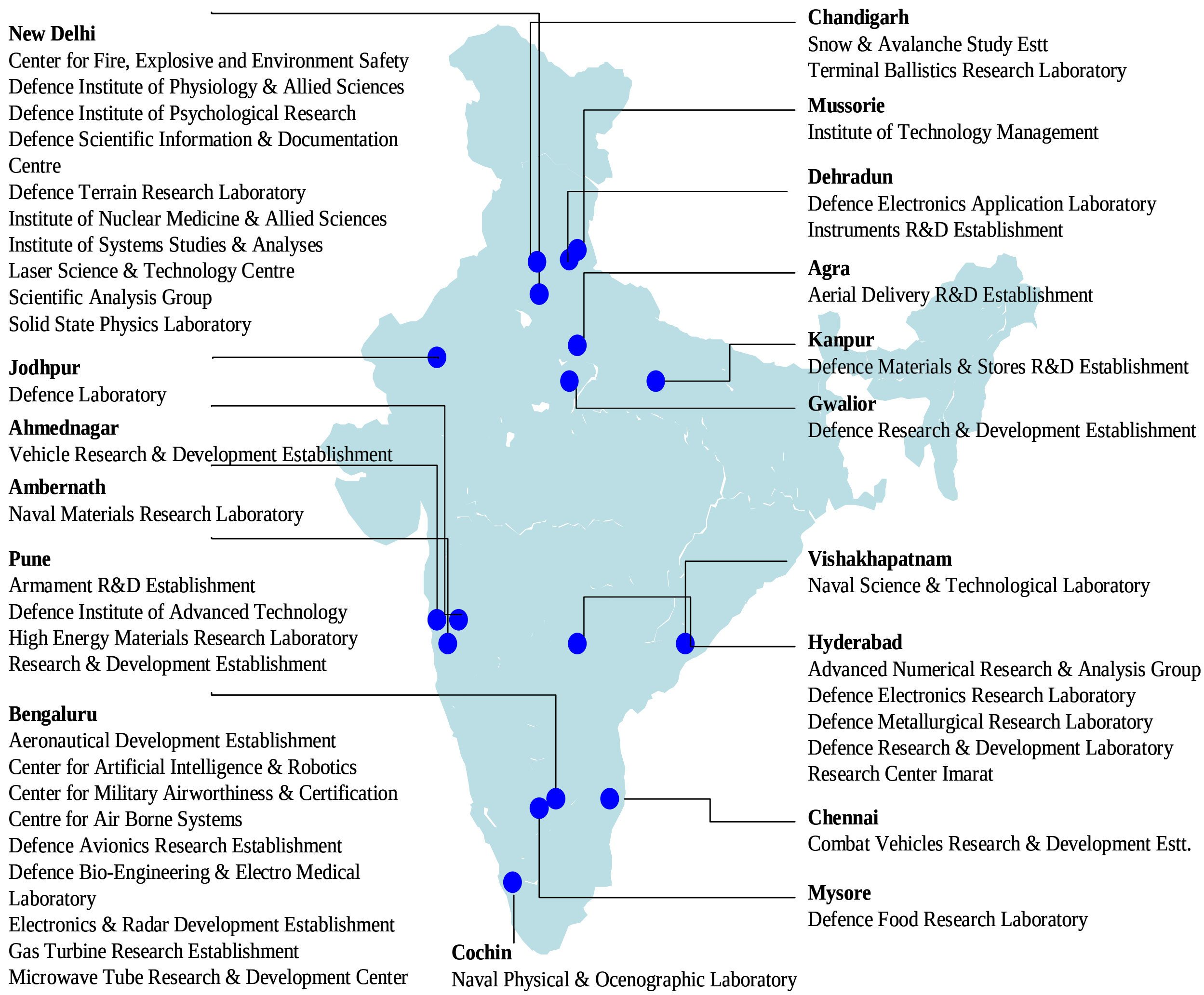
- The Defence Procurement Policy 2011 is considered to be a significant step by the government to boost foreign participation. **The policy is expected to encourage domestic companies to enter into foreign tie-ups for procuring latest technologies and improve manufacturing efficiency**.
- Another major initiative to boost domestic production is the offset obligations, which got a major boost in the Defence Procurement Policy, 2011. Offset contracts are policies imposed by the government for all foreign contracts/acquisitions to source a specific level of components from Indian companies. For all contracts where the cost of acquisition is more than USD 75 million. 30-50% is the offset obligation. This clause directly imposes a cost on the vendor. However, there are certain exemptions like acquisitions approved for FTP are exempt from offset obligation.

- **Tax incentives**: Other than the general tax benefits linked with SEZ and other activities, there are certain tax benefits for scientific activities which impact the defence industry.
  - Expenditure on scientific research gets 100% deduction for revenue and capital (other than land) expenditure, 200% weighted deduction for in-house scientific research and 125% of deduction on payments for research activities to an approved Indian company in scientific R&D
  - DPSUs and certain work centers are given complete exemption on customs duty and excise duty for import of defence equipment or parts needed for production of defence equipment
  - Sale of certain goods like telecommunication equipment, motor vehicles, arms such as rifles, revolvers, etc. to specified defence establishment enjoys exemptions on value added tax and central sales tax
- **Setting up R&D institutes:** The government wants to develop up to 90% indigenous capability in warship design and construction in the next 10 years. With this aim the government is setting up USD133.3 million, National Institute for Research and Development in Defence Shipbuilding (NIRDESH) at Chaliyam in Kerala. Set-up with a vision to promote indigenous R&D capabilities in warship and submarine design in for Indian Navy and Coast Guard, NIRDESH will be funded by Defence Department production as the four state-owned defense shipyards
- **Special Economic Zones (SEZs)**: Different state governments have taken steps to set up SEZs for design and manufacturing of aircrafts and defence equipment. Governments of Tamil Nadu, West Bengal, Maharashtra and Gujarat have already announced their plans for setting up such industrial

parks. SEZs help in creating an ecosystem with all facilities for promotion of research and manufacturing activities.

DRDO RESEARCH CENTERS

Figure 34: DRDO centers



OUTLOOK

The Indian defence industry is set on a high growth trajectory with continued focus from the government on strengthening the defence capabilities of the country. The focus is both on meeting the demands of the defence forces and building indigenous capabilities in defence research and manufacturing activities. Up until now, the responsibility for defence activities was borne by the public sector but now, the private sector is also stepping up its investment and participation in the industry. With government improving its regulations, the building blocks for greater presence of the private sector are being laid.

A first step in this regard will be to encourage the DPSUs to focus on their core capabilities and outsource the remaining activities to the private sector. SMEs will also play a major role in these outsourcing projects. This in turn will increase the competitiveness within the industry bringing better results. Private sector participation would also benefit the government in taking advantage of the inherent capabilities of the sector like IT and Manufacturing where the domestic companies have well established capabilities. It can leverage this strength to capitalize on high-tech engineering and research and design projects for the defence sector. This in turn can also enable India to become a global hub for the defence industry.

However, along with encouragement the government and related institutes also need to take a number of steps to facilitate the participation of the private sector and the foreign companies:

- The private sector needs to be given stimulus and provided with adequate provisions to play an active role in the defence R&D activities. The government needs to address the regulatory and tax disadvantages faced by the private sector in comparison to DPSUs and also provide funds for their R&D activities. For instance the government can provide tax holidays for defence R&D activities.
- Along with regulatory support the IP laws of the country needs to be strengthened to encourage foreign sector participation
- There is a need to develop focused and relevant skills specifically for the defence industry. The government, industry and the academia need to come together and work towards matching the skills with demand

The government's aim is to reverse the trend of 70% imports to domestic procurement. One of the major factors promoting self reliance is that during technology transfer from the foreign country, the latest technology never gets transferred. Industry experts are of the view that no country would like to part with their most modern technology in a strategic sector like defence. Hence, it has become essential for India to develop its own technological base for defence activities. However, at the same time, **most of the technological development would take place in collaboration with the foreign countries. India does not have the required capabilities in terms of funding, infrastructure and expertise to be at par with latest technologies. Thus India would look at foreign collaborations in order to step up its technological and equipment capabilities through a combination of outsourcing, technology transfer and manufacturing activities. European companies with advanced defence technologies or funding agencies can step in here to collaborate with Indian firms on defence R&D and manufacturing projects.** However, it needs to be ensured that these collaborations result in transfer of the sunrise technologies to the country and not outdated technologies.

12. SPACE

The India Space industry which is worth approximately USD 125 billion has made giant strides in the past several years due to its notable achievements in the fields of broadcasting and telecommunications and application of space technology. The space policies have been molded to facilitate national development and boost its growth as a commercial endeavor. The strong partnership with over 500 small, medium and large scale private industry players has helped the industry in dealing with complexities of advanced technology. It has facilitated the flow technology know-how and created space for delivering technical consultancy. The increased encouragement for private company participation in the industry has widened the opportunity of large international players looking to outsourcing manufacturing of critical components to set up captive units in India.

Today efforts are on to ramp up operations to move beyond development of the traditional satellites and venture onto new area like navigation. This has made India the most sought after space application driven program provider. Internationally, the Indian space industry is perceived as a fast emerging power by other already established space faring nations.

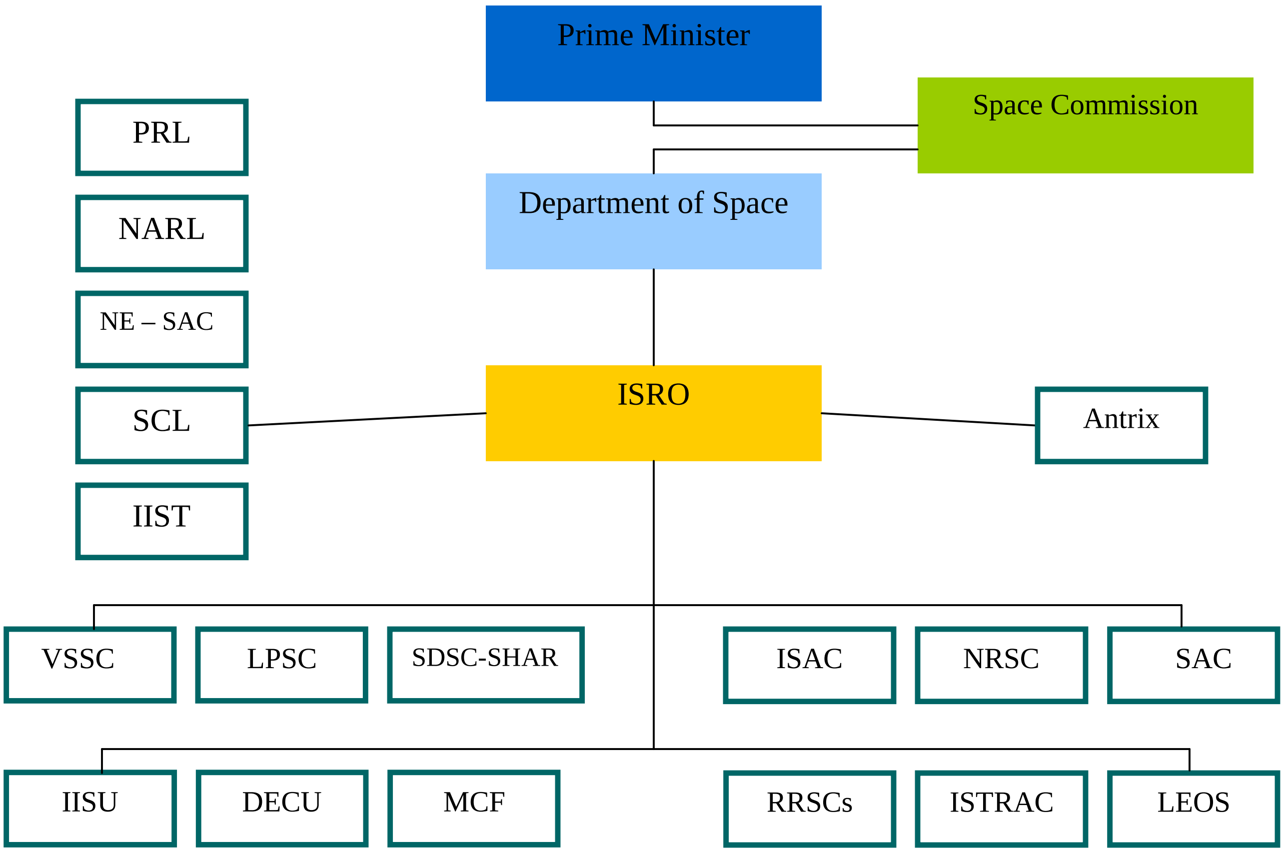
DEPARTMENT OF SPACE (DOS)

The primary objective of the Department of Science and Space Commission is the promotion and advancement of Space Science and Technology in India. The Space Commission formulates policies and handles the execution of the Indian space program. While the Department of Space puts these programs into action through organizations like the Indian Space Research Organization (ISRO), Physical Research Laboratory (PRL), National Atmospheric Research Laboratory (NARL), North Eastern-Space Applications Centre (NE-SAC) and Semi-Conductor Laboratory (SCL).

STRUCTURE OF DEPARTMENT OF SPACE[43]

Figure 35: Department of Space organisation

[43] Organisation Structure, http://www.isro.org/scripts/Aboutus.aspx



NRSC: National Remote Sensing Centre, **PRL**: Physical Research Laboratory, **NARL**: National Atmospheric Research Laboratory, **NE-SAC:** North Eastern Space Applications Centre, **SCL:** Semi-Conductor Laboratory, **ISRO**: Indian Space Research Organisation, **Antrix:** Antrix Corporation Limited, **VSSC:** Vikram Sarabahi Space Centre, **LPSC:** Liquid Propulsion Systems Centre, **SDSC:** Satish Dhawan Space Centre, **ISAC:** ISRO Satellite Centre, **SAC:** Space Applications Centre, **IISU:** ISRO Inertial Systems Unit, **DECU:** Development and Educational Communication Unit, **MSF:** Master Control Facility, **RRSSCs:** Regional Remote Sensing Service Centres, **ISTRAC:** ISRO Telemetry, Tracking and Command network, **LEOS:** Laboratory for Electro-optic systems, **IIST:** Indian Institute of Space Science and Technology

ISRO is the research wing of the Department of Space. It was established in August 1969 and bought under Department of Space in 1972. Its purpose is to develop and catalyze the advancement of space technology in the country. Antrix is the commercial arm of ISRO and deals in the marketing of space products and services to global organizations. In September 2008 the Government of India conferred it with the "Miniratna" status. The company reported a turnover of USD 200.61 million in 2009-2010 a 16.52% fall over the previous year due to capacity constraints.

ISRO ACTIVITIES

ISRO's activities comprise of development of three segments namely Satellites, Launch Vehicles and Ground System. The table below shows details of activities within each of these segments;

Table 28: Main segments and activities of ISRO

Satellite	Launch Vehicles	Ground Systems
• Geo-Stationary Satellites (INSAT) • Earth Observation Satellites (IRS) • Experimental & Small Satellites • Space Missions • Space Technology Application	• Polar Satellite Launch Vehicle (PSLV) • Geosynchronous Satellite Launch Vehicle (GSLV)	• Launch Facility • Tracking Facility • Data Reception & Dissemination • (National Remote Sensing Centre (NRSC)) • Data Analysis

Indian National Satellites (INSAT) and Indian Remote Sensing (IRS) are ISRO's two major satellite systems for communication services and management of rural resources respectively. Furthermore to launch these satellites in to orbit, specialized launch vehicles have been designed and developed like the Polar Satellite Launch Vehicle (PSLV) and Geostationary Satellite Launch Vehicle (GSLV). ISRO has build state of the art infrastructure ground facilities and is continually innovating technologies to develop advanced ground systems for future missions.

Space Technology Application

IRSO has used its space technology to extend healthcare, higher education and natural resources information services to the common man via its Telemedicine, Tele-education and VRC (Village Resource Centre) programs. These programs have directly benefited lives of millions of people irrespective of their location. Satellite derived information is also provided to the State and Central government for disaster management purposes.

INNOVATION IN INDIA

For the Indian space industry the major driver for innovations is the global scarcity of low-cost launching facilities. Since ISRO has proven capabilities in this particular area, the same proves to be a major opportunity for becoming a leading commercial player. Given this, ISRO now has to bring about balance between development of new technology to cater to the increasing demand of cost effective launches and its current focus of development of indigenous technology. **The need to develop indigenous technology**

arose from the restrictions imposed by technology transfer policies of different countries over the years. This in effect has bolstered the space R&D program in the country.

One of the key innovations from the space program has been the government's initiative to bridge the economic barrier in society by using the space program to make the benefits of space technology available to the common man. This has generated wide scope for ISRO to apply its acquired technology in various fields to bring about dissemination for different sectors.

R&D INITIATIVES

ISRO has undertaken various research projects in accordance with the policies and directives laid down by the Department of Science. These programs are carried out by the ISRO centers which are organized on the basis of specific areas of expertise and Grant-in-aid Institutes (whose R&D efforts are funded by the ISRO).

Table 29: Major Centers/Units of ISRO/DOS undertaking R&D initiatives:[44]

Centers/Units of DOS/ISRO	R&D Activities
Vikram Sarabhai Space Centre (VSSC)	Aeronautics, avionics, composites, computer & information, control, guidance & simulation, launch vehicle design, mechanical engineering; mechanisms, vehicle integration & testing, propellants, polymers, chemicals & materials, propulsion and systems reliability
Liquid Propulsion Systems Centre (LPSC)	Liquid and cryogenic propulsion stages for launch vehicles and satellites
Satish Dhawan Space Centre-SHAR (SDSC-SHAR)	Operational Centre for launching Sounding Rockets and Satellite Launch Vehicles
ISRO Satellite Centre (ISAC)	Satellite technology and satellite systems for scientific, technological and application missions.
Laboratory for Electro-Optics	Design, development and production of electro-optics sensors and

[44] Outcome Budget 2010-2011.pdf

Systems (LEOS)	cameras required for satellites and launch vehicles
Space Applications Centre (SAC)	Payloads for communication, meteorological and remote sensing satellites and space programs
Development & Educational Communication Unit (DECU)	Conceptualization, definition, planning, implementation and socio-economic evaluation of innovative developmental communications in space applications
National Remote Sensing Centre (NRSC)	Satellite data acquisition, processing and dissemination of aerials and remote sensing data

Grant-in-aid institutions of DOS:

- Physical Research Laboratory (PRL)
- National Atmospheric Research Laboratory (NARL)
- North-Eastern Space Applications Centre (NE-SAC)
- Semi-conductor Laboratory (SCL)
- Indian Institute of Space Science & Technology (IIST)

Apart from this ISRO has launched two major programs to support its R&D initiatives:

Sponsored Research: The "Sponsored Research Program (RESPOND)" run by ISRO is an important initiative of the DOS as it supports and sponsors research activities for various institutes through grants-in-aid. Through this program quality space research and educational activities are endorsed and supported by DOS at multiple levels including colleges, universities, research institutions as well as the IIT's. The annual estimated budget for the program is USD 3.4 million per year.

Technology Transfer (TT)[45]

The TT program is a well designed policy to transfer the usage of technology and other application crafted by Indian Space Centers for commercial purposes. The main purpose of the TT program is to support ISRO's R&D activities and to accomplish its goals set for advancement in space technology and completion of other set projects. So far approximately 294 technologies have been transferred by ISRO to

[45] ISRO Annual Report 2010 – 2011
www.isro.gov.in

industries in the domain of electronic, electro-optical mechanism, broadcasting, meteorology, etc. It has been investing in safeguarding its technology creation and has filed 268 patent applications till date of which 137 have patents have been granted to date.

TYPE OF INNOVATION

SATELLITES

- **Cost Effective Launching Services:** Given the high demand of low cost launching services ISRO is now in a race to develop cost efficient technology. ISRO increased its focus on this service to bring in the possibility of manufacturing small satellites for European satellites system. Some of the major competitors of ISRO in this area are Britain-based Surrey Satellite Technology Ltd, OHB Germany, and Thales Alenia in Europe.
- **Small Satellites:** There has been a significant rise in the launch of small satellites designed for specific purposes. The major reason for this is the flexibility they provide to include new innovative ideas and reduce mission risk due to lower costs. ISRO has encouraged academic institutes to design and develop several nano-satellites which can act as a testing medium for nascent technologies.
- **Satellite Communication and Navigation:** To free itself from the dependence on U.S. Global Positing System (GPS-Aided Geo Augmented Navigation) project, ISRO has undertaken the task of developing its own Navigation Satellite System. This system would provide the PNT (Position Navigation and Timing) service to India and its neighboring countries.
- **Space Applications:**
    - ISRO's space infrastructure has been used to provide vital services to the country and its satellite technology has been utilized for a range of scientific application. India today, is a global leader with one of the largest constellations of civilian remote sensing satellites. These earn significant revenues for the country by selling imageries. For eg: The remote sensing technology played a very important role in the creation of the satellite imaging tool "Bhuvan" developed to compete with the likes of "Google Earth" and "Wikimapia".
    - **India is recognized as a worldwide leader in deployment of space technology for social benefit. Several countries have approached ISRO seeking to use its space technology for**

alternate purposes. A recent example, France's interest in incorporating ISRO's space technology to help the fishing industry. Taking cue from the deployment of space technology to provide healthcare in remote locations of India they were keen to implement similar technology to search areas in the Atlantic Ocean for new schools of fish. The French government is eager to implement similar technologies to study natural calamities, deep sea exploration and ocean surface temperature measurement.

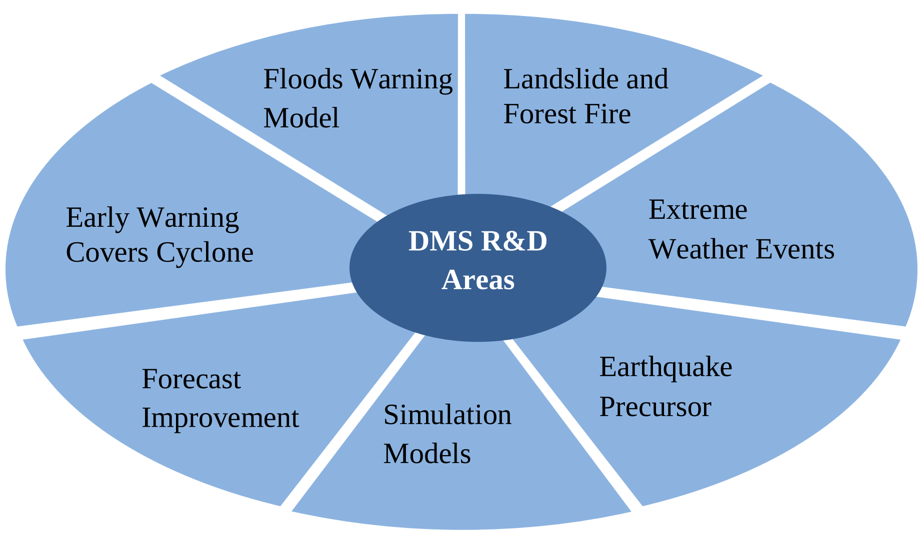
- **Disaster Management Program (DMS):** The DMS program of the Department of Space aims to cater to the nation's disaster related services by developing innovative technology in two specific areas:

  1. Developing constellation of Earth Observation (EO) satellites
  2. Village Resource Centre – focusing on local community disaster and emergency services

The benefits of developing new innovative technology for this program would result in creation of high-tech EO missions' which would benefit many local communities.

According to the 11th Five year plan proposal (2007 – 2012) the Department of Science has listed the following areas given below as the focus for R&D study in disaster management that would be conducted in association with the academia.

Figure 36: Focus areas



LAUNCH VEHICLES

The GSLV Quest: ISRO has spent decades and millions of dollars trying to master the cryogenic rocket technology in the GSLV project in an effort to contest with the launch capabilities of other top space agencies. The launch of this vehicle will be a landmark for the Indian Space Industry and will help materializing ISRO's plan to provide low-cost satellite launch services. So far, India has been completely dependent on Russian engines but wants to attain self reliance. ISRO has undertaken several innovative steps in modifying its infrastructure to accommodate the GSLV project by re-designing facilities previously built for PSLV. Unfortunately all previous attempts at launching this highly complex technology have ended in a failure and left ISRO grappling with delays. Undeterred by the string of failure ISRO scientists have analyzed data from previous failed launches and are continuing their work on the GSLV. This technology would enable them to directly tap the heavy satellite launch market. In this view, ISRO is currently developing the GSLV – Mark III scheduled for launch in 2012.

SPACE MISSIONS

Manned Mission: [46]A human space mission is on the charts as ISRO plans to put 2 human beings in orbit around the planet. This project currently doesn't have a set timeframe but the Institute of Aerospace Medicine has been given USD 2 million to conduct research.

Chandrayan – 2: The successful launch of Chandrayan 1, India's unmanned lunar mission satellite has secured a place for the country in the select club that has undertaken similar lunar missions. India received acknowledgment from international scientists including NASA for its publication on the findings of significant amount of water on the lunar surface. Following the successful of Chandrayan-1 ISRO has now planned Chandrayan-2 Lander/Rover to be launch in 2013. Collaborating with the Russia's Federal Space Agency (Roskosmos) which would be providing the landing module and research equipment this mission aims to study the moon's Polar Regions. Development of the system requirements of the rover and orbiter are currently in progress at the ISRO centers in Ahmedabad, Bengaluru and Thiruvananthapuram.

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[46] 'ISRO allocates Rs 9 cr for manned mission research' Jagran Post, 19 Jan 2011

DRIVERS FOR INNOVATION

INCREASED DEMAND FOR LOW COST LAUNCHES[47]

ISRO has exhibited praiseworthy track record in low-cost launch services. It can deliver a space satellite in about 28 months compared to the 30 months global average from the date of placing an order. It is currently aiming to capitalize on the increasing demand of low cost services and become a major player in the global space industry supply chain. ISRO offers satellites at a cost range of INR 1.7 – 2.6 billon and PSLV's launches at a cost of approximately INR 0.8 billion. Many countries that lack the technology know-how of launch satellites are seeking to tie up with ISRO.

Different variant of PSLV and GSLV projects are currently being developed which will enable ISRO to compete in the global commercial launch market and help attract more clients for its cost effective services. ISRO's cost cutting measures include developing new air-breathing engines, alternate fuel testing, study and development of reusable launch vehicles.

SMALL SATELLITES – OPPORTUNITIES IN COMMUNICATION AND REMOTE SENSING [48]

Indian universities are being encouraged by ISRO to build small satellites to be launched by its PSLV. Students from the nation and international are being attracted toward the concept of space technology and the opportunity of having their space project launched via 'piggybacking' facilities. Educational institutes like IIST, IIT – Kanpur and Mumbai, Satyabhama and VIT, etc, are currently in the process of building such satellites. This institutional/academic collaboration is being utilized by ISRO to make up for the deficit of transponder capacity by using these small satellites to boost its capacity. These satellites are also being considered for civilian applications and utilizing its technologies for military and security related applications.

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[47] 'Deloitte - Overview of Indian Space Sector 2010.pdf'
[48] 'Swarms of satellites possible: ISRO', Zee News, 05 Jan 2011

TRANSPONDER DEMAND – BOOMING DTH INDUSTRY [49]

The Direct to Home (DTH) industry is a major customer of ISRO transponder leasing business. According to the recent RNCOS research report DTH subscriber base in the country in 2011-2013 is expected to grow up at a CAGR of around 14%. ISRO is at present marred by an acute shortage of transponders which is temporarily provided for from International satellite operators. Keeping in mind the demand it will be essential for ISRO to generate new innovation technology to increase its transponder capacity to 500 as intended in its 11th plan.

EMERGENCE OF MIDDLE CLASS

India's growing population and emerging middle class has led to vibrant consumer market and would increase the scope for space technology to meet with their varying demands. Also emerging markets are demanding low cost innovation, owing to which ISRO is in a race to collaborate with private companies to come up with innovative technologies to capitalize on this trend. It has gauged the need to build more PSLV and GSLV to sustain the scores of satellites in space. P**rivate companies have expressed their eagerness to work in partnership with ISRO need to come up with innovative high end technology.**

CHALLENGES FOR INNOVATION

HIGH ATTRITION RATE[50]

As of 1st April 2010, ISRO boasts of staff capacity of 12,517 in its scientific and technical category and 5,732 in administrative category. ISRO selects its engineer and scientist through a stringent recruitment

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[49] India to Witness Remarkable Growth in DTH Subscriber's Base', AnyRelease.com, 28 Jan 2011

[50] 'ISRO Annual Report 2010 – 2011'

program and provides them with vigorous training molding them into value assets for the space organization. Over the years, especially after the IT boom, ISRO has been plagued by a persistent problem of its scientists exiting for the private sector. Higher pay package is cited as the major reason for the high attrition rate. The Government is combating this issue by providing its staff with incentives for equal opportunity for training and career progression.

HIGH FAILURE RATE[51]

ISRO has struggled to bring back the faith in its launch system due to the high failure rate of its missions. While IRSO's failure rate during experimentation of a new rocket launch can be accommodated, the failed mission of more advanced rockets is a major cause of concern. An example would be the consistent failure of the ongoing GSLV program. The cause of these failures seems to differ for different launches which imply a hitch in several sub-systems thus making it difficult to sort out the issue. ISRO is making an effort to bring down its failure rate to 10% which is as per industry standards. It aims to cut down its failure rate to 1% in the next ten years.

RESRTICTED SPACE BUDGET

There is a belief in the Indian space industry that they do not receive recognition in the manner it is hailed in other countries. The scientists are constantly lobbying for more funding from the government to initiate new programs and projects. Although the space budget has been increasing on a consistent basis at a higher rate as compared to other nations, only 3% of the budget is spent on advanced research and the rest is utilized for developing space technologies and facilities to benefit the nation. **Increased funding is required from private companies and investor community for projects as ISRO plans on competing and conquering international space market.**

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[51] 'Big Increase for Indian Research Is Not Good Enough, Say Scientists', American Association for the Advancement of Science, 28 Feb 2011
'Indonauts Must Wait For A Better Rocket' 13 Jan 2011
'ISRO trying to reduce failure rate in launches', Outlook India, 26 Sept 2007

INTROVERTED SPACE POLICY

The current space policy adopted by the Indian space industry limits private company participation only to outsourcing component manufacturing and technology development**. There is a need for the government to enforce a more extrovert policy and create a business atmosphere to encourage entrepreneurs to participate and compete in the international space market.** New entrants in the market will ensure development of breakthrough innovations necessary to continue the growth curve.

GOVERNMENT INITAITIVES

SPACE POLICY

ISRO being India's sole space industry player has always tried to balance its goal between becoming a leading commercial player in the global market and working toward bringing self-reliance to the nation. In view of this, the existing space policy can be viewed as a protectionist policy which is presently limited to only facilitating the outsourcing business between the space industry and the private players.

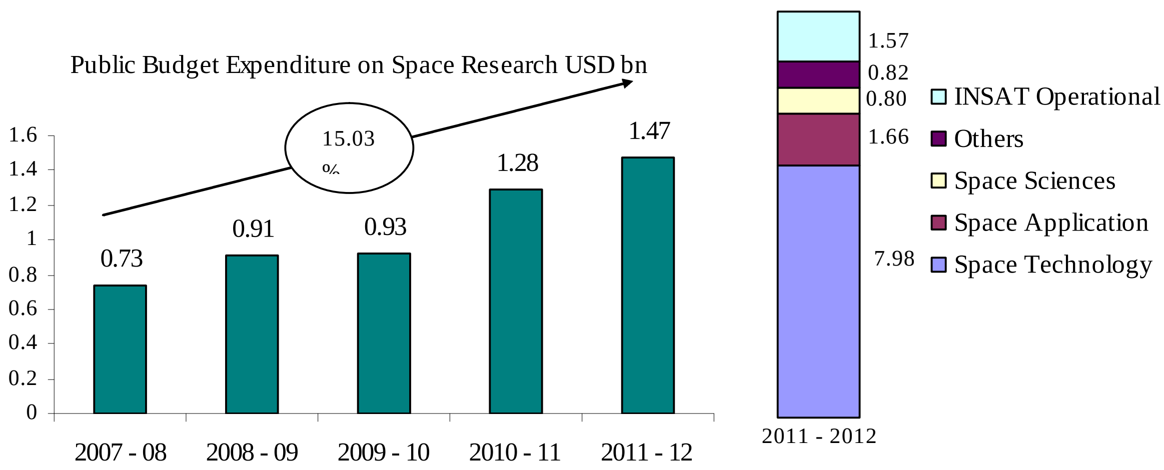
The SATCOM policy is instrumental in setting up the procedure for private Indian companies seeking to set up an Indian Satellite System (ISS). Agrani a Zee Group/Dish TV venture is the only ISS in India setup with the sole objective of establishing and operating a satellite system. **The policy restricts the use of foreign satellites under a condition that it would have to be coordinated with an Indian satellite**. **A foreign company seeking to enter India's satellite market can do so by providing bandwidth capacity through transponder leasing via ISRO.** This is a time consuming process requiring clearance which has no guarantee of approval from the Indian regulatory authorities because If adequate capacity is available in the Indian Satellite System use of foreign satellite is not permitted. Foreign companies such as SES Americom, Asiasat, and New Skies have provided services to the Indian market.

FUNDING:[52]

[52] 'Indian Space Budget Boost Supports Existing Programs', Space News,

The Government of India finances approximately 80% of India's investment in research and development in various industries. ISRO's R&D is fully funded by the state. The 2011-2012 budget allocated is approximately USD 1.47 billion representing a 36% jump over the revised estimate of USD 1.28 billion of last year's budget.

Chart 44: Budget Expenditure on space research



**Figures are Budget Estimated*

ISRO has always catered to the nation's day to day needs of communication, disaster management, broadcasting, etc and even today most of its budget is directed towards the development of space technology to benefit the nation. A sizeable amount has been directed to fuel its plans of becoming a leading commercial player for building its satellite launch services. Currently ISRO is venturing on a more ambitious and challenging journey into deep space exploration. Hence, approximately USD 14.8 million has been allotted for the India's manned and the lunar mission Chandrayaan-2 being developed jointly with Russia scheduled for launch in 2013.

TAX INCENTIVES FOR R&D ACTIVITIES[53]

Expenditure on Scientific Research

- Revenue expenditure and capital expenditure on scientific research faces 100% deduction
- In-house scientific research availed to good manufacturing and production companies faces 200% weighted deduction

[53] 'Deloitte - Overview of Indian Space Sector 2010.pdf'

- Payments for research services to approved Indian firm in scientific R&D faces 125% deduction

Research and development (R&D) Cess

- R&D Cess @ 5% is charged on import of technology by an industrial concern into India.
- In certain cases the R&D Cess can be adjusted against service tax liability.

INTERNATIONAL COLLABORATIONS

ISRO- INDIAN PRIVATE COMPANIES

The Government of Indian and ISRO has been aggressive in promoting private industry involvement in the space program by adopting the Industry participation policy. This partnership has helped ISRO deal with challenges regarding technology and manufacturing. ISRO handles most of the R&D for satellites via in-house facilities. Approximately 20 – 25% of hardware supply is outsourced to private companies. Aerospace companies like Taneja Aerospace and Aviation (Taal) provides electronic and avionic components to ISRO. Similarly major technology firms like Wipro, Infosys and TCS are in talks to provide engineering design services. Since ISRO's project in the next 10 years will demand a major supply of components and technology the commercial-aerospace industry is bound to play a major role in the space development program.

ISRO- FOREIGN PRIVATE COMPANIES

Numerous space projects have been undertaken and completed with the co-operation of foreign companies and space agencies. ISRO continually seeks assistance from private companies as partners for the development of several technologies. **Through these partnerships the foreign companies can make the most of the low cost base, huge supplier base, educated pool, low cost skilled workforce, IT manpower, and technology that the Indian industry has to offer.** This provides great opportunities for European companies to actively seek participation in the field.

ISRO – INTERNATIONAL SPACE AGENCIES

Over the year's ISRO has laid immense importance on building multilateral relations with global space agencies. **These collaborations are undertaken with a view to engage in new scientific and technological challenges, study international policies and frameworks for exploitation, make use of**

outer space for peaceful purposes, etc. Previous international collaborations with countries like U.S., Europe has helped cement India's image in the global space industry.

International space organizations are keen on partnering with ISRO to capitalize on its capabilities in space communications, navigation and space transportation systems. But these collaborations are limited to space exploration and space sciences as competition in the technology area is very high. Thus sharing of essential technologies that are needed is highly unlikely and ISRO is continuing to develop its indigenous technologies. A major benefit of strong international links are that it helps ISRO exchange and purchase certain space products from the international market depending on the strength and cost effectiveness of the product.

ISRO – United States Government

- The US Government has recently lifted its 13 year old curb on export of high-tech, dual-use items to the Indian space and defense industry
- Removal of ISRO from the "Entity List" will facilitate smooth trade of hi-tech technology between the nations
- Increased collaborations with National Aeronautics and Space Administration (NASA) with help ISRO sharing vital data and take on several more research projects jointly.

ISRO – European Agencies

- French government considers doing business with India in the space and nuclear arena as a major priority
- Emphasis on ISRO launching several more European satellites and increase business with the European Union
- Currently European spacecraft manufacturers seem to be developing "ITAR-free" [54]models which puts ISRO at a major gain
- France wants to partner with ISRO to minimize the monopoly of other major international space agencies in the industry

Table 30: List of Recent Collaborations can be seen in Appendix I

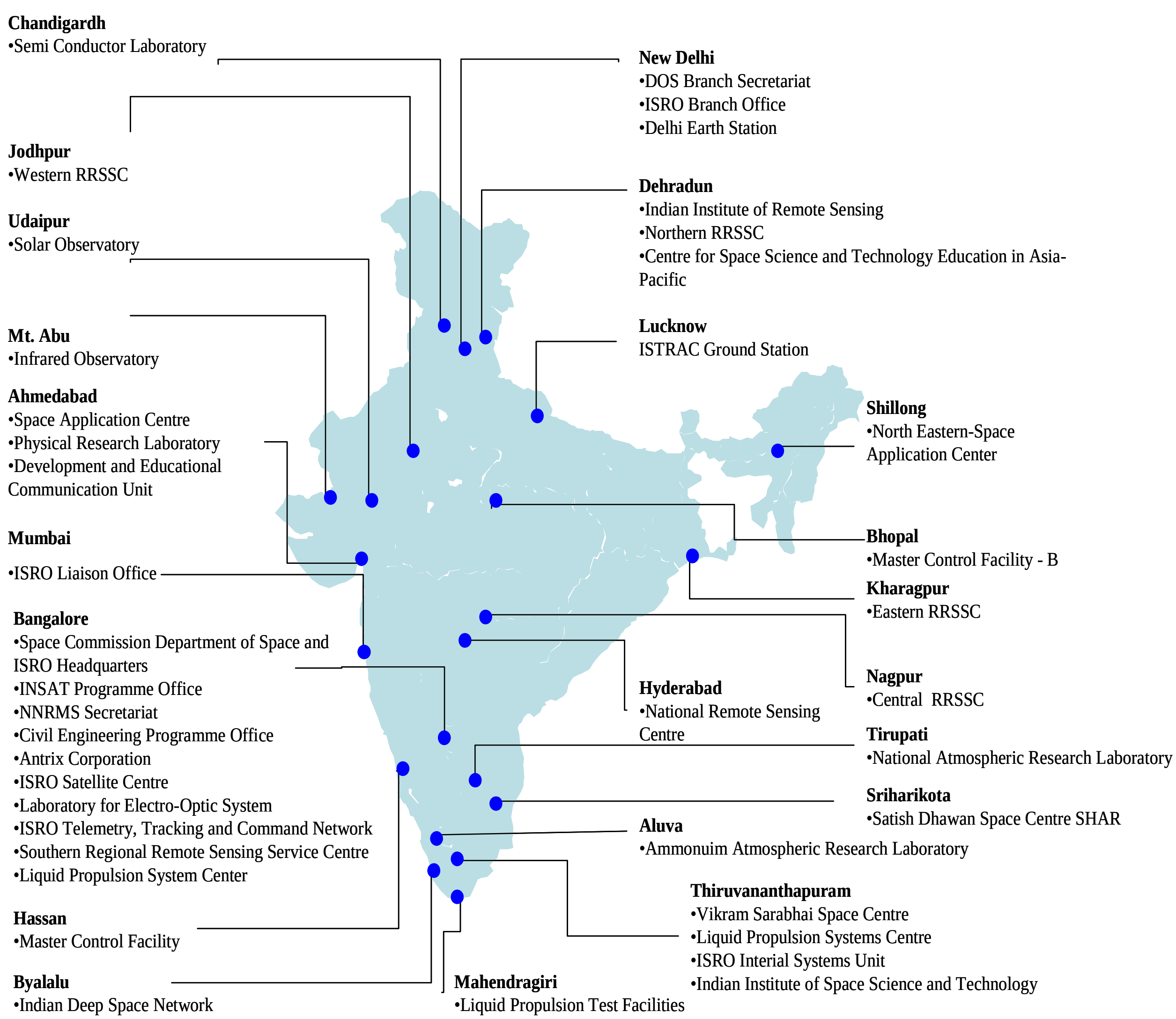
[54] ITAR - Government regulations that control the import and export of defense-related services on the United States Munitions List (USML) set by the United States.

Agreements of Government of India with other Nations	
Brunei	Telemetry tracking and tele-command station for satellite and launch vehicles and co-operation in space research, science and applications
Brazil	Augmentation of a Brazilian earth station for receiving and processing data from IRS Satellites
United States of America	Technology Safeguards at all facilities under the jurisdiction and/or control of the Government of India associated with the launch of US licensed spacecraft.
Mauritius	Establishment of telemetry, tracking and tele-command station for satellites and launch vehicles and for cooperation in the fields of space research, science and applications
France, Egypt, Argentina	Peaceful Uses Of Outer Space
ISRO - International Space Agencies	
Japan Aerospace Exploration Agency (JAXA)	Space X-Ray observations
The Agenzia Spaziale Italiana	Flying ROSA Instrument on Megha-Tropiques Satellite.
Federal Space Agency of Russia	Field of Joint Moon Exploration
Canadian Space Agency	Development of the Ultraviolet Imaging Telescope (UVIT) planned on ISRO's multi wavelength astronomy satellite ASTROSAT
ISRO - French Space Agency (CNES)	**Megha-Tropiques Satellite** • Facilitate the understanding of tropical weather and climate dynamics to water-cycle mechanism in tropical atmosphere. • It will be integrated in the virtual satellite constellation for the Global Precipitation Measurement (GPM) by ISRO, CNES and NASA to facilitate better understanding of global climate system

	SARAL Satellite: To conduct study of the ocean surface and 'ARGOS' a data collection platform.
ISRO - Russian Universities	**YOUTHSAT Satellite:** A joint development presently under progress by Indian and Russian universities to encourage academic contribution

ISRO CENTERS - LOCATIONS

Figure 37: ISRO centers



OUTLOOK

The Indian Space industry is poised on a growth path and currently is experiencing a major push towards next-generation products and services. This increase in demand is causing ISRO to extend and encourage more private industry participation in the space program. Industries are playing a major role in providing space-based services such as DTH television, Geospatial information and VSAT networks by using ISRO's technologies.

The industry currently requires strong private sector partnership in the area of space R&D where the risks undertaken are high. Also the investments require a long term view as the gestation period of technology development is large. **Thus in the next few years there could be significant scope for integrations and consolidation within the industry.**

India's satellite manufacture and launch market is on an upward swing since it is developing next stage satellite launchers and plans to launch approximately 30 satellites in the next decade. ISRO has been constantly teaming up with universities and many educational institutes encouraging R&D in satellite development especially small and pico satellites. Currently major R&D and investment as being diverted toward deep space exploration mission like lunar mission, Human Spaceflight Program, etc which assure of high returns but not without undertaking high risks. The risks to be dealt with range from technological, commercial, industrial, financial, legal / legislative and insurance in particular.

As ISRO takes on more ambitious projects European private companies and venture capital firms can help share the risk by investing/ funding and entering the Space Business.

13. CONCLUSION

PRESENT SCENARIO

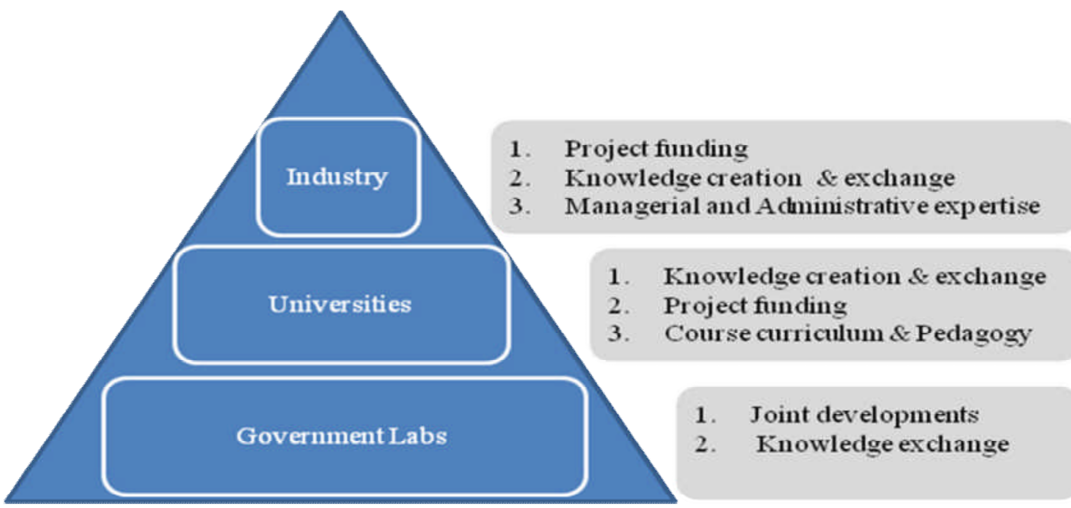
India is at the cusp of major transformation as one of world's largest economy with its democratic structure acting both as an enabler and impediment. The country has been growing at a break neck speed since economic liberalization which has led to the emergence of a dynamic economy with significant demographic transformations. With unabated growth continuing, India faces a multitude of problems in order to bring its large population within the ambit of prosperity. Successive governments have tried balancing between economic and social development but has only succeeded moderately. In the present circumstance the government is focused on developing India as knowledge based economy by means of expanding R&D activities in different sectors while simultaneously creating an environment where innovators can thrive. Several initiatives like SIBRI, INSPIRE and other programs to promote innovation have been undertaken at different levels which needs to percolate down further. With the formation of the 'National innovation Council' these initiatives are to be brought under single stewardship to provide direction and build necessary ecosystem. The roadmap charted out for 2010-2020 is to cascade down promotion of innovation to state level and further to sectoral levels and be able to reach out to a wider spectrum of applications and more grass root level.

OPPORTUNITIES & WAYS TO ENGAGE

The evolution of the Indian economy and the market has been the centre of many debates and discussion across various forums around the world. The diversity and the demographic complexity of the country provides unique opportunities for domestic and international organisations to innovate, co develop to expand existing products and services offerings. The sheer size of the untapped market also referred to as the 'bottom of the pyramid' is mind boggling. Almost all organisations operating in India have a keen eye on this segment and want to tap the potential of the hitherto unaddressed population. On one hand, products like the USD 2500 car 'Nano' from TATA motors and mobile handsets costing as much as USD 30 from Nokia are good examples of frugal innovations while on the other hand concepts like 'e-choupal' by ITC and low cost ultrasound systems from GE Healthcare demonstrates the capabilities of IT adoption and precision manufacturing in the country. Opportunities lie at various levels for different stakeholders. The ability to harness this potential will depend on the extent of coordination between government agencies, industry, academia and the financing institutions which in its present state, leaves a lot to be desired.

For European agencies and TAFTIE member organisations too, there exists excellent opportunities at various levels within the innovation ecosystem in India. From ideation to co-development in the field of technology to knowledge exchange to manpower enhancement through improvement of course curriculum and pedagogy and project financing the possibilities are numerous. However, the success of the engagement will depend on the value proposition put forth to respective stakeholders and Indian counterparts. As per many experts, India currently requires combined expertise in several initiatives and they feel Europeans can fill the certain gaps where other countries haven't yet established critical mass. The figure below denotes possible areas of engagement with different types of organisations.

Figure 38: Possible areas of engagement



To be able to utilize its brand equity and advance its level of interaction, European agencies need to create better visibility of its offerings and establish a compelling value proposition amongst Indian counterparts. As a first step, promotions can be done through bilateral interactions, ministerial delegations, industry events and conferences. On establishing the foreground, individual stakeholders can be approached and collaborations solicited via formal channels. For government laboratories and universities approach can be made via respective ministerial departments of the central and state governments while for private industries approach can be made through industry bodies like CII, FICCI, ASSOCHAM or Chambers of commerce in different states. To tap into private universities, trust foundations or the management board of the same can be independently contacted.

FUTURE OUTLOOK

The process of globalization that has engulfed the world is irreversible. Different countries are coupled on to this phenomenon differently. For India, globalization is a part of its existence. Therefore, to survive, thrive and play an active role internationally the country needs to reinvent itself depending on external conditions. Given its current disposition, India has to step up technologically in order to remain relevant in international markets and bring development to its citizens. Taking cognizance of this reality, the current government has increased its focus on creating an ecosystem conducive for innovations. While the intent is novel, proper coordination between different stakeholders in executing the plan will be critical.

To be able to succeed in transforming the economy into a knowledge driven one, India needs stronger engagements with advanced countries in several areas which it needs to seek out aggressively. Both social and industrial enablers need to get built and for this the country needs assistance from the international community. All forces have to come together and in the right time to bring sustainable success. However, as most experts say, 'with all the chaos and the conundrum, the future of India in terms of its knowledge prowess seems bright'.

14. APPENDIX

APPENDIX I: GOVERNMENT SUPPORT FOR RESEARCH ACTIVITIES[55]

Direct financial support	
Department of Pharmaceuticals (DoP)	• Plans to set up INR 100 billion. venture capital fund which will provide funds for new drug discovery projects and biopharma products. 15% of the fund amount will be contributed by DoP and the rest would be raised from other interested investors. The funds would be raised in three phases INR 30 billion. in FY 2011-12; INR 50 billion by 2013 and the rest INR 20 billion by 2015
Department of Biotechnology (DBT)	• The budget of the department was INR 12.2 billion and INR 14.2 billion for FY 2011 and 2012 respectively. Out of this almost 30% is allocated for PPP activities • DBT operates three funding schemes Small Business Innovation Research Initiative (SBIRI), Biotechnology Industry Partnership Program (BIPP) and Biotechnology Industry Research and Assistance Program (BIRAP). The aim of these schemes is to encourage innovation activities, through PPP model. For the FY 2010 INR 1.2 billion was granted for all three schemes
CSIR	• New Millennium Indian Technology Leadership Initiative (NMITLI): Operates PPP model for research projects and provides grants and loans to companies
Tax Exemptions	
Government of India	• Additional weighted deduction of 200% for expenditure on in-house R&D • 125% weighted deduction for expenditure incurred towards outsourcing of R&D

[55] Jaya Prakash Pradhan, Partha Pratim Sahu, Defining the role of government in transnationalization efforts of Indian SMEs. A case study of Indian Pharmaceutical Industry, January 2008;
Biospectrum, India drives biotech innovation, October 7, 2010;
Business standard, Govt to step up pharma research in country, December 4, 2009;
PriceWaterhouseCoopers, Global Pharma Looks to India: Prospects for growth

	activities • Concession rate of 5% customs duty and zero countervailing duty (CVD) provided on import of specified items, by public-funded R&D institutes • For institutes registered with DSIR – Certain items for research, when domestically procured are exempted from excise duty • Exemption of service tax of 12.24% on clinical research services • Duty free import of pharmaceutical reference standards, analytical and specialty equipment for R&D and production for recognized pharma companies
Special Economic zones	
Government of India	• Apart from the general benefits available to all SEZs, pharma SEZ have certain additional benefits: o Proposal to exempt pharma SEZ from adhering to positive net foreign exchange obligation policy o Located in industrial areas which are in close proximity to chemical manufacturing companies and have developed infrastructure
Other schemes and programs	
Government of India	• Six new National Institutes of Pharmaceutical Education and Research (Nipers) are proposed to be set up and there is proposal to set up innovation center at each of these and encourage foreign collaboration o The first Niper at Mohali has association with the University of Helsinki, Finland for collaborative research programs in association with Systems Biologics Worldwide and Genzyme • Cold chains have been classified as an infrastructure sub-sector which will directly impact the pharma cold chain especially in semi-urban and rural areas
CSIR	• Open Source Drug Discovery (OSDD) program: to discover cost effective drugs for tuberculosis, through collaborative research

APPENDIX II: KEY COLLABORATIONS

Indian – Foreign company collaboration		
Company	**Collaboration**	**Collaboration details**
Dr. Reddy's Laboratories	ClinTec International	Joint development of an anti-cancer compound, DRF 1042, for use as potential treatment of various types of cancer.
Jubilant	AstraZeneca	Jubilant will develop a stream of new drug candidates for neurological and psychiatric diseases to AstraZeneca's preclinical pipeline. In return the company will get research funding, milestone payments and royalties
Jubilant	Eli Lilly	Collaboration since 2005 – discovered several pre clinical molecules
Merck	Wellcome Trust	Develop the MSD Wellcome Trust Hilleman Laboratories in Delhi with an investment of UK£90 million over the next 7 years. With around 60 researchers, the center will develop vaccines
Biocon Limited	Amylin Pharmaceuticals	Collaboration to jointly develop, make and market a novel peptide drug to treat diabetes.
Biocon Limited	Bristol Myers Squibb	Develop biosimilars in oncology
Biocon Limited	Amylin	Develop novel peptides for diabetes treatment
Biocon Limited	Vaccinex	Develop mABs and oncology products
Zydus Cadila	World Health Organization	Develop monoclonal antibody for treating rabies
Zydus Cadila	Prolong Pharmaceuticals	Develop a novel next generation PEG-EPO
Zydus Cadila	Eli Lilly & Company	Discover and develop new molecules in cardiovascular research

Piramal Life Sciences	Eli Lilly & Company	Collaboration in area of diabetes and metabolic disorders
Torrent Pharmaceutical	Astra Zenca	Aimed at discovering a novel drug for the treatment of hypertension
Indian – Foreign institute collaboration		
Institution	**Partnering institute**	**Collaboration details**
Indian Council of Medical Research	Helmholtz Association (HGF), Germany	Established Indo-German Science Centre for Infectious Diseases (IG-SCID) for scientific enquiry and research
INDOX (India's leading academic oncology network)	Oxford University, Sanofi-aventis	Agreement to conduct multi-phase oncology clinical and translational research
ABLE (Association of Biotechnology Led Enterprises)	BIOTECanada	A MoU was signed in 2006 for collaboration to develop technologies that benefit the people of both the countries
ABLE	Irish Bio Industry Association (IBIA)	Agreement for increased research and commercial collaboration in the biotech sectors of both the countries
ABLE	AusBiotech	The association aims to strengthen the relationship between the two countries and provide a common platform for companies, academic and research institutions

Industry – Academia collaboration	
Company	**Collaboration details**
Dr. Reddy's Laboratories	As part of its research program, the company enters into collaborations with leading institutions and laboratories. It has collaborated with the National Cancer Institute in Maryland, a part of the United States National Institutes of Health
Shanta Biotechnics	National Cancer institute, Bethesda, and John's Hopkins University collaborated with Shranta Biotechnics, to work towards the development of human pappiloma

	virus (HPV) vaccine
Dupont	Has a research program underway in collaboration with Indian Institute of Science (IISc) on life science, material science and polymers
Marvel Chemicals	It is partnering IIT Delhi in research on drug intermediaries

APPENDIX III: KEY INDUSTRY ASSOCIATIONS AND EVENTS

Industry Associations	
Organisation of Pharmaceutical Producers of India (OPPI)	http://www.indiaoppi.com
Indian Pharmaceutical Alliance (IPA)	http://www.ipapharma.org
Indian Drug Manufacturers' Association (IDMA)	http://www.idma-assn.org
Association of Biotechnology Led Enterprises (ABLE)	http://www.ableindia.in
All India Biotech Association (AIBA)	http://www.aibaonline.com
Pharmaceuticals Export Promotion Council (PHARMEXCIL)	http://www.pharmexcil.org
Bulk Drug Manufacturers Association (BDMA)	http://www.bdmai.org
The Confederation of Indian Pharmaceutical Industry (SSI)	http://www.cipi.in
Federation of Asian Biotech Associations (FABA)	http://www.biofaba.org
National Pharmaceutical Pricing Authority (NPPA)	http://www.nppaindia.nic.in
Association of Pharmaceutical Teachers of India (APTI)	http://www.aptiindia.org
Indian Pharma Machinery Manufacturers Association (IPMMA)	http://www.ipmma.org
Key Events	
BioAsia 2012 - The Global Biobusiness forum	http://www.bioasia.in/

BioInvest 2011	http://ableindia.in/
India Bio 2011	http://www.bangalorebio.in/
Bengaluru India Bio 201	http://www.bangaloreindiabio.in/
CPhi India 2011	http://pharmexcil.org/

APPENDIX I: KEY INDUSTRY ASSOCIATIONS AND EVENTS

Industry Associations	**Website**
Trade Association of Information Technology (TAIT)	http://www.tait-mumbai.com/
National Association of Software and Service Companies (NASSCOM)	http://www.nasscom.in/
Electronic and Computer Software Export Promotion Council (ESC)	http://www.escindia.in
Software Technology Parks (STPs)	http://www.stpi.in/
Manufactures Association of Information Technology (MAIT)	http://www.mait.com/
Computer Association of Eastern India	http://www.compassindia.com/
Association for Information Technology	http://www.ait4u.com/
Confederation of Indian Industries	http://www.ciionline.org/
The Cellular Operators Association of India	http://www.coai.com/

Events	
GFair-Mumbai	http://www.tradeshows-biz.com/trade_event/gfair-mumbai.html
Biz Expo - Hard Ware & Software Solutions Expo	http://www.biztradeshows.com/trade-events/bizexpo-hardwaresoftware-expo.html
Embedded Systems Conference Expo-Bengaluru	http://www.biztradeshows.com/trade-events/embedded-systems-conference-Bengaluru.html
Interop Mumbai	http://www.interop.in/registration.htm
ET Asia ITEX – Mumbai	http://www.tradeindia.com/TradeShows/36299/ET-Asia-ITEX-Mumbai.html
Franchise & Retail Opportunities Show Pune 2011	http://www.indobase.com/events/details/franchise-and-retail-opportunities-show-fro-2011-4270.php
Office Today	http://www.eventseye.com/fairs/f-office-today-10369-1.html
Broadcasting Expo	http://www.bvexpo.co.uk/page.cfm/ID=1
RFid India Expo	http://www.biztradeshows.com/trade-events/rfid-india-expo.html
Broadcast India	http://www.broadcastindiashow.com/
Import Expo India 2007	http://www.indobase.com/events/details/import-expo-india-2007.php
IT & Office Expo	http://www.theofficeexpo.com/about-office-expo-2011.html
ESC India-Bengaluru	http://www.tradeshows-biz.com/trade_event/esc-india-Bengaluru.html

APPENDIX I: KEY INDUSTRY ASSOCIATIONS AND EVENTS

Industry Associations	
Centre For Development Of Telematics (C-DoT)	www.cdot.com
Centre For Telecom Management Electronics & Telecommunications Engineering (IETE)	www.iete.org
Telecommunications Consultants India Limited (TCIL)	www.tcil-india.com
Advanced Level Telecommunication Training Centre (ALTTC)	www.alttc.bsnl.co.in
Telecom Equipment Manufacturers' Association (TEMA)	www.tfci.com/cni/tema.htm
TEC - Telecommunication Engineering Centre	www.dotindia.com/tec
Wireless Planning & Coordination Wing	www.wpc.dot.gov.in
Software Technology Park of India	www.stpi.in
Key Events	
India Telecom 2011	http://indiatelecom.org
VAS Asia 2011 - 10th International Conference & Exhibition	www.bharatexhibitions.com/
Mobile Payment India 2011 - 3rd International Conference	www.bharatexhibitions.com/
LTE India 2011 - 2nd International Conference	www.bharatexhibitions.com/
Mobile Advertising India 2011	www.bharatexhibitions.com/
6th CMAI India International Communication Fair 2011	www.cmai.asia/
India Connect 2011	www.esuppliersindia.com/

InfoComm 10-11	www.indiainfocom.com
TTH CAP Annual Conference	www.ftthcouncilap.org/
Managed Services India 2011 - 3rd International Conference	www.bharatexhibitions.com/
VAS India 2011 - 9th International Conference	www.bharatexhibitions.com/
Wireless Vitae 2011 - 2nd International Conference	www.bharatexhibitions.com/
LTE Summit 2011	www.cerebralbusiness.com/
19th Convergence India 2011, International Exhibition & Conference	www.convergenceindia.org/

APPENDIX I: TENTATIVE INITIATIVE UNDER AMP 2006-16

The AMP 2006-16 lists down the following measures to boost the Automotive industry

- Investment: Tariffs and Policies to boost investment in the Indian automotive sector
- Infrastructure: Develop road, rail, port and power infrastructure. Also create infrastructure for testing, certification & homologation and for automobile retailing & servicing
- Expansion of domestic demand
- Encouraging Exports
- **Support to develop R&D**
- Long-term emission roadmap
- Harmonization of Safety standards and road safety
- Incentivizing modernization of vehicle fleet
- Inspection & Certification: To curb the pollution from old or unmaintained vehicles
- Computerization of RTOs & drivers license
- Ensuring availability of human resources
- To set-up a monitoring committee, to keep a check on the progress of the AMP 2006-16.

The table below lists down the detailed initiatives under the plans to provide support to automotive R&D:

Infrastructure Support	The Government is making an investment of USD 380 million to Establish NATRIP. (Details mentioned under Government Initiatives)
Encouraging R&D in Academia	Modernization of lab facilities in IITs
	Modular programs to be initiated in IITs and IIMs
	Automotive Infotronics and Intelligent Transport Systems to be the areas of focus
Incentives for R&D on fuel	Innovation and R&D projects for fuel efficient vehicles and conversion / adoption of vehicles run on alternative fuels appropriate for Indian market will be encouraged

efficient/alternate fuel vehicles	and incentivized. In this regard, the option of consortium approach would be explored.
Alternative fuel R&D	Hydrogen is to be developed as future fuel. The National Hydrogen Energy Board has prepared National Hydrogen Energy Roadmap and will be coordinating various concerned agencies involved in R & D, development and commercialization in the area of hydrogen energy.
Tentative Tax concessions, grants/funding for R&D (The request for these incentives is being considered by the Ministry of Finance)	100% grant for fundamental research, 75% for pre-competitive technology / application and 50% for product development.
	Promoting technology acquisition (for manufacturing) through tax/ levy exemption. Zero taxes/levies on technology transfers (products, features, alternate fuel, etc.)
	Increased weighted deduction for expenditure incurred on R&D from 150% to 200%. The scope of deduction will be extended to all R&D expenditure whether incurred in-house or externally.
	Provide excise duty concession for "Made in India" products.
Synergize the following miscellaneous initiatives	Encourage collaborations for developing advanced machine tools and equipment for manufacturing; Support development of hybrid engines, advanced/cost-effective materials, design & styling; Support IT integration in manufacturing and development of auto-infotronics; Creating centers of automotive manufacturing excellence in IITs; Creation of Advanced Research Center to manage Indian automotive regulations; Creation of technology modernization Fund (with emphasis on SMEs)

APPENDIX II: COLLABORATIONS IN THE INDIAN AUTOMOTIVE INDUSTRY

Parties Involved		**Type/Purpose**
Collaborations by Indian OEMs		
Maruti Suzuki	Suzuki Motor corporation-Japan	Joint Venture
M&M	Renault, S.A, France	Joint Venture
Tata Motors	Fiat, Italy	Tie-up for manufacturing & marketing

		in India
	Sanyang Industry Co Ltd (SYM, Taiwan)	Technology tie-up
Kinetic Group	Italjet, Italy	Tie-up for manufacturing and distribution
Hero Group	Honda, Japan	Technology
Hero Cycles	Ultra Motor Company, U.K	Technology
	Kawasaki Heavy Industries Ltd., Japan	Engine Technology
	Tokya R&D Co. Ltd., Japan	Technology
Bajaj Auto	Kubota Corp., Japan	Technology
L&T Ltd.	Scania, Spain	Tie-up for marketing in India
	Hino, Japan	Engine Technology
	Irizar, Spain	Bus body Technology
	Nissan, Japan	LCVs
Ashok Leyland	ZF, Germany	Gearbox Technology
	Marco Polo, Brazil	Bus/Coach Technology
Tata Motors	Cummins, USA	Engine Technology
Collaborations for Auto components		
Amtek Auto Ltd., Gurgaon	Bendo Kogyo, Japan	Fly wheel ring gears
Jay Bharat Maruti Ltd., Gurgaon	Allied Signal, USA	Seat belts and Air bags
Subros Ltd., New Delhi	Allied Signal, USA	Catalytic converters
Mark Exhaust Systems Ltd., Gurgaon	Sankei Giken, In.Co., Japan	Exhaust Systems, Catalytic Converters
Atul Glass Industries Ltd., New	Saint Gobain Vitgrage,	Laminated Safety Glass

Delhi	France	
Menon Pistons Ltd., Kolhapur	Alcan Deutschland GmbH, Germany	Pistons & Piston Rings
Automotive Axles Ltd., Mysore	Rockwell International Corp., USA	Axle systems
Autolec Industries, Madras	Blue Chip Products Inc., USA	Water pumps
Spicer India Ltd., New Delhi	Dana Corp., USA	Engine bearings
Sona Steering Systems Ltd., New Delhi	Somic Ishikawa, Japan	Ball joints & Suspension joints
	Fedoro, UK	Asbestos free brake linings
	Matsuda Industries, Japan	Cold forging
Haryana Sheet Glass Ltd., Haryana	Pilkington Plc., UK	Laminated sheet glass
Tata Industries Ltd., Bombay	Johnson Controls Inc., USA	Seating systems
	Sommer Allibert, France	Interiors and Plastics
	Yazaki, Japan	Wiring harness
	ZF, Germany	Transmission of steering systems
	NIFCO, Japan	Plastic Fasteners
	ITT, USA	Brake systems, Electrical & wiper systems

APPENDIX III: LIST OF CORE GROUP OF AUTOMOTIVE R&D (CAR) PROJECTS[56]

Project	Parties involved - Academia	Parties involved – Industry
Low cost engine management system for two	IIT Bombay, IIT	TVS Motor Co., UCAL

[56] Technology Information, Forecasting and Assessment Council Website

wheeler (Completed)	Madras	Fuel Systems
Public transport telematics for vehicle tracking – using GPS/GSM technology (Completed)	IIT Bengaluru	Ashok Leyland, Lattice Bridge, Bharat Electronics Ltd., Pallavan Transport Consultancy Services
Public transport telematics for vehicle tracking – using Wifi (Ongoing)	Amrita Vishwa Vidyapeeth	NA
Hydroforming and Tailor-welded blanks processes for weight reduction of the vehicle (Ongoing)	Astra Research Centre India, IIT Bombay	Tata Motors, M&M, Tata Steel, ProSI
Process Development in Semisolid Forming and Squeeze Casting of Aluminium Alloy Components for Automobiles - to produce light weight components, with superior mechanical properties, higher integrity, and with potential for near net shape manufacturing. (Ongoing)	IISc. Bengaluru	Sundaram Clayton, TVS Motors, M&M
Low Cost Flexible Automation using Robotic Arms – to reduce the cost of automation in manufacturing (Ongoing)	IIT Madras, IIT Bombay	M/s. Systemantics India Pvt. Ltd., Magtorq, TVS Motor Co., M&M, Sona Koyo Steering Systems, TVS Lucas, Bosch Ltd.
Acoustic Diagnostics for 2 wheeler engine assembly line - The system will indicate possible types of defect in engines. (Ongoing)	IIT Kanpur , IIT Delhi, IIT- Allahabad,	Kritikal, Knowledge Online, and TVS Motor Co
Use of Straight Vegetable Oils in IC Engines (Ongoing)	IISc Bengaluru, IIT Madras	ICAT/ NATRIP (research organizations)
Developing a suitable material for Ultracapacitor for Electric and Hybrid Electric Vehicles (Ongoing)	IISc Bengaluru, IIT Kharagpur, National Chemical laboratory	Kaptronics Pvt. Ltd., NED Energy Ltd
Development of Automobile Components through	Advanced Materials	Brakes India Ltd. and

Electromagnetic Forming (EMF) Process (Ongoing)	and Processes Research Institute, IIT- Bombay, IIT- Delhi, Central Manufacturing Technology Institute & Institute for Plasma Research	Wheels India Ltd.
Electronic Stability Control System for Automotive Systems (New)	IIT Kanpur , IIT Bombay	Pricol, Tata Consulting Services, Apna Technologies , Tata Motors, M&M

APPENDIX IV: GEOGRAPHIC CLUSTER WISE STATISTICS

	Cluster	R&D		Installed Capacity		Gross Turnover	
		USD million	%	in numbers	%	USD million	%
Cars							
	North	25.76	4.3	1,056,500	27.2	6,308.13	24.9
	South	69.20	11.7	1,041,700	26.8	7,195.78	28.4
	West	497.62	84.0	1,784,305	46.0	11,792.00	46.6
	Sub-total	592.58	100.0	3,882,505	100.0	25,295.91	100.0
Motorcycles							
	North	7.27	13.6	6,891,500	48.2	4,055.71	53.5
	South	19.13	35.7	2,98,0000	20.8	980.98	12.9
	West	27.24	50.8	4,435,000	31.0	2,549.58	33.6
	Sub-total	53.64	100.0	14,306,500	100.0	7,586.27	100.0
Total							
	North	33.04	5.1	7,948,000	43.7	10,363.87	31.5
	South	88.33	13.7	4,021,700	22.1	8,176.73	24.9
	West	524.87	**81.2**	6,219,305	34.2	14,341.58	43.6

Grand total		646.22	100.0	18,189,005	100.0	32,882.18	100.0

Source: SIAM, Automotive Industry in India 2008-09

Share Of Top Five Regions (States Covered) In FDI Inflows For Automobile Industry (from January 2000 to December 2009):			
RBI Regional office	**State Covered**	**Amount of FDI (USD Millions)**	**%age with inflow for automobile industry**
Mumbai	Maharashtra, Dadra & Nagar Haveli, Daman & Diu	1,553.89	34.18
New Delhi	Delhi, Haryana, NCR in Uttar Pradesh	1,367.94	30.09
Ahmedabad	Gujarat	479.65	10.55
Chennai	Tamil Nadu, Pondicherry	447.57	9.84
Bengaluru	Karnataka	230.11	5.06
Total		**4079.16**	**89.72**

Source: Ministry of Commerce and industry, FDI in Automobile Industry (as on December 31, 2009)

APPENDIX V: LIST OF TOP AUTOMOTIVE SPENDERS ON R&D (2009-10)[57]

Company	R&D Expenditure (USD million)
Tata Motors	170.82
Ashok Leyland	44.96
TVS Motor Co.	21.79
Bajaj Auto	16.56
Eicher Motors Ltd.	13.19
Escorts India (Tractor Division)	6.96
International Tractors Ltd. (Sonalika Group)	4.49

[57] DSIR Annual report 2009-10: (Annexure 3) List of in-house R&D Units in industry reporting annual expenditure more than Rs 500 Lakh (USD 1.11 million)

Bajaj Tempo	4.39
Tractors and Farm Equipment Ltd.	3.86
Punjab Tractors	2.84

Company - Auto-component manufacturers	R&D Expenditure (USD million)
Motor Industry Co. Ltd.	6.61
Lucas TVS	5.16
Brakes India Ltd.	3.40
MRF Ltd.	2.70
UCAL Fuel Systems Ltd.	2.44
Bharat Forge	1.82

APPENDIX VI: KEY INDUSTRY ASSOCIATIONS AND EVENTS

Industry Associations	
The Automotive Component Manufacturers Association of India (ACMA)	http://www.acmainfo.com
Federation of Automobile Dealers Associations (FADA)	http://www.fadaweb.com
Society of Indian Automobile Manufacturers (SIAM)	http://www.siamindia.com
The Western India Automobile Association (WIAA)	http://www.wiaaindia.org
Automobile Association Of Upper India	http://www.aaui.org
Association of International Automobile Manufacturers, Inc (AIAM)	http://www.aiam.org
Automotive Research Association of India (ARAI)	https://www.araiindia.com
Key Events	
Tyrexpo India 2011	http://www.eci-international.com

Automotive Engineering Show 2011	http://www.indobase.com
2nd International Auto Show 2011	http://www.indobase.com
International Machine Tools & Auto Components Exhibition	http://www.acmee.in/
Auto Expo 2012	http://www.autoexpo.in
Automation 2011	http://www.biztradeshows.com
Automotive Testing Expo India 2012	http://www.testing-expo.com
Gears Motors & Controls Expo 2011	http://www.gmconline.in/
Motor Match 2011	http://www.motormatch.com
North East Auto Expo 2011	http://www.autoexponortheast.com/
Industry Automation & Control	http://www.chemtech-online.com
Busworld India 2011	http://www.busworld.org/
Surat Auto Expo 2011	http://www.biztradeshows.com

APPENDIX I: KEY INDUSTRY ASSOCIATIONS AND EVENTS

Industry Associations	
Indian Wind Energy Association	http://www.inwea.org
Indian Association of Energy Management Professionals	http://www.iaemp.org
Indian Wind Turbine Manufacturers Association (IWTMA)	http://www.indianwindpower.com
Solar Energy Society of India	http://www.sesi.in
The Independent Power Producers Association of India (IPPAI)	http://www.ippai.org
Indian Wind Power Association	http://www.windpro.org
Advanced Bioresidue Energy Technology Society (Abets)	http://cgpl.iisc.ernet.in/site/ABETS/tabid/60/Default.aspx
Cogeneration Association of India	http://www.cogenindia.org
Electrical Research and Development Association	http://www.erda.org
Key Events	
Renewable Energy India Expo	http://www.renewableenergyindiaexpo.com
Bio-Energy 2011	http://www.renewableenergyindia.org/reif-events/upcoming-events/
CableWire 2011	http://www.ieema.org/cablewire/
CAPACIT 2018	http://www.ieema.org/Contents/Events/Event_Show.aspx?k=6
EnerTech World Expo 2012	http://www.chemtech-online.com/events/enertech/index.html
GEO India 2011	http://www.geoindia2011.com

Hydropower 2011	http://www.renewableenergyindia.org/reif-events/upcoming-events/
HydroVision India 2011	http://www.hydropowerindia.com
IBRX India 2012	http://www.bfi.org.in/
IET Chennai 2nd International Conference SEISCON 2011	http://seiscon.ietypschennai.org
India Electricity-2011	http://www.indiaelectricity.in/
India Nuclear Energy 2011	http://www.indianuclearenergy.net/introduction.htm
International Conference on Energy, Water & Environment	http://www.interscience.ac.in/ICEWE/icewe.html
National Energy Investment Summit 2011	http://nationalenergysummit.com/EventContent/Home.aspx?id=130&new=1
Power India 2011	http://www.indobase.com/events/details/power-india-2008-1348.php
POWER-GEN India & Central Asia	http://www.power-genindia.com/index.html
PV+Solar India Expo 2011	http://www.electronicstoday.org/solar/2011/solarindiaexpo2011.htm
Renewable Energy World India	http://www.renewableenergyworldindia.com
RenewCon Solar India 2011	http://www.renewconsolar-india.com/
Waste2Energy 2011	http://www.indobase.com/events/details/waste2energy-2011-3817.php
Wind Power India 2011	http://www.windpowerindia.in/

NANOTECHNOLOGY

APPENDIX I: PROJECTS SANCTIONED BY DST, YEAR: 2009-2010

Sr.No.	Sanction No.	Project Title	PI& Add
1	SR/NM/NS-09/2007	Quasistatic and Ultra fast Magnetization Dynamics in Nano magnet Arrays	Dr. Anjan Barman S.N. Bose National Centre for Basic Sciences Block – JD Sector-III, Salt Lake Kolkatta – 700 098
2	SR/NM/NS-20/2008	Computational nano-Engineering of Patterned Nanostructures	Dr. Arti Kashyap The LNM Institute of Information Technology Rupa Ki Nangal Sumel Jaipur – 303012
3	SR/NM/NS-49/2007	Electronic Structure of Semiconductor Nanostructures	Dr. Pranav Sarkar Department of Chemistry Visva Baharati Santiniketan – 731235
4	SR/NM/NS-28/2008	Synthesis of Functionalized Gold Nanoparticles and their Self-Assembly on Electrode Substrates for Sensing of Biomolecules	Dr. S. Abraham John Department of Chemistry Gandhigram Rural University Gandhigram – 624302 Tamilnadu
5	SR/NM/NS-58/2008	Development of magneto resistive thin film sensor for magnetic field sensing applications	Dr. Prasanta Chowdhury Surface Engineering Division National Aerospace Laboratories Post Bag No. 1779 Hal Airport Road Bengaluru – 560017

6	SR/NM/NS-38/2008	Multimodal nanodot imaging probes as contrast enhancing agents for MRI and as optical probes for fluorescence imaging towards cancer diagnosis	Dr. V. Alexander Department of Chemistry Loyola College, Chennai – 600034
7	SR/NM/NS-37/2008	Deformation mechanisms of nanoparticles through in situ Transmission Electron Microscope	Dr. M.S. Bobji Department of Mechanical Engineering Indian institute of Sciences Bengaluru – 560012
8	SR/NM/NS-84/2008	Electrochemical synthesis of nanowires and their characterization	Dr. Sanjeev Kumar Department of Physics, University College of Engineering Punjabi University Patiala – 147002
9	SR/NM/NS-40/2008	Preparation of core-shell structure of silica (SiO_2)-coated Cadmium Sulphide (Cds) nanocomposites by size-selective photo etching and study of photo catalytic organic syntheses reactions	Dr. Bonamali Pal School of Chemistry and Biochemistry Thapar University Patiala – 147004
10	SR/NM/NS-13/2007	Studies on chemical synthesis of peptidomimetics based self assembling organic nanotubes and application of carbon nanotubes in peptidomimetics synthesis	Dr. V.V. Suresh Babu Department of Studies in Chemistry Central College Campus Bengaluru University Bengaluru – 560001
11	SR/NM/NS-42/2008	Motor and cognitive behaviour in 6-hydroxydopamine (6-OHDA) Adult rat model of Parkinson's disease following magnetic field exposure and implantation of ferromagnetic nanoparticles	Dr. Suman Jain D/o Physiology All India Institute of Medical Sciences Ansari Nagar New Delhi – 110029
12	SR/NM/NS-55/2008	Current-voltage characteristics of semi conducting Nanoparticles	Dr. Amlan J.Pal Department of Solid State Physics Indian Association for the Cultivation of Science

			Jadavpur ,Kolkata – 700032
13	SR/NM/NS-52/2008	Controlled Drug Delivery using Layer-by-Layer Self-Assembly on Magnetic PLGA Nanoparticles using Dual Drug Regimen for Breast Cancer Therapy	Dr. Rohit srivastava School of Biosciences and Bioengineering Indian Institute of Technology – Bombay, Powai Mumbai – 400076
14	SR/NM/NS-80/2008	Studies on Protein-Metal Colloid Interactions by Raman spectroscopy	Dr. Rohit srivastava School of Biosciences and Bioengineering Indian Institute of Technology – Bombay, Powai Mumbai – 400076
15	SR/NM/NS-98/2008	Development of Direct Glucose Fuel Cell based on metal electro-catalystelectrodes	Dr. Suddhasatwa basu Department of Chemical Engineering Indian Institute of technology – Delhi ,Hauz Khas New Delhi – 110016
16	SR/NM/NS-66/2008	Synthesis of nanostructure metals/metal oxides for catalysis/photo catalysis	Dr. Tarun K. Mandal Polymer sience Unit & Centre for Advance materials Indian Association of the Cultivation of Science 2A & B Raja S.C. Mullick Road Jadavpur Kolkata 700032
17	SR/NM/NS-42/2009	Nano Science Unit at Indian Institute of Science Education & Research – Pune (IISER-Pune)	Dr. Sulabha Kulkarni Indian Institute of Science Education & Research Pune 900 NCL Innovation Park Dr. Homi BHabha Road Pune – 411008

18	SR/NM/NS-91/2008	Development of a novel process for the synthesis of nano-crystalline zinc oxide particles	Dr. M Hameedullah Department of Mechanical Engineering Z.H. College of Engg. & Technology Aligarh Muslim University Aligarh – 202002
19	SR/NM/NS-87/2008	Nanophosphor Application Centre	Dr. Avinash Chandra Pandey Nano phosphor Application Centre University of Allahabad Allahabad – 211002
20	SR/NM/NS-77/2008	Fabrication and characterization of self-assembled one-dimensional semiconductor nanostructures	Dr. K. Jeganathan Centre for Nano Science and Nano Technology School of Physics Bharathidasan University Tiruchirapalli – 620024
21	SR/NM/NS-95/2008	Growth and Characterization of Fallium Nitride and related Alloy Heterostructures	Dr. K. Baskar Crystal Growth Centre Anna University Chennai – 600025
22	SR/NM/NS-81/2008	Phase Transformation of Multiphase Embedded Alloy Nanoparticles and Multilayer Thin Films	Dr. Krishanu Biswas Department of Materials and Metallugical Engineering Indian Institute of Technology Kanpur- 208016
23	SR/NM/PG-13/2007	PG Teaching Programme (M.Tech. – Duration: 2 Years) in Nano Technology with annual intake of 20 Students at the Jawaharlal Nehru Technological University Hyderabad	Dr. M Anji Reddy Professor of Environmental Science and Technology Jawaharlal Nehru Technological University, Kukatpally Hyderabad – 500085

24	SR/NM/NS-92/2008	Development of nanodielectric polymeric material for industrial application	Dr. R.C. Jain Material Research Cell Technology Development and Commercialization Centre Electrical Research & Development Association Post Box No. 760 ERDA Road Makarpura Industrial Estate Makarpura Vadodara – 390010
25	SR/NM/NS-99/2009	Theragnostics Re-Generative Medicine and Stem Cell Research Using Cell-Targeted Nanomaterials	Dr. Shantikumar V. Nair Amrita Centre for Nanoscience and Molecular Medicine Ponnekara (P.O.) Kochi – 682041
26	SR/NM/NS-90/2009	Nano Structured Multifunctional Magnetic nanoparticulates	Dr. D. Bahadur Department of Metallurgical Engineering and Materials Science Indian Institute of Technology – Bombay Powai Mumbai – 400076
27	SR/NM/NS-97/2009	Photo physics of Nanosystems	Dr. A.K. Sood Department of Physics Indian Institute of Science Bengaluru – 560012
28	SR/NM/NS-56/2009	Unit of Nanoscience at the Indian Institute of Technology – Madras, Chennai	Dr. T. Pradeep Department of Chemistry and Sophisticated Analytical Instrument Facility Indian Institute of Technology – Madras, Chennai
29	SR/NM/NS-19/2009	Nanocomplexes for the Targeted Drug Delivery to the Inflamed Site of Lungs	Dr. (Ms.) K. Ruckmani Department of Pharmaceutical Technology Anna University , Tiruchirapalli – 620024

30	SR/NM/NS-75/2009	Studies on formulation and characterization of alginate nanospheres for targeted radionuclide therapy of neuroendocrine tumors	Dr. G.P. Bandopadhyaya Department of Nuclear Medicine All India of Medical Sciences Ansari Nagar New Delhi – 110029
31	SR/NM/NS-25/2009	Nanostructured Transition Metal Borides for anti-corrosion and superhard coatings	Dr. Ashok K. Ganguli Department of Chemistry Indian Institute of Technology – Delhi, Hauz Khas New Delhi

Source: http:/nanomission.gov.in

APPENDIXII: PROJECTS SANCTIONED BY DST, YEAR: 2008-2009

Sr. No	Sanction. No.	Title	PI & Add
1.	SR/NM/PG-04/2007	PG Teaching Programmes (M.Sc. - Duration 2 Years) in Nano Science and Technology with an annual intake of 15 students.	Prof. S.S.Sekhon Deptt.of Applied Physics Guru Nanak Dev University Amritsar – 143 005
2.	SR/NM/PG-16/2007	PG Teaching Programmes (M.Tech. - Duration 2 Years) in Nano Science and Technology with an annual intake of 20 students.	Dr. S. Swaminathan Centre for Nanotechnology and Advanced Biomaterials SASTRA University Thanjavur-613402
3.	IR/S2/PF-02/2007	Augmentation of computing resources for simulation and data analysis at the inter university accelerator centre.	Dr. Sumit Mookerjee Inter University Accelerator Centre Post Box No. 10502, Aruna Asaf Ali Marg New Delhi-110067
4.	SR/NM/NS-23/2007	Nanostructuring by erergentic ion beams	Dr. D.K. Avasthi Inter University Accelerator Centre Post Box 10502, Aruna Asaf Ali Marg New Delhi-110067

5.	SR/NM/NS-07/2008	Ferric pyrophosphate nanoparticles:Feasibility, bioavailability and toxicity assessments.	Dr. Amit Kumar Mandal Molecular Medicine and Clinical Proteomics St. John's Research Institute Sarjapur Road Bengaluru-560034
6.	SR/NM/NS-28/2007	Novel strategies to use nanotechnology methods in cellular & clinical oncology.	Prof. Anjan Kumar Dasgupta Deptt. of Biochemistry Calcutta University 35, Ballygunge Circular Road, Kolkata-700019
7.	SR/NM/PG-01/2007	PG Teaching Programme (M.Tech. - Duration 2 Years) in Nano Science and Technology with an annual intake of 20 students.	Dr. Ashok Chaudhary Department of Bio & Nano Technology Guru Jambheshwar University of Science & Technology Hisar – 125 001
8.	SR/NM/PG-21/2007	PG Teaching Programme (Integrated M.Tech-Duration 3 Years) in Nano Science and Technology at University of Delhi.	Prof. S. Annapoorni Department of Physics & Astrophysics,University of Delhi, Delhi-110007
9.	SR/S5/RFNS-01/2008	Ramanna Fellowship.	Prof. TP Radhkrishnan School of Chemistry University of Hyderabad Central University P.O. Hyderabad-500 046
10.	SR/S5/NM-07/2007	Development of bulk nano-crystalline materials: Nanoparticle synthesis and consolication.	Dr. BS Murthy Department of Matallurgical & Materials Engineering IIT Madras, Chennai-600 036
11.	SR/NM/PG-06/2007	PG Teaching Programme (Integrated M.Tech-Duration 3 Years) in Nano Science and Technology at VIT University, Vellore.	Prof. JP Raina Dean School of Electrical Sciences Vellor Institute of Technology University Vellore-630 014
12.	SR/NM/PG-02/2007	PG Teaching Programmes (M.Sc. Nano Physics-Duration 2 Years) in Nano Science and Technology at Osmania University, Hyderabad.	Prof. S. Ramana Murthy Osmania University Hyderabad

13.	SR/NM/NAT-02/2007	Preparation of Silicon Sheets by Capillary Action Shaping Technique (CAST) for Solar Cell Applications.	Prof. RC Verma Panjabi University Patiala
14.	SR/NM/NAT-02/2007	Preparation of Silicon Sheets by Capillary Action Shaping Technique (CAST) for Solar Cell Applications.	Dr. Shruti Aggrawal Guru Govind Singh University Delhi
15.	SR/S5/NM-24/2007	Potential use of Nanoparticles for DNA Vaccine in fish model to control becterial and viral diseases.	Dr A Sait Sahul Hameed Aquaculture Biotechnology Division, Department of Zoology C.Abdul Hakeem College Melvisharam-632509
16.	SR/S5/NM-24/2007	Potential use of Nanoparticles for DNA Vaccine in fish model to control becterial and viral deseases.	Dr. K. Pandian Department of Inorganic Chemistry School of Chemical Sciences University of Madras Chennai-600025
17.	SR/NM/PG-02/2008	P.G. Teaching Programmes (M.Tech Nano Medical Science) at Nano Science and Technology At Amrita Institute of Medical Sciences.	Dr. Shantikumar V Nair Amrita Centre for Nanosciences, Amrita Vishwa Vidyapeetham Elamakkara P.O. Kochi Kochi-682 026
18.	SR/NM/NS-31/2007	Detection of Latent Fingerprints by Nanoparticles-size Compositions.	Dr. G.S. Sodhi Department of Chemistry SGTB Khalsa College University of Delhi New Delhi- 110016
19.	SR/NM/NS-16/2007	Photoinduced reactions between Nanosized Quantum Dots of CdTe andporphyrins/rins/Metallo-Porphyrins.	Dr. R. Renganathan School of Chemistry Bharathidasan University Palkalaiperur Tiruchirapalli -620024
20.	SR/S5/NM-14/2007	Theoretical Investigations of Photophysics and Photo Chemistry of DNA using metal nano particles.	Dr. Harjinder Singh Centre for Computational Natural Sciences and Bioinformatics IIIT Gachibowli ,Hyderabad-500032
21.	SR/S5/NM-14/2007	Theoretical Investigations of Photophysics and Photo Chemistry of DNA using metal nano particles.	Dr. Biman Bagchi Solid State and Structural Chemistry Unit,Indian Institute of

			Science Bengaluru-560012
22.	SR/S5/NM-21/2007	Synthesis and Applications ofNanoparaticles in Ionic Liquids.	Prof. Manikrao M Salunkhe Department of Chemistry Shivaji University,Kolhpur-416004
23.	SR/NM/PG-11/2007	P.G. Teaching Programmes (M.Tech. Nano Technology) in Nano Science and Technology at Z.H. College of Engineering & Technology, Aligarh Muslim University, Aligarh.	Prof. SAH Naqvi Department of Applied Physics Z.H. College of Engineering & Technology Aligarh Muslim University Aligarh-202002
24.	SR/NM/INST-Mohali/2008	Institute of Nano Science &Technology(INST) Mohali.	Prof. N. Sathymurthy Indian Institute of Science Education and Rereach Transit Campus: MGSIPAP Complex, Sector 26 Chandigarh- -60019
25.	SR/NM/NS-06/2007	Measurement of Optical Non-Linerarities in Wide Bandgap II-IV Semiconductor Quantum Dots Suitable for All-Optical Switching Devices.	Dr. P.K. Bhatnagar Department of Electronic Science Delhi University South Campus Benito Jaurez Road New Delhi-110021
26.	SR/NM/NS-02/2007	Effect of Interface Morphology and Spatial Distribution of Nanoparticles on Optical and Thermal Properties of Polymer Nanocomposites.	Dr. Jaydeep K Basu Department of Physics Indian Institute of Science Bengaluru- 560 012
27.	SR/NM/NS-47/2008	Development of novel drug carriers for effective treatment of cancer by way of targeting.	Dr. N Udupa Manipal College of Pharmaceutical Sciences Madhav Nagar Manipal-576104.
28.	SR/S5/NM-92/2006	Synthesis of Single-Molecule magnets: A molecular approach to nanoscale magnetic materials.	Dr. Mukkamala Saratchandra Babu Department of Chemistry College of Science,GITAM University, Gandhinagar Campus Rushikonda,Visaphapatnam-

			530045.
29.	SR/NM/NS-01/2007	Targeted Drug Delivery of nanoparticulate formulations of Methylglyoxal andAssessment of their Antitumor Activities.	Prof. Manju Ray Department of Biological Chemistry Indian Association of Cultivation of Science Jadavpur, Kolkata-70 032.
30.	SR/NM/PG-01/2008	P.G. Teaching Programme (M.Sc./M.Tech.) in Nano Science and Technology-M.Sc. Nanoscience and Nanotechnology Course at Sri Sathya Sai University, Vidyagiri Prassanthi Nilayam, Anantapur District, Andhra Pradesh 515134	Dr. K. Venkatramaniah Dean Science Faculty and Head Department of Physics Sathya Sai University, Vidyagiri Prassanthi Nilayam, Anantapur District, Andhra Pradesh 515134
31.	SR/NM/NS-22/2008	Growth and characterization ofnanostructured materials and itsapplications.	Dr. MK Jayaraj Department of Physics Cochin University of Science & Technoloy,Kochi-682002.
32.	SR/NM/NS-50/2008	Interactions of carbon nano-particles and their chemically modified forms with cells and organs in vitro and in vivo.	Dr. Rajiv K. Saxena School of Life Sciences Jawaharlal Nehru University New Delhi-110067.
33.	SR/NM/NS-27/2008	Synthesis and characterization ofnanomaterials for engineeringapplications.	Dr. T. Srinivasa Rao Department of Metallurgical and Materials Engineering National Institute of Technology Tiruchirapalli-620015.
34.	SR/NM/PG-04/2008	P.G. Teaching Programme (M.Sc./M.Tech.) in Nano Science and Technology at Karunya University, KarunyaNagar,Coimbatore.	Dr. B.C. Pillai Dean Research Karunya University Karunya Nagar Coimbatore-41114

35.	SR/NM/PG-07/2008	P.G. Teaching Programme (M.Sc./M.Tech.) in Nano Science and Technology at Kuvempu University,Shankaraghatta,Shimoga	Dr. H.S. Bhojya Naik Department of PG Studies and Research in Industrial Chemistry, Kuvempu University, Shankaraghatta Shimoga-577 451.
36.	SR/NM/NS-45/2007	Investigations of Magnetic, Optical and Electrical properties of nanomaterials: Synthesis, characterization andapplications.	Dr. S. Annapoorni Department of Physics & Astrophysics University of Delhi Delhi-110007.
37.	SR/NM/NS-112/2008	Development of high temperature resistant polymeric nano fibers for flexible polymer electrode and membrane application.	Dr. (Mrs.) R. Vasanthakumari Department of Polymer Technology,BSA Cresent Engineering College GST Road, Vandalur,Chennai-600048
38.	SR/NM/NS-32/2008	Computer aided design of dendrimeric nanoparticles for anti-diabetic drug delivery.	Dr. P.V. Bharatam Department of Medicinal Chemistry National Institute of Pharmaceutical Educational & Research (NIPER) Sector-67, S.A.S. Nagar Mohali-160 062.
39.	SR/NM/NAT-18/2008	Creation of a Centre for Knowledge Management of Nanoscience andTechnology (CKMNT) International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI), Hyderabad.	Dr. S.V. Joshi International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI) Hyderabad-500 005.
40.	SR/NM/NS-11/2008	Biodegradable Polymeric Composites based on Cellulose Nanoparticles: An Alternative to Petroleum-Based Polymer Composites.	Dr. Shashi D. Baruah Department of Natural Gas North East Institute of Science & Technology,Jorhat-785 006.

41.	SR/DST-NIMITLI/HDPDP/2007	Development of next gen. Plasma Display Panel (PDP) Technology and a 50 inch High Definition (HD) PDP TV Demonstrator.	Dr. Yogeswar Rao Head TNBD Division Council of Scientific & Industrial Research (CSIR), Anusandhan Bhavan, Rafi Marg, New Delhi-110 001.
42.	SR/NM/NAT-04/2007	Nano Technology for Biomedical Applications.	Dr. Lalji Singh Director, Centre for Cellular Microbiology,Uppal Road Hyderabad-500 007.

Source: http:/nanomission.gov.in

APPENDIX III: PRODUCT DEVELOPMENTS

HEALTHCARE

Sr.No.	Recent Development
1	Bhaskar Center for Innovation and Scientific Research, Chennai is developing an antimicrobial spray using silver nanoparticles and herbal extracts
2	Biocon has launched breast cancer nanodrug, Abraxane, developed by Abraxis Biosciences, US, in early 2008
3	Starkey India is the first company to incorporate nanotechnology into hearing aids. The technology uses sensors that contain a giant magneto-resistance (GMR) switch, which uses electron spin rather than magnetic charge to sense signals and store information.
4	In January 2007, Dabur Pharma has developed Nanoxel – indigenously developed nanotechnology based new drug delivery system for cancer treatment in Indian market
5	Virtuous Innovation, a group company of Khandelwal Laboratories, has already developed a patented technology on Gene Repair Therapy (GRT) to stimulate dormant genes in an attempt to cure diseases like cancer and AIDS. The company will soon launch a nano silver gel, developed from nano particles of silver to cure burns at 10 per cent of the cost of existing topical pharmaceutical creams to cure burns. The product is undergoing clinical trials.
6	Nano Cutting Edge Technology-Nanocet, an R&D nanobiotechnology company, is pioneering the development of uniquely advanced biostabilized nanoparticles technology in the areas of cancer hyperthermia, targeted drug delivery,diagnostics, antimicrobial agents and treatment of pollutants.

7	Bengaluru-based Velbionanotech is designing drugs for various diseases such as heart, kidney stones, AIDS, cancer, and cosmetic generic products using a short fragment of DNA as a new type of drugs. These drugs are assembled in nanochips and as nano particles for delivering in human body, which are affective in curing the sick / diseased and healing the injured.
8	VBN is working in new gene therapy procedures, DNA-based sensors, and other medical applications by using a new method developed to initiate and control chemical reactions on DNA strands.

Source: India R&D "Nanotechnology- The Science of the future", 2008

PHARMA

Sr.No.	Recent Developments
1	Development of one dose a day ciprofloxacin using nanotechnology
2	Tumor targeted taxol delivery using nanoparticles in Phase 2 clinical trial stage
3	Improved ophthalmic delivery formulation using smart hydrogel nanoparticles
4	Oral insulin formulation using nanoparticles carriers
5	Liposomal based Amphotericin B formulation

Source: India R&D "Nanotechnology- The Science of the future", 2008

TEXTILES

Sr.No.	Recent Developments
1	Raymonds has had a big hit with its nano-treated trousers and is now launching nano-shirts under the Park Avenue label.
2	Mohan Clothing, makers of Blackberry's has already introduced nano-based trousers.
3	Ashima Group has exported over 1million yards of nano-treated fabric to top retailers like Gap and Banana Republic
4	Arrow has launched stain-resistant Nanotechnology shirts in Mumbai. One out of every five shirts in the Arrow office range currently uses some nano-based chemical to make it stain-resistant and wrinkle-free. The company is now testing nano-chemicals on its denims.

Source: India R&D "Nanotechnology- The Science of the future", 2008

FILTERATION

Sr.No.	Recent Developments
1	Tide Waters from Iran has entered into a tie-up with Mumbai-based SSB Technology to market its range of products under the brand Nanocid in India.
2	IIT-Madras has released a water purifier using nanotechnology. Technology used in the product is the very first of its kind and is home-grown. No nanoparticle based water filter exists in the world as of now. The filter uses technology developed by IITM, and is released by Eureka Forbes Ltd. It removes pesticides from drinking water by an unusual chemistry utilising metal nanoparticles

Source: India R&D "Nanotechnology- The Science of the future", 2008

APPENDIX IV: TECHNOLOGY TRANSFER FROM ACADEMA/R&D CENTRES TO INDUSTRY

Sr.No.	Technology
1.	Hydrogels
2.	Sensor technology
3.	Multilayered coating for cutting tools
4.	Ceramic water candles with nanosilver loadings
5.	Nano-ceramics and nano-fluid application
6.	Textile treatment
7.	Bio-separation through magnetic particle
8.	Production of nano sized white pigments and nano sized stabilized ZrO2
9.	Electrochemical Ion and sensors, Electro analytical equipment and Classified X-ray diffraction spectro equipment
10.	Plasma assisted nanofinishing and nanofibers
11.	Selective electrodes
12.	Bio-synthesis of gold nanotriangles
13.	Metal nanovarification for the removal of pesticide from drinking water
14.	Pt/CNT electro catalysts
15.	Nanosized hydroxyapatite powder
16.	Synthesis of composition of photoactive titania
17.	Textiles with polyurethane clay nanocomposites band

18.	Nano structured coatings/materials
19.	Nano and ultra filtration ceramic membranes for drinking water
20.	Anti-scratch coatings for plastic ophthalmic lenses
21.	Nano rare earth phosphates for strategic applications

Source: National Foundation of Indian Engineers "Status of Nanotechnology", 2008

APPENDIX V: KEY EVENTS

Key Events	
Nanotech India 2011	http://www.nanotechindia.in
International Conference On Nanoelectronics (ICONE-2011)	http://www.mecece.com/icone2011/
CDAMOP 2011	https://www.tbimice.com/cdamop2011/
International Conference on Nano Science, Technology & Societal Implications (NSTSI 11)	http://cvrgi.edu.in/NSTSI11/home.htm
Bangalore Nano	http://www.bangalorenano.in/nano_2011/index.html
Cochin Nano 2011	http://cochinnano2011.cusat.ac.in/

APPENDIX I: KEY COLLABORATIONS

Solar Energy		
Research Institute	**Collaborations**	**Description**
The Solar Energy Centre (SEC)	TERI	Design, development and testing of low temperature solar desalination system
	IIT Delhi	Solar, optical as well as thermal modeling and measurement of energy flow at different nodal points of 50 KW solar power plant at SEC. Establishment of computer software for detailed design and specifications of solar water heating systems in India. Development of test standards for thermal performance of solar cookers. Application of Finite-time thermodynamic and second law assessment of solar thermal power generation Design and cost optimisation techniques for solar hybrid absorption refrigeration plants using second law analysis & exergo economics. Round-robin testing of flat plate solar collectors and box type solar cookers in India.
	IIT Bombay	Development of a transient test procedure for characterizing solar flat plate collectors

	National Renewable Energy Laboratories (NREL), USA	Solar photovoltaic technology
	University of Stuttgart, Germany	Solar thermal testing
	Inter-solar Centre, Moscow	Solar energy
Centre for Renewable Energy and Environment Development (CREED)	Technische Universitat, Braunschweig; Gadhia Solar Energy Systems Pvt Ltd; Birla Institute of Technology, Pilani	Development of life-cycle and efficiency optimized power plants based on Scheffler concentrators.
Indian Institute of Technology Bombay	Applied Materials Inc	Next-generation solar cells
	MNRE	Development of cost-effective solar thermal power generation
	Loughborough University; National Physical Laboratory (NPL), India	Development of stable, efficient and low-cost solar energy systems
Moser Baer Solar Limited	SINTEF, Norway; UMOE Solar, Norway; National Physical Laboratory (NPL), India	Defect engineering of solar grade silicon material
	National Chemical Lab, India	Development of solar grade silicon

Centre for Electric Transporation (CET)	U.S. Government	Solar dish based power plant

Bio-fuels		
Research Institute	**Collaborations**	**Description**
PRAJ-Matrix - The Innovation Center	Novozymes	Praj and Novozymes will optimize the enzymatic hydrolysis processes and the use of enzymes in the production of advanced biofuel.
	Qtreros	Praj and Qteros will jointly develop Process Design Packages (PDPs) that enable low cost, commercial-scale ethanol production from sugarcane, corn and wheat residuals.
The Energy and Resources Institute (TERI)	British Petroleum (BP)	BP is funding a 10 year project to research turning Jatropha into renewable fuel in Andhra Pradesh.
	Mission Biofuels India Private Limited; Tamil Nadu Agricultural University	Genetic improvement of Jatropha through biotechnological tools
The Energy and Resources Institute (TERI)	Department of Biotechnology(DBT)	Multilocational field trial of superior Jatropha clones in different agroclimatic zones of Northeastern States Genetic enhancement of Jatropha
The Energy and Resources Institute (TERI)	Department of Biotechnology (DBT); Praj Industries Limited	Bioethanol from sweet sorghum bagasse

The Energy and Resources Institute (TERI)	Department of Biotechnology (DBT)	Development of a cost effective and environment friendly method of producing butanol from biomass like rice husk and sugar cane bagasse.
Central Mechanical Engineering Research Institute (CMERI)	CSIR – NMITLI (New Millennium Indian Technology Leadership Initiative)	Generation of hydrogen through thermo-chemical gasification of biomass
	Medors Biotech Pvt. Ltd	Biodiesel from deoiled cake of Jatropha
Central Salt & Marine Chemicals Research Institute (CSMCRI)	US Department of Energy(DoE); General Motors (GM); Defense Research & Development Organization (DRDO)	To develop Jatropha as a sustainable crop
	Daimler Chrysler; DEG, Germany; University of Hohenheim	For cultivation of Jatropha on wasteland and utilization of oil and deoiled cake
	Lubrizol India; DaimlerChrysler India	Bio-diesel performance at high altitude in rarefied atmosphere
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	National Research Systems (NARS); Rusni Distilleries Ltd	To develop sweet sorghum based ethanol technology
Indian Institute of	TCE Consulting	Process and Catalyst development studies for synthesis

Technology Bombay	Engineers Ltd.	of biodiesel
IOCL Research & Development Centre	UOP LLC (Honeywell)	R&D for a range of biofuels technologies and projects
Indian Institute of Science (IISc)	University of Manitoba	Use of solar panels to extract oil from algae and make biofuel.
Punjab Agricultural University	Petroleum Conservation Research Association (PCRA)	Development of package of cultural practices for Jatropha
Mechanical Engineering Research & Development Organization(MERADO)	Petroleum Conservation Research Association (PCRA)	Design & development of energy efficient oil expeller suitable for jatropha seeds
G.B. Pant University of Agriculture and Technology	Indian Institute of Petroleum (IIP), Dehradun; Hindustan Petroleum Corporation (HPCL), Mumbai	Pantnagar University has collaboration with Indian Institute of Petroleum, Dehradun and Hindustan Petroleum Corporation, Mumbai for addressing issues linked with Jatropha promotion

Transmission & Distribution		
Research Institute	**Collaborations**	**Description**
Centre for Electric Transporation	United Nations Development	CET has been established by Bharat Heavy Electricals

(CET)	Program (UNDP)	Limited with assistance from UNDP
Indian Institute of Technology Kanpur	Secure Meters Limited, Udaipur; Indian Telephone Industries, Raebareli; DataPro Electronics Private Limited, Pune; and Danke Switchgears, Vadodara	IIT Kanpur has embarked on an effort to develop indigenous technology for an integrated power distribution automation system in collaboration with four industry partners
Indian Institute of Technology Kharagpur	Damovar Valley Corporation (DVC)	Collaborative research aiming at developing futuristic and efficient power generation technologies and solving the maintenance problems of power generation, transmission and distribution systems
	IBM	To develop systems to make power grids more efficient and resilient
Indian Institute of Technology Madras	IBM	To develop systems to make power grids more efficient and resilient.
Motilal Nehru National Institute of Technology	All India Council for Technical Education (AICTE)	Development in digital control facilities
	Ministry of Human Resources & Development	Computer aided instrumentation and control
The Energy & Resources Institute (TERI)	Commonwealth Scientific and Industrial Research Organization	TERI leads the work on simulation, design and demonstration of smart mini-grid systems at TERI Gual Pahari and Solar Energy Center (SEC), Gual Pahari in collaboration with CSIRO under Asia Pacific

	(CSIRO), Australia; MNRE	Partnership. The project is supported by MNRE.

Energy Efficiency		
Research Institute	**Collaborations**	**Description**
CSIR	Alcoa	Energy Efficiency
Mechanical Engineering Research & Development Organization (MERADO)	Petroleum Conservation Research Association (PCRA)	Design & development of energy efficient oil expeller suitable for Jatropha seeds
Indian Institute of Petroleum (IIP)	Petroleum Conservation Research Association (PCRA)	Studies on passenger cars for fuel efficiency at different speeds Development of high thermal efficiency offset burner type kerosene pressure stoves
Bombay Textile Research Association (BTRA)	Petroleum Conservation Research Association (PCRA)	Energy saving in decentralized power loom sector of textile industry by developing a Energy Saver unit
	Ministry of Textiles	Assessing the potential and formulating / suggesting measures for fuel saving in decentralized process house units
Indian Institute of Technology Bombay	Petroleum Conservation Research Association (PCRA)	Energy efficiency improvement in Glass Furnace

Indian Institute of Technology Guwahati	Petroleum Conservation Research Association (PCRA)	Development of a multi fuel cooking stoves Design and Development of Kerosene stove with Porous Burner
Indian Institute of Technology Delhi	Duke University	Development of clean, efficient hybrid solar biomass cook stove Development of petrol - alcohol - water micro emulsion fuel as substitute for petrol & ethanol - blended petrol

APPENDIX I: KEY COLLABORATIONS

Indian company	Foreign company	Collaboration details
Mahindra Defence system	BAE system	Manufacture of land combat vehicles based on BAEs RG 31 mine protected vehicles
Mazagaon Dock Ltd	Direction des Constructions Navales, Navantia	Development of Scorpene Submarine, which is incorporated with the SUBTICS integrated combat system
Larsen & Toubro	EADS	Setting a facility in Pune for design, development and manufacturing of electronic warfare, radar, military avionics & mobile systems
Larsen & Toubro	Raytheon, Boeing	MoU for joint business in defence industry
Larsen & Toubro	RAC, SAAB	Manufacture of structures on which MMRC aircrafts are built
TATA advanced systems	Israel Aerospace Industries Ltd.	Develop & manufacture missiles, UAVs, electronic warfare, radar and security systems
Hindustan Aeronautics Ltd	Israel Aerospace Industries (IAI)	IAI will help Hindustan Aeronautics in converting the 'Dhruv' ALH into an unmanned maritime rotorcraft
DRDO	Israel Aerospace Industries (IAI)	A USD 2 billion partnership to co-develop an anti-aircraft missile
DRDO	Ukrspecexport	Agreement for possibility of technology transfer, and joint designing and production of military equipment
DRDO	MBDA missiles	Co-development of a new range of Short Range Surface to

		Air Missiles (SRSAM) for the Indian Army

APPENDIX II: KEY EVENTS

Key Events	
Aero India 2011	http://www.aeroindia.in/Main.aspx
India Defense & Aerospace Symposium 2011	http://digital.ni.com/
IMDEX Asia 2011	http://www.imdexasia.com/

SPACE

APPENDIX 1: KEY EVENTS

Key Events	
Bengaluru space expo 2010	http://www.bsxindia.com/
99th Indian Science Congress, Bhubaneswar	http://www.sciencecongress.nic.in/
International Conference on Underground Space Technology & 8th Asian Regional Conference of IAEG	http://www.icust2011.com/