INAE Forum on Technology Foresight and Management for Addressing National Challenges

Second Report

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Indian National Academy of Engineering

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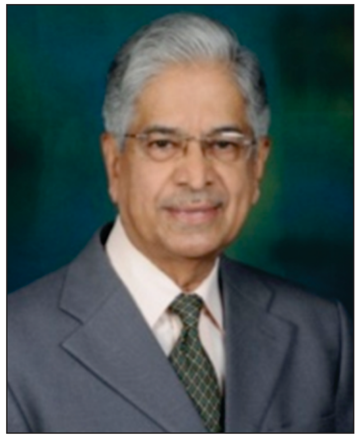
The First Report is available at INAE website under the Head INAE Publications. It contains the following four chapters:



Foreword

I am delighted that the INAE Forum on Technology, Foresight and Management under the Chairmanship of Mr VK Agarwal, FNAE has brought out the second Report on addressing national challenges pertaining to Agriculture, Energy and Mass Transit Systems. India has advanced greatly in the last decade, however there are multi-fold challenges being faced by the common man including food, water & energy security, affordable healthcare, education for all citizens and access to economical transportation. These challenges are going to get magnified in the near future on account of demands placed by the ever growing population. Therefore, there is a need to forecast and predict the technological interventions that shall play a vital role in mitigating these and other areas of concern for the society.

While analysing the benefits of a technology foresight exercise; it is globally recognized that foresight plays a key role in the technology development process both in terms of guidance for policymakers as well as in suggesting critical technologies for technological advancement and development of infrastructure for benefit of the common man. Several international organizations including the United Nations Industrial Development Organization (UNIDO) are implementing global and regional initiative on technology foresight. The aim of this initiative is to use technology foresight as a practical tool in designing policies and strategies that exploit emerging and critical technologies for the benefit of developing countries. Suitable methodologies are also suggested to promote sustainable development through large scale deployment of innovative technologies.

At the national level the technology foresight is beginning to assume greater importance and I am happy that the INAE Forum on Technology, Foresight and Management has taken cognizance of application of technology foresight to three pertinent issues of topical interest such as waste reduction in the Agriculture sector; energy security with emphasis on solar energy and the need for mass transit systems and have focused the studies on these areas with the objective of arriving at actionable recommendations.

I am confident that this report shall be of immense benefit to all stakeholders from Government, industry and R&D organizations in addressing these challenges and suggesting an action plan for growth of these sectors and shall be well accepted by the engineering community in domains of interest.

Dr BN Suresh
President, INAE

PREFACE

1. A proposal to constitute a **Technology Foresight and Management Forum for addressing National Challenges**, composed as under, was discussed during the Governing Council meeting of the Academy held on July 27, 2012 at New Delhi and approval conveyed vide Indian National Academy of Engineering (INAE)'s Letter No. INAE/413/TFMF dt. 22nd August 2012 :

(i)	Mr. V. K. Agarwal	Fellow INAE – Chairman
(ii)	Dr. Y. P. Anand	Fellow INAE
(iii)	Dr. Prem Vrat	Fellow INAE
(iv)	Dr. C. R. Prasad	Fellow INAE
(v)	Mr. A. K. Anand	Fellow INAE
(vi)	Mr. K. P. Singh	Ex MD RITES & Ex. MD Tata Projects
(vii)	Mr. S. C. Gupta	Ex. Member Electrical, Railway Board
(viii)	Mr. V. N. Mathur	Ex. Member Traffic, Railway Board
(ix)	Mr. A. K. Gupta	Ex. CAO Railways & currently Editor, RITES Journal

2. The broad **Terms of Reference for the Forum** were as under :

2.1 Domain of National Challenges is very wide and also keeps on changing from time to time. However, this Forum would address the following as a broad guide but could suitably modify the list as required :

(a) Food Production and Utilisation and Conservation of Water.
(b) Energy Generation and Utilities.
(c) Manufacturing Technologies.
(d) Mass Transit Systems.
(e) Building and Construction Technologies.

2.2 This Forum will evolve solutions keeping in view the issues of sustainable development, poverty reduction, and climate change in focus and suggest appropriate technologies accordingly. Further, suitable Engineering Management techniques will be employed to find cost effective and optimal solutions.

2.3 For formulation of the Recommendations / Solutions the Forum could also invite Specialists as required and / or conduct Workshops as found desirable.

2.4 Meetings of the Forum can be held at a frequency of say once in two months anywhere in the country as desired by Chairman of the Forum. Logistic support will be provided by INAE.

3. The Members of Forum (Group in short) during the initial meetings decided the line of action to be followed for effectively and speedily handling this daunting task. Even though the Forum will be working on the various National Challenges on a continuous basis it was thought prudent to select some priority areas for directed attention in the first instance. Since the domain of National Challenges is very wide and keeps on changing with time, it was felt that use of expertise of domain 'experts' may be difficult and may cause avoidable delays in formulating recommendations. It was,

therefore, the view of the Group to make use of the available data (published literature, reports, media information, INAE literature, data from internet, etc.) and contacts/knowledge of the Group Members with occasional interaction with the experts. The option to invite Specialists as required and/or conduct Workshops as found necessary was kept open.

4. To achieve commonality of approach and to have a common understanding of the various technical terms/issues, some of the areas, as discussed by the Group, are mentioned below:

- Solutions for addressing the National Challenges have to keep in focus issues concerning Sustainable Development, Climate Change, and Poverty-reduction / Inclusive Growth.

- Boundaries between Science, Technology, and Engineering have to be made more explicit. This is all the more necessary because of the growing role of Engineering and its close interface with Society/Nature.

- For Technology Foresight exercises to be more useful / effective it was necessary to bring together expertise in social affairs, business management, financial issues, and policy with the scientific, technological, and engineering issues.

- Too much emphasis on the authenticity of Data / Source was not a practical reality as the challenge was many a times to venture into new areas not only Scientific / Technological / Engineering but also areas concerning Social affairs / Business management / Finance / Policy and their inter-relationships.

- Dimensions of Project Management were becoming more and more complex and diverse and needed special attention. Our poor track record in Project Implementation amply testified this need.

- Expanding definitions of Growth / Progress / Development need to be taken into account (Gross Domestic Product – Human Development Index – Gross National Happiness).

- Ethical issues especially concerning the Environment needed to be addressed.

- Innovations needed to be such so as to achieve More from Less for More people (MLM) for sustainability and equity.

- Role of Technology was not only to be seen from the point of view of achieving the desired objectives but also from the point of view of its consequences.

- Many of the Challenges / Risks have Global dimensions and this had to be kept in view.

- Necessary inputs for Skill development and Training were needed to match the futuristic technologies. Quality of Engineering education especially for Tier II, III & IV colleges needed special inputs.

- Policy frame work will have to be in place to improve the 'image' and 'role' of Engineering to make it more effective especially in tackling social and economic development and for provision of commensurate infrastructure.

5. After discussions the Forum Members selected some Areas for examination and the First Report (March 2014) was published. The Report had Four Chapters as given under :

Chapter	**Title**
1.	**Introductory / Explanatory Notes**
2.	**Waste Management**
3.	**Water – Meeting the Future Challenges**
4.	**Transport – Making it Greener**

The First Report is available at INAE Website under the Head INAE Publications

6. The current Report (Second Report – March 2016) covers the following three Areas :

Chapter	**Title**
1.	**Agriculture – Waste Reduction and its Use**
2.	**Energy – Major Thrust on Solar**
3.	**Mass Transit Systems**

7. The Group will now be taking up following areas for detailed Study / Examination :

(i) **Issues of Environment / Sustainability / Climate Change**
(ii) **Urban Rural Divide / Equilibrium**
(iii) **High Speed Rail for India**

8. It is hoped that Suggestions / Recommendations of the Forum will be helpful to Society / Nature / Policy-makers / Engineers / Administrators in addressing the Challenges in three studied / examined areas viz. (v) Agriculture – Waste Reduction and its Use, (vi) Energy – Major Thrust on Solar and (vii) Mass Transit Systems.

V. K. Agarwal

Chairman of the Forum

March 2016

Chapter 1

Agriculture – Waste Reduction and its Use

1.1 Preface

Agriculture plays a crucial role in ensuring food security, while accounting also for a significant share of India's Gross Domestic Product (GDP). It engages almost two-third of the workforce in gainful employment. Several industries such as sugar, textiles, jute, food and milk processing etc. depend on agricultural production for their requirement of raw materials. On account of its close linkages with other economic sectors, agricultural growth has a multiplier effect on the entire economy.

Presently, the threat of climate change poses a challenge for sustainable agricultural growth. This threat is compounded due to accumulated anthropogenic greenhouse gas emissions in the atmosphere, through long-term intensive industrial growth and high consumption lifestyles and preferences. While the international community is collectively engaging itself to deal with this threat, India needs to evolve a national strategy for adapting to climate change and its variability in order to ensure ecological sustainability in its socio-economic developmental priorities.

Some of the major impacts of Climate Change are [*National Mission for Sustainable Agriculture (NMSA)-2010*]

- Reduction of Agriculture Yields in Medium term (2010-2039): up to 4.5-9%
- Fall in GDP growth in Medium Term: up to 2% per annum
- Reduction of Agriculture Yield in Long Term (2040 and beyond) : > 25% if no measures are taken
- Need for more food: 310 million tonne of Food grains in 2050
- Stagnating Net Sown area: 140±2 mega ha since 1970
- Land share under fallow: 38% increase since 1951
- Per Capita land availability: From 0.91 ha in 1951 to 0.32 ha in 2001 and to 0.19 ha as projected by 2050

1.2 Waste Reduction and its Use

It is essential that whatever is produced is not lost either due to wastage or infestation. Though it is argued, that the wastage during storage is <2% only, but the pictures shown in the media are very alarming and damaging with captions like 'The great grain drain'. These losses are mainly due to open storage. The States keep blaming the FCI (Food Corporation of India) for not picking up the stock in time and FCI blames the States for not storing in covered storage. This wastage during storage can certainly feed all the persons who die of hunger or are malnourished in the country.

1.3 Challenge

Indian agriculture now faces the challenge of ensuring food security amidst constraints such as stagnating net sown area, deterioration of land quality, reduction in per capita land availability etc. In recent years, issues such as competing demand for water in the context of changing demographics and its various end uses, further aggravate the degree of risks in the agriculture sector. These have considerable implications for food and livelihood security and the agriculture production being risk prone, may lead to migration from rural to urban and sub-urban areas. Fostering rapid, sustainable and broad-based growth in agriculture is, therefore, a key priority keeping in mind the overall socio-economic development trajectory of the country, especially in the light of existing vulnerabilities that relate to a shrinking land resource base, additional stresses arising from the non-agricultural sector, and issues emerging due to changing climate. This necessitates a strategic approach with a renewed vision and redefined focus.

The damage to crops caused by pests, pathogens and weeds increases due to higher ambient temperature. Change in climate is likely to bring about a change in the population dynamics, growth and distribution of insects and pests thereby, upsetting crop-pest balance. Drought conditions would increase pathogen and insect survival rate due to change in plant nutrient level and decrease in plant defense system. These changes could lead to enormous crop losses in altered environment.

1.4 Food Safety before Food Security

The cause of agony is the way the grains produced by farmers with loving care are being handled. The various State marketing agencies and the Food Corporation of India are trying their best to procure and store the mountains of grains arriving every day. The gunny bags containing the wheat procured during April-May occupy a considerable part of the storage space available at several Mandis. The condition of the grains of earlier years presents a sad sight. The impact on the quality of paddy is even worse.

1.5 Sustaining an Evergreen Revolution

Malathion sprays and fumigation with methyl bromide and ethylene dibromide, and aluminium phosphide tablets are used to prevent grain spoilage. Safe storage of grains involves attention to both quantity and quality. Grain safety is as important as grain saving. Due to recent changed rain patterns and relatively milder temperatures, grain arrivals have become erratic. For all concerned, procurement, dispatch and storage of wheat grains in the Punjab-Haryana-Western UP region, which is the heartland of the green revolution, is becoming a nightmare. Safe storage of procured grain is the weakest link in the food security chain. India is yet to develop a national grid of modern grain silos. Post-harvest losses are high in food grains and in perishable commodities such as vegetables and fruits. A Rural Godown Scheme was initiated in 1979, but it is yet to take off. The government called off the "Save Grain" campaign some years ago, ending a relevant programme in the context of food security.

It is time that we organize a national grid of grain storages, starting with storage at the farm level in well designed bins, extending to rural godowns and regional ultra-modern silos. Post harvest losses can then be minimized or even eliminated. Unless the prevailing mismatch between production and post-harvest technologies is ended, neither the producer nor the consumer will derive full benefit from bumper harvests.

Prof. M. S. Swaminathan, who is

popularly called the Father of the Green Revolution in India, brings out in this very informative article (2012) the adverse impact of the changing climate on food security. He highlights that a one degree rise in mean temperature would result in a six million tonnes of loss in wheat yield. In this perceptive paper, he discusses the steps that are needed for mitigation and adaptation of effects of climate change. The areas suggested are wide ranging, covering increase in soil carbon sequestration, building up soil carbon banks and a host of others. He also gives a detailed action plan for achieving a climate resilient National Food Security System. Pulses, he highlights, play a very important role in ensuring food security for which he suggests a 'Panchsheel' for farmers producing pulses. He reiterates that their production should reach atleast 32 million tonne by 2030.

Prof. Swaminathan also provides a road map for achieving Nutrition Sensitive Agriculture for tackling the problem of under/ malnourishment. For this, increased emphasis is also needed for system research in cropping, farming, amongst others. He also advocates the formation of Farmer's Council for National Security in different agro-ecological regions.

1.6 General Impression about the Losses

Although, the tone used for describing the present losses, "by various persons at different forums", at times, is alarming; after going through the literature, one gets the impression that the reality is different. It is more a statement of facts, and from the conclusion, one can infer that improvements will be possible to reduce the losses as more facilities are added and the persons handling the produce in the supply chain get educated. Over the years, the reduction in losses has been directly proportional to the development of infrastructure, including the education and general awareness of the workers handling the produce in the country.

One of the latest Report on the subject, with proper quantification in data collection and sample size, is summarised below. It is observed that the Report is very authentic and is prepared by professional scientists and engineers in the field of agriculture. Losses due to harvesting, collection, threshing, winnowing, cleaning, drying and transportation mainly depend on education of persons handling the produce. Efforts are required to create awareness for adoption of already developed and readily available improved processing technologies and equipment resulting in reduction of post harvest losses. Harvesting and threshing need to be standarised and refinement in existing machines, especially multi crop threshers, is essential.

1.7 SUMMARY of the Report titled "Harvest and Post Harvest losses of Major Crops and Live Stock Produce in India—All India Coordinated Research Project on Post Harvest Technology. Indian Council of Agricultural Research, September 03, 2010, published in September 2012".

PREFACE---This being the first Report of its kind, several issues could not be addressed. Post harvest losses due to weather aberrations in isolated locations and on account of market gluts are not included. **Losses due to dearth of storage facilities, proper handling or transport are highly variable in time and space coordinates and are not included** The results of the study shall help in prioritizing R & D agenda and determining the impact of technological and policy interventions.

INTRODUCTION—Most of the studies

focused on durable food grains because of their prominence in daily diet; the perishable crops because of moisture content are more susceptible to deterioration. Total annual losses are estimated to be Rs. 50,000 crore.

OVERVIEW OF LOSSES AND ASSESSMENT- Entomological storage studies are not particularly relevant to estimation of losses since the sampling and experimental designs are study specific and do not provide the actual extent of damage done by insects in the field conditions of storage. The experience of earlier surveys provided information for estimating losses in storage, through method of random sample surveys. The statistical approach has been mentioned with necessary modifications according to local conditions.

Table 1.1: Post Harvest Losses of Rice and Wheat

Stages	Loss (%) in rice	Loss (%) in wheat
Harvesting	0.40	0.36
Threshing	0.52	0.44
Cleaning/Winnowing	0.20	0.14
Drying	0.80	0.66
Packaging	0.20	0.22
Transportation	0.50	0.51
Storage	1.20	0.95
Total losses at farm level	**3.82**	**3.28**
Total losses at wholesale level	0.29	0.20
Total losses at processor level	0.03	0.03
Total losses at retailer level	1.06	0.82
Total post-harvest losses	**5.19**	**4.32**

(Data collected in 2003-2004, study concluded in 2007)

SAMPLING DESIGN OF THE SURVEY—There is a good deal of variation in concepts and definition of loss by various research workers; the following criterion was adopted :

1. Only the quantitative post harvest losses would be assessed.
2. The data for harvest and post harvest losses would be collected for one full cycle of the selected commodities.
3. While the data for losses would be collected
   (i) through enquiry with the respondents and also (ii) by recording on site observations, these two sets of data would be suitably combined to report a single figure for loss in each operation and channel.

DATA COLLECTION PROCEDURE--- Different schedules were developed based on detailed group discussion with experts to collect the data through enquiry and actual observations. These were evaluated in the field before making them available to the data collection centers. Field investigations were employed to collect the data for subsequent scrutiny and analysis. Data was collected at the time of harvest or within one week after the harvest. Five schedules for collection of data by "enquiry" were formulated and 18 schedules were formulated for data collection by "observation".

ANALYTICAL TOOLS AND PROCEDURES- Data collected by the centers was scrutinized for functionality through internal consistency checks at the time of data entry. The digital data from different centers were pooled appropriately for further analysis. Data collected through enquiry was analyzed using 'statistical analysis software' whereas data by observation were analyzed using 'Microsoft Excel'. Data for each selected district were analyzed separately and then the results were pooled by assigning appropriate weights at higher levels like agro-climate zones, states etc. Sampling weights were obtained for each record according to sampling design implemented for data collection at district level (i.e weightage of sample numbers of farmers, villages and blocks to their actual numbers) For estimating the losses for agro-climatic zone level, weightages were assigned based on the production of specific crop in all the sample districts. Similarly post harvest losses at national level were estimated by assigning weightage on the basis of production of specific crop in the agro climatic zone.

Estimates of Post Harvest Loss for Different Crops and Commodities

Tables 1.2 : Harvest and Post Harvest Losses (%) of Cereals at Nationals Level in India

S. No.	Crop	Harvesting	Collection	Threshing	Winnowing/ Cleaning	Drying	Transportation	Total loss in farm operation	Total loss in storage	Overall Total Loss
1.	Paddy	1.2 ±1.1	0.74 ±0.53	1.13 ±0.44	0.36 ±0.48	0.23 ±0.23	0.13 ±0.16	3.91 ±0.58	1.28 ±0.31	5.19 ±0.49
2	Wheat	1.69 ±0.7	0.56 ±0.43	1.62 ±0.48	0.48 ±0.59	0.04 ±0.11	0.16 ±0.13	4.67 ±0.47	1.28 ±0.31	5.96 ±0.38
3	Maize	0.5 ±0.42	0.19 ±0.17	1.57 ±0.36	0.21 ±0.30	0.17 ±0.09	0.07 ±0.08	2.81 ±0.26	1.29 ±0.31	4.10 ±0.29
4	Bajra	0.8 ±0.64	0.56 ±0.41	1.30 ±0.60	0.33 ±0.72	0.30 ±0.25	0.17 ±0.16	3.82 ±0.52	0.98 ±0.42	4.80 ±0.47
5	Sorghum	0.6 ±0.78	0.38 ±0.39	0.67 ±0.82	0.39 ±0.49	0.34 ±0.20	0.13 ±0.09	2.76 ±0.52	1.12 ±0.17	3.87 ±0.38

Economic losses have been computed as follows

Cereals-Rs.7614 crore; Pulses-Rs.999 crore; Oilseeds-Rs.3800 crore; Fruits-Rs.5694 crore; Vegetables-Rs.3972 crore; Spices & Plantation crops-Rs.1631 crore and Live Stock produce-Rs.4092 crore, Total amounting to Rs. 27802 crore.

Conclusions from the Study

- The losses for cereals range between 3.87% to 5.96%; storage losses being 0.98% to 1.29%
- The losses for pulses range between 4.28% to 6.06%; storage losses being 0.96% to 1.96%

- The losses for oilseeds range between 2.76% to 10.07%; storage losses being 0.41% to 0.96%
- The losses for fruits range between 5.77% to 18.05%; storage losses being 1.2% to 4.13%
- The losses for vegetables range between 6.88% to 12.98%; storage losses being 1.51% to 3.04%
- The losses for spices range between 1.12% to 8.64%; storage losses being 0.23% to 1.66%
- The losses for live stock produce and sugar & khandsari range between 0.77% to 6.92%; storage losses being 0.1% (milk) to 1.75% (inland fish)

Based on the Study, it is found that there has been an appreciable reduction in the losses as compared to the earlier studies. The results of this survey have helped in identifying the critical operations and channels for a given crop where losses are high and need technological interventions. Efforts are required to create awareness for adoption of already developed and readily available improved processing technologies and equipments resulting in reduction of post harvest losses. Harvesting and threshing need to be standardised and refinement in existing machines, especially multi crop threshers, is essential. The scientific village level storage systems recommended by experts need to be promoted to store farmers' grain.

Appropriate preservation techniques and infrastructure for short term storage such as precooling or cold storage for fruits and vegetables need to be made available. The value addition technologies need to be promoted by providing incubation centers. Researchers, policy makers and other stake holders need to not only design and implement future strategies for reducing losses but also develop infrastructure for handling and storage.

1.8 Losses due to Dearth of Storage Facilities

A news item on August 23, 2013 quote –

Due to lack of adequate storage infrastructure, fruits, grains and vegetables worth Rs 44,000 crore goes waste every year, food processing industries minister Sharad Pawar informed Rajya Sabha on Friday. Pawar said during Question Hour that the value of annual wastage of fruits and vegetables was estimated at Rs 13,309 crore. However, if the wastage value of rice, wheat, cereals and others are taken into account, it would go up to Rs 44,000 crore a year.

He said government has already initiated various steps to encourage creation of additional storage capacity and complimented certain States, without naming them, for showing "lot of interests".

Pawar said the Saumitra Chaudhuri Committee, constituted by the Planning Commission in 2012, has indicated 61.3 million tonne of cold storage requirement in the country against the present capacity of around 29 million tonne. "The present gap is around 32 million tonne," Pawar said. Government provides financial assistance in the form of grant-in-aid at the rate of 50 per cent of the total cost of plant and machinery and technical civil works in general areas and at the rate of 75 per cent in difficult areas, including northeastern states, for creation of cold chain infrastructure. The ceiling is, however, at Rs 10 crore.

Pawar said investment of FDI in Retail was expected to help in developing back-end cold storage infrastructure.

– unquote

Without taking into account the dearth of storage facilities, Indian Council of Agriculture Research projects a loss of Rs. 59,000 crore while the Minister of Agriculture reports a loss of Rs 44,000 crore because of dearth of storage facilities. The total amounts to Rs 94,000 crore which is about 70% of the Food Security Bill of the Government.

1.9 Reduction of Losses in Storage and Increase of Shelf Life

1.9.1 *General*

There is a dearth of storage facilities and cold storages in the country. One of the main recommendations is to have **covered storage of grains and introduce pre cooling of fruits and vegetables for short term storage.** During storage, there are losses due to infestation and microbial spoilage; though there are chemical treatments available and are used (other than methyl bromide) for reducing the losses and extending the shelf life, the residues from chemical treatment, even at ppm level, are not desirable.

1.9.2 *Gamma Irradiation*

The Department of Atomic Energy (DAE) has carried out a lot of R&D to extend the shelf life of food and agricultural produce by treating these with Gamma rays in seventies and eighties. The Food Technology Division at Bhabha Atomic Research Centre (BARC) is still pursuing active R&D in this area This Gamma ray treatment has been used for sterilization of medical devices like surgical gloves, catheters, IV sets etc. since the sixties and the first such plant was commissioned in BARC in 1974. For the sterilization of medical devices, the dose required is high; to reduce the bio burden for different food products, a minimum and a maximum radiation dose had to be established and the Ministry of Health had to be convinced to allow the food irradiation on a commercial scale.

The Atomic Energy (Control of Food Irradiation) Rules were first established in 1991 by the efforts of AERB (Atomic Energy Regulatory Board) and BARC. As a result of this, PFA (Prevention of Food Adulteration) Act rules under Ministry of Health were amended in 1994 permitting use of irradiation for onion, potato and spices. The Atomic Energy (Control of Food Irradiation) Rules were further amended in 1999 by AERB/BARC efforts. PFA Act rules were further amended in 1998 and 2001 giving approval to several commodities. Under the above rules a minimum, maximum as well as an average dose was prescribed. Now PFA is a part of FSSAI (Food Standards & safety Authority of India) In 2012 Atomic Energy (Radiation Processing of Food & Allied Products) Rules were published approving commodities on generic class-wise basis. Under these rules, a technological dose range is prescribed for each application, where the lower dose represents the minimum effective dose.

The first such cobalt-60 gamma irradiation based commercial technology demonstration plant was commissioned in 2000 by DAE for the microbial decontamination of spices; this was followed by another technology demonstration plant at Lasalgaon in Nashik district, KRUSHAK, for low dose applications for preservation of agricultural produce like sprout control and insect disinfestation. This plant is also being used for quarantine treatment of mangoes for export to USA. After this, technology has been transferred to the private sector with some subsidy from the Ministry of Food Processing Industries. In the past ten years, ten plants have come up in the private sector and a number of plants are at different stages of construction. While other plants are multipurpose, two are designed as Agro Irradiators; typically each plant can treat about 20,000 tons/year.

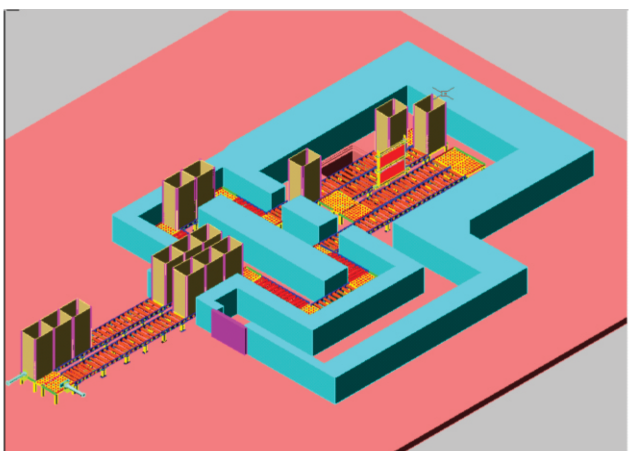
This method has not caught up on a very large scale due to logistics, the cost involved and the consumer acceptance.

The products are unloaded, put it in the tote boxes and after irradiation, these are unloaded and dispatched. More innovation is being done to further improve these plants and to reduce the cost of handling the product and the irradiation.

Every two years, there is an International meeting on Radiation Processing to promote this technology, in particular for Food Irradiation.

IAEA-TECDOC-1386
Emerging Applications of Radiation Processing

Lists RADIATION PROCESSING FACILITIES FOR FOOD IRRADIATION IN 16 DEVELOPING COUNTRIES—The products listed are Garlic powder, spices, condiments, shelf-stable food, fruits, Potato, onion, dried fish, grains, rice etc.



Agricultural Product Low Dose Gamma Irradiation Plant

1.9.3 *Electron Beam Irradiation*

A lot of R&D has been done in the past three decades on the application of Electron Beam Technology as well as in the manufacture of machines for different applications. To start with, these machines have been used for cross linking of cable insulations (polymer modification) before these found the other applications like curing and coating, sterilisation and food irradiation.

In many respects, Electron Beam Irradiation is far better than Cobalt-60, gamma irradiation except for the capital cost which is much higher and is justified if the through puts are very high and the thickness (penetration depth of E Beam) of the product is not much. The product moves on a conveyer at a fast speed of a few meters per minute under the Electron Beam. The through put for food/agro products would be in the range of a few tons/minute.

A few Electron Beam Machines (imported) are installed in the country; these are being used for the cable insulation and some of these are utilising the spare capacity for sterilisation of medical devices. Recently two machines have been developed and the commercial trials are going on; one in Indore, developed by Raja Ramanna Centre for advanced Technology and the second in Navi Mumbai, developed by Bhabha Atomic Research Centre. Once the indigenous machines are available with maintenance back up, these would be ideally suited for food irradiation and would complement the gamma technology in a big way. These machines can be turned on and off as any other industrial electrical equipment. **Food and waste irradiations are envisaged as the largest potential applications.**

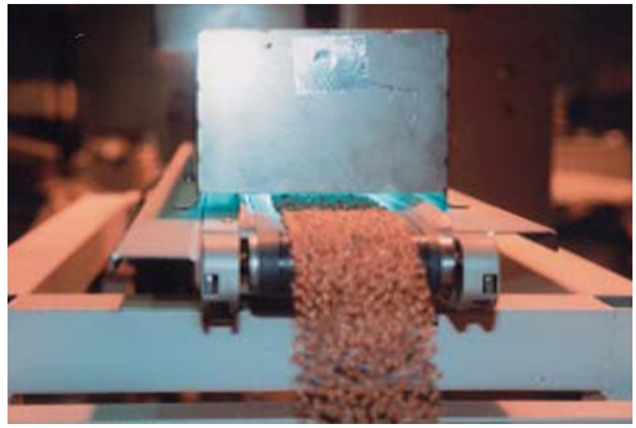
1.9.4 *UV Treatment*

Some R&D is being done **on the Sterilization of Grain Surface Using Ultra Violet Radiation,** and its sterilization effect on microorganisms adhering to grain was confirmed. **Following is one such reference Study on the Sterilization of Grain Surface Using UV Radiation—Development**

and Evaluation of UV Irradiation Equipment—Yasuyuki HIDAKA* and Kotaro KUBOTA1

Crop Production Machinery and System Department, Bio-oriented Technology Research Advancement Institute (BRAIN) (Kita, Saitama 331–8537, Japan)

Ultraviolet (UV) radiation, unlike gamma radiation, causes excitation rather than ionization of atoms by raising electrons to a state of higher energy without removing them The maximum biocidal effect of UV is between 240 and 280 nm The mercury vapor sterilizing lamp generates and emits a wavelength of 253.7 nm. When microorganisms are irradiated with U V at this wavelength, chemical reactions occur in vital cell components, particularly the nucleic acids. This action results in death to the cell provided the dose is of sufficient magnitude The aim of this study was to control microorganisms that cause grain degradation using ultraviolet (UV) sterilization, as a method that is eco-friendly and safe for storage without the need for postharvest application. In order to obtain practical ultraviolet sterilization, recirculating grain sterilization equipment was manufactured that uses UV irradiation. Applying UV sterilization directly to microorganisms that adhere to the surface of the wheat was investigated, and then checked in quality. Sterilization tests indicated that the required sterilization time to obtain a 90% sterilization rate was 6.3 h for bacteria and 5.6 h for Mold (*Mold or Mould is a fungus that grows in the form of multicellular filaments called hyphae.*) using 254 nm wavelength and 97 W/m2 UV irradiance. The germination and amylograph tests suggested that quality was minimally affected by UV irradiation in this range. The amount of UV energy to reduce microorganisms by 90% was estimated to be 3.6 MJ/t.



View of UV irradiation for wheat

1.10 Conclusions / Recommendations

In addition to increasing the food production, the losses in transportation, storage and handling, need to be drastically reduced. This can be done by improving the infrastructure and educating the personnel handling the produce.

Setting up the gamma irradiation plants, in particular, in the 'food parks' should be encouraged. Ideally, the irradiation should be carried out just after harvesting and before packing; these measures would reduce the need for transporting long distance and unpacking & re packing. The subsidy provided by the 'Ministry of Food Processing Industry' should continue and the 'soft' loan which used to be provided by the TDB (Technology Development Board) of DST (Department Science and Technology) should be restarted.

More effort should be put to make the electron beam machines in the country and use these for mass scale irradiation of food products. Some R&D should be initiated on the UV treatment of grains.

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Chapter 2

Energy – Major Thrust on Solar

2.1 Growth and Development

2.1.1 Sustained and equitable growth is needed for eradicating extreme poverty and hunger from our country. Energy is a key input for Sustainable Growth and Development.

2.1.2 As part of Millennium Development Goals (MDGs), world has lately been making extraordinary progress in lifting people out of extreme poverty (Ref.1). Between 1990 and 2010 their numbers fell by half as a share of total population in developing countries, i.e. from 43% to 21% (Ref. 2). In this period, the driving force behind the reduction in worldwide poverty was Growth. Regions with largest numbers of poor people registered substantial reduction of 8% in China and Southeast Asia, and 7% in South Asia including India (Ref. 3). World Bank has recently set the Goal to reduce extreme poverty around the world to under 3% by 2030. India must maintain a growth rate of above 7.5% to achieve this Goal (Ref. 4).

2.1.3 With ecological and environmental concerns for Sustainable Development and Inclusive Growth, great emphasis is now being laid on Energy Efficiency and Renewable Energy Sources.

2.1.4 This exercise examines India's energy requirements for sustainable growth and the role of Renewable Energy, specially, the Solar Energy towards Low Carbon Sustainable Development. Brief details of Solar Technologies and their growth globally, and in India, are described. Action plan for future growth is also suggested.

2.2 Energy for Sustainable Development

2.2.1 India has been one of the fastest-growing economies over the past five years, with an average annual growth rate of roughly 8%. The erstwhile Planning Commission of India believed that the country needs to sustain this growth rate over next 25 years if the country is to eradicate poverty and meet its human development goals.

2.2.2 Government of India's Integrated Energy Policy (IEP) – 2006 has suggested that in order to achieve sustained growth of 8% through 2031-32 and to meet lifeline energy needs of all citizens, India needs, at the very least, to increase its primary energy supply by 3 to 4 times and its electricity generation capacity/supply by 5 to 6 times of their 2003-04 levels. By 2031-32 power generation capacity must increase to 8.00,000 MW from current capacity of around 1,60,000 MW inclusive of all captive plants, a fivefold increase (Ref. 5).

2.2.3 More than 75% of this additional capacity is planned from fossil fuels viz. coal, gas and petroleum products, which have adverse environmental impact. Renewable Energy has been projected to contribute less than 5% of the total generation planned. Solar Energy was projected to cost Rs 15-20 per KWh and, therefore, did not receive the importance inspite of its abundant availability.

2.2.4 Realising the importance of energy supply for rapid growth, Government has been laying strong emphasis by planning huge capacity additions in line with the projections of IEP. However, there have been consistent shortfalls in every Plan period in capacity addition achieved vis-à-vis the targets as under:

Plan	Target	Achievement
IXth Plan (1997-2002)	40,245 MW	19,015 MW
Xth Plan (2002-2007)	41,110 MW	21,180 MW
XIth Plan (2007-2012)	62,375 MW	54,963 MW

Source : (i) Ministry of Power-Central Electricity Authority (CEA)-Report on Growth of Electricity Sector in India – July 2013.
(ii) Ministry of Power – CEA-Executive Summary – December 2014.

2.2.5 Consistent shortfalls of up to 50% or more are due to various reasons, such as delays due to environmental clearances, land acquisition, relief and rehabilitation problems, shortfall in assured fuel linkages for coal and gas etc. Heavy short fall in electricity supply, causing long scheduled and unscheduled blackouts, is seriously affecting growth of industry and commerce. Industry and Services requiring uninterrupted power have to depend on power from DG sets costing three times more. Such a situation affects global competitiveness of Indian Industry.

2.2.6 There is urgent need for India to tackle huge energy deficit to maintain its GDP growth of more than 8%, required for reducing extreme poverty and meeting other Millennium Development Goals. A paradigm shift in energy planning to develop Renewable Energy sources to their full potential is thus urgent.

2.2.7 India is faced with the challenge of sustaining its rapid economic growth while dealing with global threat of Climate Change. The development path must be based on its unique resource endowments, the overriding priority of economic and social development and poverty eradication, and its adherence to its civilizational legacy that places a high value on environment and maintenance of ecological balance (Ref. 7). Harnessing of abundantly available Solar Energy can meet the rising demand of energy for Low Carbon Sustainable Development and simultaneously address the challenges of environment conservation in conformity with its global commitments.

2.2.8 In order to achieve sustainable development path that simultaneously advances economic and environmental objectives, National Action Plan for Climate Change (NAPCC) has been formulated. There are Eight National Missions which form the core of NAPCC. First two of the eight missions deal with Energy – Jawaharlal Nehru National Solar Mission (JNNSM) and National Mission for Enhanced Energy Efficiency. (See Box No. 1)

Box No. 1

National Action Plan on Climate Change

In June 2008, the Prime Minister of India released the National Action Plan on Climate Change (NAPCC) outlining existing and future policies and programmes for addressing climate mitigation and adaptation. The Plan identifies 'eight core missions' each having a lead Ministry responsible for developing objectives, implementing strategies, time lines, and monitoring and evaluation criteria which are to be submitted to the Prime Minister's Council for Climate Change. **These Eight Missions and their Broad Goals are as under** :

No.	National Mission	Goals
1.	National Solar Mission	Specific goals for increasing the use of solar thermal technologies in urban areas, industry, and commercial establishments; Long term aim is to make solar competitive with fossil based energy.
2.	National Mission for Enhanced Energy Efficiency	Initiatives based on the Energy Conservation Act 2001.
3.	National Mission on Sustainable Habitat	Extending the existing Energy Conservation Building Code; Emphasis on urban waste management and recycling, including power production from waste; In the Transport Sector it calls for stronger enforcement of automotive fuel economy standards, using pricing measures to encourage the purchase of efficient vehicles, and providing incentives for use of public transport.
4.	National Water Mission	20% improvement in water use efficiency through pricing and other measures.
5.	National Mission for Sustaining the Himalayan Ecosystem	Conservation of biodiversity, forest cover, and other ecological values in the Himalayan region, where glaciers are likely to recede.
6.	National Mission for a "Green India"	Expanding forest cover from 23% to 33%.
7.	National Mission for Sustainable Agriculture	Promotion of sustainable agricultural practices.
8.	National Mission on strategic Knowledge for Climate Change	The plan envisions a new Climate Science Research Fund that supports activities like climate modeling, and increased international collaboration; It also seeks to encourage private sector initiatives to develop adaptation and mitigation technologies.

2.2.9 Jawaharlal Nehru National Solar Mission (JNNSM) was launched to significantly increase the share of solar energy in total energy mix while recognising the need to expand the scope of other renewable and non-fossil options such as nuclear energy, wind energy and biomass.

Box No. 2

Non Renewable and Renewable Energy

Energy sources that are replenished slowly (or not at all) are classified as **non-renewable**. These include **fossil fuels** e.g. coal, petroleum, natural gas, and **nuclear fuels** e.g. uranium. Sources that are replenished more rapidly are termed as **renewable**. These include solar, wind and water which are inexhaustible and wood or other forms of organic material that may be converted into gaseous or liquid fuel by thermo-chemical or biological processes. Other renewable energy sources are geothermal energy (Temperatures inside the earth vary between 3000^0 to $10{,}000^0$C) and energy from the oceans (Tapping tides, waves, and currents).

Biomass includes all the living or dead organic materials like wastes and residues. The demarcation between biomass and fossil fuel energy begins with the peat, the fossil fuel being the secondary product of the decaying mechanism. Not only are plants, animals and their residues and wastes regarded as biomass, but also the materials which originate through conversion process like paper, cellulose, organic residues from the food industry, and organic waste material from industries and houses (Ref. 22).

The various energy sources and their attributes can be seen in Table No. 1.

Table No. 1

Energy Source	I	II	III	Electricity Generation Mix in the Year 2030
Coal	NR	F	C	63%
Petroleum	NR	F	C/G	4% (Petroleum and Natural Gas)
Natural Gas	NR	F	C/G	
Nuclear	NR		C	8%
Hydro	R		C/G	7%
Biomass	R		I	2%
Wind	R		I	8%
Solar	R		I	8%

Notes : (i) Column I indicates Non Renewable (NR) and Renewable (R) energy sources. (ii) Column II indicates Fossil fuels (F). These are primarily responsible for CO_2 emissions, main component of green house gases (GHGs). (iii) Column III indicates Plants which normally operate round the clock (C); the Plants which can operate round the clock but can also be stopped / started in a short period of time for grid balancing (C/G); and Plants which give intermittent supply during a limited period of the day (I); (iv) Electricity generation mix in the year 2030 is based on Low Carbon Inclusive Growth (LCIG) Scenario – Planning Commission (April 2014). (Ref. 29); (v) Geothermal energy and Ocean energy have not been considered.

2.2.10 India accords high importance to development of Renewable Energy sources. It is perhaps the only large country with dedicated Ministry of New and Renewable Energy (MNRE). Renewable Energy as defined in India primarily covers four forms: Solar, Wind, Biomass and Mini-hydro. Large hydroelectric projects are excluded from MNRE even though the power from these projects is a renewable source of energy.

2.2.11 Technically mature Renewable Energy Technologies (RETs) are Wind, Solar PV, Solar Thermal, Co-generation with Biomass which can be employed both for Grid connected or Stand-alone systems. New and emerging RETs are Geo-Thermal, Tidal and Ocean-Thermal energy conversions.

2.2.12 Hydrogen is emerging as an alternative clean energy source. Technology for Hydrogen Fuel Cells has already matured and is being used for stand- alone home power and for powering zero emission automobiles. Toyota and Mercedes car companies have announced launch of Hydrogen Fuel Cell powered Zero Emission cars by early 2017. Research is going on for developing Controlled Fusion by a multinational team at CERN. Sun and Hydrogen are projected to provide unlimited clean energy sources for mankind by the second half of twenty first century.

2.2.13 Potential of Wind, Biomass and Mini-hydro are limited. For India, Wind power potential has been assessed as 49 GW at 50 meter hub height and 103 GW at 80 meter hub height. Potential of Biomass and Mini-hydro has been assessed at 20 GW each. (Source : MNRE)

2.2.14 5000 trillion KWh/year Solar Energy is incident over India's land mass with most part receiving 4-7 KWh per meter square. Harnessing of 0.001% of this energy will give a potential of 5000 GW which will be sufficient to meet our growing energy demand.

2.2.15 Expert Group on Low Carbon Strategies for Inclusive Growth has suggested that the aim should be that at least one-third of power generation by 2030 is from fossil-free sources (Ref. 29).

2.3 Some Points to Ponder

2.3.1 *Energy – A Theoretical Perspective*

While discussing "smart energy" Piccioni (Ref. 28) cites Einstein's most famous equation E=mc2 and its implications for generating energy, namely that all useful energy ultimately comes from the conversion of mass into various forms of energy. If we convert 1 ton of mass into suitable energy and define it as '1 ton of energy' then Table No. 2 will indicate the current huge resource use (and consequent pollution) vis-à-vis the position if we are able to use hydrogen fusion. It has further been mentioned that providing the world's energy needs in 2004 would have required converting only **six tons of mass** into other forms of energy.

Table No. 2

Process	**Tons of Fuel Needed to Supply "1 ton of Energy"**	**Clean**
Burn Coal	5,000,000,000	No
Burn Gasoline	2,000,000,000	No
Uranium Fission	50,000	No
Hydrogen Fusion	133	Yes
Mass ➔ Black Hole	1	Yes

Sun uses hydrogen fusion to generate energy. Every second our sun 'burns' 574 million tons of hydrogen, creating 570 million tons of helium, and converting 4 million tons of mass into energy. **Our research activities must, therefore, be directed with a much greater vigour to use the energy from the Sun and also towards generating energy from 'hydrogen fusion'.**

2.3.2 *Fusion Energy – Hydrogen Fusion*

Michio Kaku (Ref. 27) mentions that by mid-century the new option of Fusion is very likely, giving us a permanent solution to the energy problem. While fission power relies on splitting the uranium atom, thereby creating energy (and a large amount of nuclear waste), fusion power relies on fusing hydrogen atoms with great heat, thereby releasing vastly more energy (with very little waste). Fusion (not fission) is nature's preferred way to energise the universe. Fusion power lights up the sun and the heavens.

The public has a right to be skeptical about Fusion, since there have been so many hoaxes, frauds, and failures in the past more than 50 years. However, the advantages of fusion power are so great that many scientists are working on fusion related projects. **In France, there is the International Thermonuclear Experimental Reactor (ITER) backed by the European Union, the United States, China, India, Japan, Korea and Russia.** The ITER uses huge magnetic fields to contain hot hydrogen gas and is one of the largest international scientific project ever attempted. It is projected to cost 10 billion euros (At one Euro = Rs. 80 it will work out to Rs. 80,000 crore).

2.3.3 *Solar Energy Potential (Ref. 5 & 29)*

Solar energy is a non-polluting source and is also available in abundance. The sunlight hitting the earth's surface everyday contains 7,000 times more energy than fossil fuels which we consume. Potential thus is enormous. Technologies already exist for its use (Solar Thermal; Solar Photovoltaic) but are being used to a limited extent primarily due to their higher costs *(Rs. 2.5 to 3.5 per KWh for power from Coal vs Rs. 11.0 to 12.5 per KWh for Solar in the year 2006; However, while the cost of power from Coal has increased by about 50%, the cost of Solar power has come down to Rs. 6 per KWh as per April 2014 Report and is likely to achieve Grid parity in the coming years.)*, need for large areas for power collection, and energy availability only during a limited period of the day.

The Planning Commission Report (Ref. 5) on the "Integrated Energy Policy" mentions that with 9% GDP growth the Total Primary Energy requirement (Commercial + Non-Commercial) for our country will be as under :

2006-07	550 Million Tonnes of Oil Equivalent (Mtoe)
2031-32	2045 Million Tonnes of Oil Equivalent (Mtoe)

On the other hand, the potential of Solar Thermal and Solar Photovoltaic has been indicated as 1200 Mtoe per year for each, the total being 2,400 Mtoe per year. The wasteland requirement envisaged is 5 million hectare (one hectare = 10,000 sq. m.) in both the cases(Total 5+5 = 10 million hectare) and 15% efficiency level has been assumed for Solar Photovoltaic cells. With improving technologies, the area of waste land needed for the purpose may reduce significantly. It may not be out of place to mention that India has a total land area of 329 million hectare out of which about 30 million hectare is waste land. Further, with an all India Power Grid connectivity solar power transmission will also not pose any problem (e.g. from desert areas having abundant sunshine to other areas comparatively deficient in sunlight). But here one major problem (besides the need for making solar power commercially viable) is the need for 'storage' of energy during day hours for use in the other periods. This becomes particularly relevant if the solar power has to find a dominant place in the energy mix.

The Jawaharlal Nehru National Solar Mission (JNNSM), one of the eight Missions under National Action Plan on Climate Change (NAPCC), targets Solar Off-grid and Solar Grid powers of 2 GW and 20 GW respectively by the year 2022. These ambitious targets need to be escalated upwards to give a real boost to solar power capacity and **a recent announcement (June 2015) by the Government of India to enhance the Solar power capacity target by five times i.e. to 100 GW by the year 2022 is a very welcome step. This will, however, need suitable 'storage' systems for balancing the Grid.**

2.3.4 ***Storage of Power – Solar, Wind, etc.***

Systems to store excess energy, such as that produced by solar power, wind turbines and other such intermittent and 'time shifting' sources, will greatly help in Grid balancing. Further, energy storage will also allow 'peak shaving' by tapping stored energy rather than firing up standby generators by the utilities making their operations more economical/efficient.

One way to store energy is development of 'pumped hydraulic storage'. With the 'power grid' connectivity now available, solar power generated say in suitable desert areas can be balanced using the power grid and could also be stored in places where abundant water reservoirs/sources are available. The NHPC already has a 'pumped storage' system available at Purulia where 4x225 MW power could be stored and they are developing another system at Tehri of 4x250 MW capacity. **Typically the ratio of energy OUT to energy IN is 70% or so for such a storage**. In existing and future hydel projects, the storage aspect has to be kept in mind and large pumped storages planned.

Although most widely used form of bulk energy storage is currently pumped hydraulic storage (PHS) but various new concepts like Compressed-Air Energy Storage (CAES), and Advanced Rail Energy Storage (ARES) which harnesses the potential of gravity, are also being used (Ref. Economist; March 3rd 2012 – Print Edition – Energy Storage).

Grid level batteries are also an option to consider. Na-S, Flow battery and Li-ion battery systems are among the leaders in the international grid level battery sector. Detailed studies are, however, required to ascertain their viability under Indian condition.

Such excess power could also be used to produce hydrogen and then make use of hydrogen directly for combustion engines or in fuel cell vehicles. For it, storage and transport of hydrogen and its use in vehicles has to be made safer and cost effective. **This excess power can also be used to charge the batteries of Electric Cars / Vehicles.**

Storage of energy and its reuse always involves some loss e.g. in PHS it is about 30%. Captured carbon dioxide from coal power plants (for making coal power cleaner) could be converted into useful gaseous / liquid fuels using such excess power. **Such a conversion process is very likely to be a financially viable option considering the otherwise inherent loss associated with storage of power.**

2.3.5 *Solar Power from Thar Desert*

Availability of an all India Power Grid provides the facility to transmit Solar power from suitable areas like Rajasthan, which receive very high solar radiation and have easily available surplus land, to other parts of the Country. It has been estimated that the 35,000 sq km (3.5 million hectare) expanse of Thar Desert alone is sufficient to generate anything between 700 GW to 2000 GW (Ref. 24).

2.3.6 *Storage Thresholds for Grid Balancing*

The main problem associated with Solar power as also with power from Wind & Biomass is their intermittency and availability only during a particular period of the day. A larger share of renewable power (Solar, Wind, Biomass) in the energy mix will, therefore, need suitable energy storage systems for grid balancing. If these are not provided the Power will be wasted unless gainfully utilized during the period it is available for some other purposes e.g. Hydrogen generation, Conversion of CO_2 to fuel, Charging car batteries etc.

According to a UK Study, with intermittent variable supply from renewables when exceeding 10% of the electricity generation, the estimates of the additional reserve capacity are in the range of 3 to 6 per cent of the rated capacity of the plant. With 20% this range is approximately 4 to 8 per cent (Ref. 26). The LCIG scenario of 2030 (Ref. 29) envisages a share of 18% electricity generation from renewables. This may need storage say to the extent of about 5% of the plant capacity (Wind 120 GW + Solar 100 GW = 220 GW) i.e. about 11 GW.

2.3.7 *Decentralised Solar Energy Applications*

Decentralised Solar energy applications are attractive since they generate solar power close to the load centre and have minimum transmission losses. In villages and isolated areas not having Grid connectivity Solar Home Lighting Systems and Solar Micro-Grids should be used in a big way. Use of Solar Water Pumps is also a cost effective solution.

2.3.8 *Roof Top Photo Voltaic (RTPV) Solar Power*

Roof Top Photovoltaic (RTPV) Solar Power should be given directed attention. The potential of RTPV in the Country (commercial, residential and industrial rooftops; and rooftops of airports, railway stations, metro stations and bus stations) has been estimated to be in the range of 60 GW to 94 GW (Ref. 29).

2.3.9 *Making Power from Coal Cleaner*

It will neither be practical nor possible to do away with coal power, which even in the Low Carbon Inclusive Growth Scenario 2030 (Ref. 29) will have a major share (63%) in the electricity generation. Only way is to eliminate / reduce emissions and make the coal power cleaner. For this, capture of carbon dioxide (**carbon capture**) appears essential. In view of the costs involved (full carbon capture will reduce the amount of electricity generation by about 20%) part capture of CO_2 could be attempted in the initial years followed by full decarbonisation in due course.

For part decarbonisation Solar power can be used during the period of its availability for carbon capture. This will also not affect the power plant output. This may reduce CO_2 emissions by about 25%. The captured CO_2 could then be converted into useful Fuel using the Solar power. If greater reduction in emissions is warranted the power of the coal plant itself will have to be used for carbon capture. The captured CO_2 in all situations can always be converted to Fuel using the Solar power.

2.3.10 *International Solar Power Grid*

Another concept even though appearing utopian can also be considered. We import coal / petroleum / gas from far off places / countries. Why not import Solar power through an International Solar Power Grid developed for the purpose ? Round the clock availability of Sun will eliminate problems of intermittency and availability of power only during the limited period of the day. Solar Power will be available round the clock in all parts of the globe through the International Solar Power Grid.

2.4 Solar Energy

2.4.1 Solar Energy, radiant light and heat from sun, is harnessed using a range of ever evolving technologies such as solar heating, solar photovoltaics, solar thermal electricity, solar architecture and artificial photosynthesis.

2.4.2 Solar Energy is emerging as a major power source due to its numerous environmental and economic benefits, some of which are listed below:

- The Fuel is free. The sun is the only resource needed for harnessing solar energy and the sun will keep shining forever until the world's end.
- Most photovoltaic cells are made from silicon, and silicon is a non-toxic element and one of the most abundant material in earth's mass.
- It is most environment friendly as it produces no noise, harmful emissions or polluting gases. Fossil fuels viz. coal, oil, gas are the major fuels used presently, which generate carbon dioxide (CO_2), a leading greenhouse gas causing global warming. Solar power uses only the power of the Sun as its fuel and contributes actively to reduce global warming.
- Photovoltaic (PV) systems are very safe and highly reliable. Estimated lifetime of a PV module is 25-30 years. Modules performance is very high, providing over 80% of initial power even after 25 years. Very high manufacturing standards have evolved globally which guarantee reliable products.
- PV modules are almost maintenance free and offer an easy installation.
- Grid losses are minimised. PV can be considered as a distributed and decentralised source of energy. Producing electricity near the place where it is consumed leads to reduction in Transmission and Distribution (T&D) losses. All India average of T&D losses is 26% while in some distribution areas these are as high as 65% (Ref. 6).
- Once installed, a PV system will produce electricity for at least 25 years at a fixed and known cost. Conventional power plants must deal with fluctuating prices and availability of fossil fuels such as oil, gas or coal in the national and international markets. Sun is an universal resource, indigenous to all countries, and solar energy offers highest level of energy security.
- PV modules can be recycled and therefore most of the materials used in production process (silicon, glass, aluminium, minute amount of precious metals etc) can be recovered and reused. In Europe, recycle laws have been enacted for PV recycling (Ref.12).

- PV systems can provide reliable and cost effective source of electricity to remote rural areas.
- With large scale use and mass production, prices of solar PV systems have fallen rapidly. Price of PV modules has been falling by over 20% every time the cumulative sold volume has doubled. System prices have declined rapidly; during ten years from 2005 to 2015 price decrease of more than 75 % has been realised globally.
- By the end of 2014, Solar Power had already achieved price parity with Commercial and Industrial power tariff in India. Recent (2015) study by US energy consulting firm Energy and Environment Economics (E3) has established that, for commercial and industrial consumers in Delhi, Solar PV installation will break even in less than five years and provide substantial financial benefits during 25-30 years lifetime of solar PV. Local DISCOM is planning 400 MW of solar PV for commercial and industrial consumers in its area.
- New Study by a German think tank, Agora Energywende, forecasted that primarily through expected doubling of module efficiency, which will mean less panels for same power and therefore less land and lower installation charges, the cost of Solar PV energy may fall to as low as 1.5 Euro cent or US$ 0.02 per KWh in high sunshine zones.
- Renewable energy sources of Wind and Solar power are inherently intermittent and therefore, not dispatchable directly. Integration of large scale wind and solar power in the grid requires additional technologies, which can ensure smooth grid operation. Smart grid, smart metering and energy storage technologies have matured. Policy frameworks, that will combine these technologies to enhance the flexibility of Base loads with Generated power has yet to evolve in India.

2.4.3 International Energy Agency (IEA) has said that solar energy can make considerable contributions to solving some of the most urgent problems the world now faces:

"The development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the cost of mitigating climate change, and keep fossil fuel prices lower than otherwise. These advantages are global. **Hence the additional cost of incentives for early deployment should be considered learning investments; they must be wisely spent and need to be widely shared."**

IEA said that solar energy technologies such as photovoltaic panels, solar water heaters and power stations built with mirrors could provide a third of world's energy by 2060.

India, being located in high sunshine zone, should move aggressively to achieve this target.

2.5 Technologies for harnessing Solar Energy

2.5.1 *General*

Use of solar energy can be classified mainly in two broad categories: **Solar Heating and Solar Electricity.**

2.5.2 *Solar Heating*

2.5.2.1 Solar hot water systems use sunlight to heat water. Solar water heaters are provided in domestic, institutional, commercial and industrial buildings. Technology of solar water heaters has matured and used widely. As of 2012, total installed capacity of solar hot water systems is approximately 175 GW. China is the world leader in their deployment with 80 GW installed capacity and long term goal of 210 GW by 2020. Israel and Cyprus are the per capita leaders in the use of solar hot water systems with over 90% of homes using them. In USA, Canada and Australia heating swimming pools is the dominant application of solar hot water.

2.5.2.2 Solar distillation is used to make saline water potable and to produce distilled water for varying commercial applications.

2.5.2.3 Solar cookers use sunlight for cooking, drying and other food processing applications. Simple solar cooker is the box cooker with an insulated container and transparent lid and has been widely adopted for home use. In these cookers temperatures from 90-150 deg C, suitable for home cooking, are reached Large size solar cookers have also been developed and used with reflectors of various geometries. These cookers reach temperature upto 300 deg C.

2.5.3 *Solar Electricity*

2.5.3.1 Solar power, in current usage, is the conversion of sunlight into electricity. Two major technologies adopted are: (i) indirectly using Concentrated Solar Thermal Power (CSTP) and (ii) directly using Photovoltaic (PV).

2.5.3.2 **Concentrated Solar Thermal Power (CSTP)** systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. The concentrated heat is then used as a heat source for a conventional power plant. Wide range of concentrating technologies exist. The most developed are the parabolic trough, the concentrating Fresnel reflector, the Stirling dish and the solar power tower. Various techniques are used to track the sun and focus its light. In all these systems a working fluid is heated by the concentrated sunlight, and then used for power generation or energy storage. Working fluids can also be circulated through storage ponds where the energy can be stored and used in generating power in periods of low or no sunshine. Energy conversion efficiencies of 20-22% are obtained in present day commercial CSTP systems.

2.5.3.3 **Photovoltaic (PV)** systems consist of:

- Photovoltaic modules to collect sunlight and convert it to electricity
- An inverter to transform direct current(DC) to alternate current (AC)
- A set of batteries for stand-alone systems
- Support structures to mount PV modules with orientation towards sun

The system components, excluding the PV modules, are referred as the **Balance of System (BOS)** components.

2.5.3.3.1 Solar cells are the basic unit of a PV system that convert solar radiation into electricity. A cell consists of one or two layers of semiconducting material. When light shines on the cell it creates an electric field across the layers (Semiconductor Junction), causing electricity to flow. Greater the intensity of light, greater will be the flow of electricity. The most common semi-conductor material used in PV cells is **Silicon**, an element most commonly found in sand. There is no limitation to its availability as raw material; silicon is one of the most abundant material in earth's mass.

2.5.3.3.2 PV cells are generally made from:

- Crystalline silicon (C-Si): Thin wafers, sliced from ingots, are subjected to diffusion to form P-N junctions and transform into solar cells. C-Si is the most common and mature technology representing about 80% of the market today. Efficiency of C-Si modules ranges from 13-19%.
- Thin Film: Thin film modules are constructed by depositing extremely thin layers of photosensitive material on to a low cost backing such as glass, stainless steel or plastic. Photo sensitive materials used in thin film solar cells are Amorphous Silicon (a-Si), Multi-junction thin silicon (a-Si/uc-Si), Cadmium telluride (Cd-Te), Copper-Indium-Gallium Selenide/Sulphide (CIGS). Efficiency of thin film solar cells varies from 7% to 12% depending upon the materials used. Thin film technology has also matured and used widely because of their cost advantage over C-Si cells.
- **Concentrator Photovoltaics (CPV)** is an emerging technology that uses lenses to focus sunlight on to solar cells. Efficiencies of 20-25% have been obtained for silicon based cells and 25 to 30% with Gallium-Arsenide (GaAs) based cells.

2.6 Solar Energy - Global Progress

2.6.1 First modern solar cell was patented in 1946 at Bell Labs. In 1950's and 1960's Solar Cells with improved efficiencies found applications in electronic appliances, stand-alone power systems and Solar Photo Voltaic (SPV) powered consumer products such as watches, calculators, toys etc. From around 1995, industry started focussing, increasingly on developing large size stand- alone systems as well as Grid connected SPV systems in USA. Japan introduced SPV in large scale when it experienced severe power outages after great earth quake in 1995. Japan remained the world leader in use of large scale grid connected and stand-alone SPV systems upto 2004 reaching the capacity of 1132 MWp.

2.6.2 Europe, led by Germany, took the lead in SPV installation from 2005 onwards. Germany introduced Renewable Energy Act and adopted Feed-in-Tariff (FiT) mechanism under which a fixed price must be paid for the energy produced by SPV plants over a 20 years period. This provided high level of security and good returns on the investments in SPV plants, leading to high growth of SPV in roof-top as well as grid connected SPV systems.

2.6.3 SPV technologies have experienced fast growth over past decade. Global growth in five year period 2010-15 has been truly remarkable as given under:

Global Growth 2010-2015
SPV Capacity – GWp

Year End	2010	2011	2012	2013	2014	2015 Est.
Cumulative	40	70	100	138	177	231
Annual	17	30	30	38	39	54
Growth / Year	74%	75%	43%	38%	28%	30%

Source: IEA – Photo Voltaic Power System (PVPS) Snapshot (2015)

2.6.4 Some highlight of this Global Growth of SPV capacity are:

- By end 2014, cumulative PV capacity reached at least 177 GWp and for 2015 deployment of another 50-57 GWp has been forecasted around the world. This capacity is projected to double or even triple beyond 500 GWp by 2020. By 2050 solar power is anticipated to become largest source of electricity with PV capacity of 4600 GW of which more than half is forecasted to be deployed in China and India.
  Source : (i) Snapshot of Global PV 1992-2014 by International Energy Agency-PV Power Systems Programme. (ii) Wikipedia- Growth of Photovoltaics.
- Around the world more than 39 GWp of SPV systems were installed in 2014 which was the total cumulative capacity at the end of 2010.
- By 2014, five leading countries in SPV were – Germany (38200 MWp), China (28199 MWp), Japan (23300 MWp), Italy (18460 MWp) and USA (18230 MWp). The combined capacity of these five countries is more than 70% of total global capacity.
- For year 2015, forecasts vary from 35 GW to 54 GW. Deutche Bank anticipates 54 GW in 2015.
- Due to exponential growth of SPV deployment, about 75% of overall capacity has been installed in last four years 2011-2014.
- China demonstrated spectacular growth of SPV in the previous five year period 2009-2014. Starting at a low base of 300 MWp in year 2009, its capacity rose to 28199 MWp in year 2014, showing a Compound Annual Growth Rate (CAGR) of close to 150 %. Maximum annual growth of 310 % was achieved in year 2010. By 2016 it is likely to overtake Germany to become the world leader in SPV installed base.
- Europe remains the world's leading region in terms of cumulative capacity with more than 87 GWp of installed capacity.
- For three years in succession SPV was number-one new source of electricity generation in Europe.
- California State in USA adopted Act AB32 in 2006, which set greenhouse gas emissions reduction goal into law. Under this Law, Renewal Purchase Obligations (RPOs) were mandated for all electric supply utilities. Procurement of renewable energy must reach 33% of total procurement by 2020 to be reached in steps – 20% for 2011-13 Compliance Period 1(CP 1) – 25% for 2014-16 (CP 2).
- In California, solar energy has emerged as major source for meeting these RPO targets. From less than 1 GW in 2010 solar contribution will reach 25 GW by 2020.

- California State launched a programme for Million Solar Homes under which capital grants were sanctioned to communities and attractive Feed-in-Tariff (FiT) to home owners.

2.6.5 In Europe major thrust for solar has come from Roof Top Photovoltaic (RTPV). Share of various segments are:

• Ground Mounted	- 28%	(100 KW to MW Range)
• RTPV - Industrial	-19%	(5 KW to 100 KW)
• RTPV – Commercial	-32%	(5 KW to 100 KW)
• RTPV – Residential	-21%	(1KW to 5KW)

Total RTPV market is 72% compared to 28% for Ground mounted (Ref. 10).

2.6.6 In India, RTPV market is still very small (less than 10%). Solar homes initiative has been taken up in Kerala, Tamil Nadu and Karnataka. Large scale grid connected RTPV initiative, under solar city programme, has been planned for five cities and being implemented through Solar Energy Corporation of India (SECI), a public sector undertaking under MNRE. In Gujarat, Gandhi Nagar Solar Roof Top Photo Voltaic programme has been taken up as a pilot project and planned for five more cities. Recently Haryana Govt has laid down RTPV obligations on all residential holdings of more than 500 sq meter. Recently GOI has identified 40 cities for RTPV under Solar City programme.

2.7 Solar Energy in India –Present and Future

2.7.1 India is a tropical country, where sunshine is available for longer hours and in greater intensity. Solar energy has great potential as future energy source. About 5,000 trillion KWh per year energy is incident over India's land area with most part receiving 4-7 KWh per sq meter per day. Solar irradiation in India is almost double that of Europe, Japan and China, that are leading in installation of PV based solar energy systems. Both technology routes for conversion of solar radiation into heat and electricity, namely Solar Thermal and Solar Photovoltaic, can effectively be harnessed for providing huge scalability for solar energy in India.

2.7.2 National Institute of Solar Energy has carried out an exercise for calculating state-wise Solar potential in the country. These calculations have been made taking data from Census 2011 and considering the wasteland data from Wasteland Atlas 2010. Institute has assessed a potential of 750 GWp for the entire country based on following assumptions:

- About 3% of wasteland in States is used for Solar power projects.
- In one square Km, 50 MWp SPV power plant can be installed with SPV module efficiency of 15%.
- The potential of putting up SPV plants on roof top has been calculated by taking data of urban India given in Census 2011 and with assumptions that 2 to 25 % of residential, commercial and industrial buildings can be used for installing 1 KWp to 100 KWp SPV plants on these buildings.
- These estimates appear highly conservative vis-a-vis the achievements of rooftop SPV plants in Europe. Also with advancing technologies, SPV module efficiencies of 20-25 % are achievable in near term, leading to larger capacity plants per unit of area. With innovative guidelines, SPV

capacity up to 3000 GWp should be achievable in India.

2.7.3 Solar energy is most environment friendly as it has zero emissions. From energy security perspective, solar is most secure of all sources, since it is abundantly available and it is captive to the country.

2.7.4 Jawaharlal Nehru National Solar Mission (JNNSM) was launched by Government of India and State Governments to promote ecologically sustainable growth while addressing India's energy security challenge. The mission adopted a 3-phase approach; three years 2010-13 as Phase I, four years 2013-17 as Phase II and 13th plan period 2017-22 as Phase III (Ref. 8).

2.7.5 Immediate aim of the JNNSM in Phase I was to focus on setting up enabling environment for solar technology penetration in the country, both at centralised and decentralised levels. In second phase, after taking into account the experience of initial years, capacity will be ramped up to create conditions for up scaled and competitive solar energy penetration in the country.

2.7.6 MNRE has been assessing the potential of Wind, Small-hydro and Biomass in the country and actively promoting these technologies. However, compared to Solar, these sources have much less and limited potential. Solar Mission has the potential to meet all future energy demands of the country.

2.7.7 JNNSM set an ambitious target of 20 GW of grid connected and 2GW of off grid capacity by 2022 in three phases. For Phase I (2010-13) target was 1100 MW of utility grid power including roof top and 200 MW of off grid solar applications. Solar power capacity of 3.1 GW has been commissioned by 31 March 2015. **Government of India has recently announced an ambitious target of 100 GW of solar power by year 2022.**

2.7.8 MNRE has issued JNNSM Phase II –Policy Document which covers progress review of Phase 1 (Ref. 9). Critical review of JNNSM Phase I, its targets and achievements, as brought out in JNNSM Phase II – Policy Document are summarised below:

	Target	**Achievement**
Grid Connected Utility Power	1100 MW	1100 MW
Off Grid Solar	200 MW	50 MW

2.7.9 Despite vast Solar potential, India's solar capacity was meagre 17.8 MW in early 2010. Overall goal of JNNSM is to make India a global leader in solar energy, by creating policy conditions for its diffusion across the country. Policy guidelines have been issued by MNRE. Centre and States have established renewable energy agencies. CERC and SERCs have issued binding regulatory orders for grid connectivity and tariff.

2.7.10 To achieve 500 MW of PV and 500 MW of Solar Thermal, Central Government conducted two batches of reverse auctions. These bidding processes offer Feed-in Tariffs and long term PPAs to the selected least cost developers. These auctions discovered competitive tariff of Rs 10.95/KWh against CERC tariff of Rs17.91/KWh

2.7.11 Performance data published by MNRE indicates that Solar Photo Voltaic (SPV) technology has matured and well established. Its price is also falling globally and it may reach grid parity by 2017. In India, the price discovery under open bidding by various State agencies have shown rapidly declining prices. Latest contract awards in Andhra Pradesh and Tamil Nadu have discovered prices of less than Rs. Seven per KWh, which is less than the price being charged in many metro cities from premium customers with energy consumption of more than 400 KWh units per month.

2.7.12 **Due to very limited commissioning of Solar Thermal systems in India the suitability of this technology under Indian environment is still to be fully evaluated.** Their reliability, efficiency and utilisation factor meeting performance specifications are yet to be established.

2.7.13 Under Phase I of JNNSM there was a segment of Roof Top Photo Voltaic and Small Solar Power Generation Programme (RPSSGP) under which out of 100 MW contracted, 76 MW has been commissioned. **Under RPSSGP small rooftop plants of capacity less than 2 MW were allotted.** Most of these systems were on large institutional roof tops. Contribution from residential Roof Top Photo Voltaic (RTPV) up to 5 KW was insignificant.

2.7.14 To encourage development of Solar power across States, SERCs in States have to specify solar Renewable Purchase Obligations (RPOs) and notify RPO regulations to ensure compliance. National Action Plan on Climate Change and notified Tariff Policy, envisage increasing trajectory of solar RPO from 0.25% (by end of Phase-I) to 3% by 2022. Rajasthan and Tamil Nadu have notified high Solar RPO of 2%, Gujarat 1.5%, while Delhi has notified 0.3%. However many States are yet to notify even such modest solar RPO guidelines.

2.7.15 JNNSM Phase I has nearly reached its goals, achieved almost all targets and has laid a solid foundation from which Solar energy can take a big leap forward to make India self- reliant in its energy needs.

2.7.16 Many stake holders have played key role in success of JNNSM Phase I.

- MNRE and other Central agencies have been framing and issuing policy guidelines;
- CERC issued regulations for grid connectivity and applicable tariffs;
- MNRE framed transparent bid documents to successfully complete the auction of 1100 MW of solar power.

2.7.17 Many States have taken lead to promote solar energy. Some notable milestones are listed below:

- Gujarat Government came out with solar power policy in 2009 even before the launch of JNNSM
- Gujarat SERC was the first one to issue detailed order for determination of tariff from grid connected solar systems after public hearings of all stake holders.
- As per the latest data issued by MNRE on 29-02-16, Rajasthan is number one in solar power with installed capacity of 1264.35 MW with Gujarat at number two with 1024.15 MW. Both these States have crossed 1 GW landmark out of the total solar capacity of 5547.21 MW for the whole country.
- Gujarat has also taken lead for Roof Top Photo Voltaic (RTPV) by promoting Solar City concept in Gandhi Nagar now expanded to five more cities, with innovative roof top leasing procedures.
- Rajasthan Government issued

Renewable Energy Policy for the State under which Government land is to be allotted at concessional rates and acquisition of private land at developers cost facilitated.

- Nodal agency Rajasthan Renewal Energy Corporation was set up as single window interface with the Government. Rajasthan is the second largest solar power producer with installed capacity of 200 MW.
- Kerala has initiated residential Roof Top Photo Voltaic (RTPV) programme for 10,000 homes.
- Karnataka has announced residential RTPV programmes.
- Tamil Nadu SERC has issued grid connectivity guidelines as well as applicable tariff. Renewable Solar Purchase Obligation Guidelines have been framed for State distribution companies as well as large industrial consumers.
- Tamil Nadu has also initiated Solar Homes programme.
- Tamil Nadu SERC has recently issued a consultative paper which proposes to set the tariff for solar projects in Tamil Nadu. Consultative paper details the methodology involved in arriving at tariff as well as assumptions of CAPEX, OPEX, Debt/Equity ratio, interest on term loan and return on equity of 20%. Final tariffs realised for solar PV, solar thermal and small KW scale PV systems were Rs 5.78 per KWh, Rs 8.34 per KWh, and Rs 8.15 per KWh respectively. This paper can become a model all over India to fix the applicable tariffs for solar energy.
- West Bengal Policy on Generation of Electricity from Renewable Sources of Energy 2012 stipulates "Building codes shall be framed under which it would be mandatory for buildings of business and commercial entities, schools and colleges hospitals, large housing societies and government establishments to install Roof Top PV devices."
- In West Bengal Solar Renewal Purchase Obligations have been mandated on large institutional consumers as 2% of the electric load for establishments having more than 1.5 MW of contracted demand and 1.5% with more than 500 KW of contracted demand.
- Haryana has recently notified Solar RPOs requirement for all buildings on plot area of more than 500 sq meter.

2.8 Solar Energy in India –Future Growth

2.8.1 JNNSM Phase I has met its goals and the experience gained in the country should become the basis for creating paradigm shift in the solar programmes under Phase II and Phase III. The experience of Europe and California solar success should be incorporated to create new benchmarks. In India, many States have taken innovative initiatives, which have been successful in promoting RTPV. All these can be replicated in other States under uniform Central guidance for accelerated development of solar energy in India.

2.8.2 MNRE has recently issued JNNSM Phase-II – Policy Document that has set a cumulative target for Phase-II (2013-17) at 4000-10,000 MW for Utility Grid Power including roof top. Document proposes share of Solar PV and Solar Thermal and share of Central and States during Phase-II as under (Ref. 9).

Inter Technology Targets at Central and State Level

Item	Ratio	Central Schemes	State Schemes
Solar PV	70%	40%	60%
Solar Thermal	30%	40%	60%

Technology-wise Capacity Allocation

Item	Capacity (MW)	Central Schemes (MW)	State Schemes (MW)
Solar PV	6300	2520	3780
Solar Thermal	2700	1080	1620
Total	9000	3600	5400

2.8.3 JNNSM Phase-II targets about 900% growth from 1000 MW to 10,000 MW (Cumulative) in four years (2013-17), is quite ambitious and should be implemented with same vigour and commitment as Phase I. As the State quota is 60%, all States will have to establish agencies to implement solar projects in their States, taking advantage of experience gained by Gujarat and Rajasthan that have setup solar plants of 700 MW and 200 MW respectively under Phase-I.

2.8.4 As per MNRE, physical progress upto March 2015 is given below in MWp

	FY 2014-2015		Cumulative
	Target	Achievement	As on 31-03-2015
Solar Power (Grid Connected)	1100	1112	3743
Solar Power (Off-Grid / Captive)	60	60	234

2.8.5 **Government of India have recently announced highly ambitious target for 100 GWp of Solar power by 2022**. Under this plan targets of solar PV have been identified for each State. Reaching this target of 100 GWp in seven years (2015-2022) will require CAGR of more than 80%. China achieved CAGR of more than 150 % in the five year period of 2009-2014 and it is possible for India to achieve the target of reaching 100 GWp by 2022 by laying countrywide uniform policy and guidelines based on the experiences gained during implementation of JNNSM.

2.8.6 **However, in all planning and policy documents, strong emphasis on RTPV is lacking.** Going by the experience of Europe, where more than 72% solar capacity is from RTPV, a separate target of 20 GW for RTPV (20% of cumulative target) should be set for the period ending 2022. **Realising this need, Government of India recently (in January 2016) has taken strong initiative of sanctioning a fund of Rs 5000 crore for providing capital subsidy of 70% in hill States and 30% in all other States for RTPV installations.** This policy initiative is likely to lead to spread of solar RTPV in a big way, as with this capital subsidy power from RTPV will become cheaper than grid power.

2.8.7 With successful implementation of Phase-I, clear guidelines have emerged that can be followed by States for success in achieving new targets of 100 GW by 2022. Transparent and open bidding procedures have resulted in falling rates, therefore, the subsidy burden over benchmark rate fixed by CERC is falling. With all States and Centre seeking bids for bulk capacity addition in coming years, there will be further price reductions, fast approaching grid parity.

2.8.8 A paradigm shift in the implementation policy for small RTPV is needed for its growth and achieving its full potential. Action plan should address issues of Policy and Regulation : Technical, Finance and Administration. A separate Sub-Group must be set up at the Centre and each State to provide similar thrust to RTPV as has been done for Main Solar.

2.8.9 Some initiatives in Indian States and Cities for promoting RTPV are noteworthy and are described below:

- **MNRE**: Pilot Scheme of MNRE for Large Scale Grid Connected RTPV has been announced by Solar Energy Corporation of India (SECI), a Govt. of India Enterprise under MNRE. Six cities Bhubaneswar/Cuttack, Gurgaon, Hyderabad, Jaipur, Noida/GNoida, Raipur/Naya Raipur are covered with capacity of 1.0 to 3.1 MW. Pilot schemes target large roofs of Government offices, PSUs, Commercial establishments, Hospitals, Cold storages, Warehouses, Industry and Educational institutes. Projects may be divided in packets of smaller size of 100 KWp to 500KWp. SECI will incentivise the roof-top project owner by giving 30% capital subsidy. SECI has awarded the projects for these six cities at capital cost varying from Rs 59/KWp to Rs 90/KWp.

- **Gujarat:** City of Gandhi Nagar has initiated a 5 MW rooftop PV programme. Under this programme, 4 MW would come from Government buildings while 1 MW would be installed on private homes. Two project developers for 2.5 MW capacity each have been selected through the process of reverse competitive bidding (in which a bidder offering highest discount from a ceiling tariff is selected), with GERC tariff of Rs 12.44/KWh acting as ceiling. The local utility, Torrent Power, will purchase entire solar power at discounted price. Torrent Power a private utility, will buy power from Azure at Rs 11.21/KWh for 25 years. Azure, in turn, will pass Rs 3.0/KWh to the building owners on whose roof the RTPV is installed . Thus the effective price of solar power without roof-top rent is only Rs 8.21/KWh. Given the success of the Gandhi Nagar programme, 5 more cities in Gujarat, namely Bhavnagar, Mehsana, Rajkot, Surat and Vadodara, will also be following the rooftop model.

- **Kerala**: Kerala has announced a pioneering programme for decentralised stand-alone roof-top solar generation. 1 KW Solar power plants on 10,000 roofs, totalling a capacity of 10 MW, are proposed to be installed. This policy is reminiscent of the 1000 roof top programme started in 1990 in Germany. A subsidy of Rs 92,000 (Rs 53000 from MNRE and Rs 39,000 from State Government) is available. Beneficiaries can select any agency of their choice for installation of the system. The list of empanelled agencies along with rates offered has been issued. Technical specifications and quality assurance procedures have also been issued. System includes 1000 Wp solar panel, 7200 Whr battery and 1KW power conditioning unit.

- **Tamil Nadu**: Tamil Nadu released most ambitious state policy for solar energy, so far by any State. The policy plans to achieve a target of 3000 MW in three years (2013-15). It includes utility scale projects through FiT, GBI and Net-Metering for RTPV. Policy includes solar purchase obligations on HT and LT consumers, and Trading of solar Renewal Energy Certificates (RECs).

  Solar RTPV has received special attention with a target of 350 MW in three years. For first 50 MW of RTPV, GBI of Rs 2/KWh for first two years, Rs 1/KWh for next two years, and Rs 0.50/KWh for subsequent 2 years will be provided for all solar roof-tops being installed before 2015.

  A scheme of subsidy of Rs 20,000/ KWp, over and above the subsidy of 30% given by MNRE, will be provided to 10,000 applicants. This scheme is similar to 10,000 solar homes of Kerala.

  To promote RTPV, Net-Metering facility will be extended to Solar Power systems installed in commercial establishments.

  State has mandated 6% Solar Purchase Obligation (starting with 3% till December 2013 & 6% from January 2014) for all HT consumers and for high tariff LT commercial consumers.

- **Karnataka:** Under new Karnataka Energy Policy 2009-14, State seeks to promote RTPV with Net Metering. It has targeted 25,000 solar RTPV of 5-10 KWp with a potential of 250 MW.

- **West Bengal**: The State has initiated a Net-Metering solar rooftop model promoting self-consumption by institutional consumers like Government departments, Academic institutions, etc., with system size limited to 2-100 KWp. Solar RPOs have been mandated on large institutional consumers – 2% with more than 1.5 MW and 1.5 % with more than 500 KW of contracted demand.

2.8.10 The best features of the policy initiatives taken by various States should be integrated, a model policy document should be framed that can be adopted by all States to boost the RTPV. The Solar Policy of Tamil Nadu is the latest and most comprehensive document that includes the best feature of other States. Gujarat has provided payment of Rs 3.0/KWh, as roof rent for installation of RTPV. This could also become a model feature of all States to facilitate leasing of roof by individuals. Target of 350 MW for RTPV has been set by Tamil Nadu. When followed by other States, it will be very easy to reach 2 GW for whole country.

2.9 Solar Electricity – Tariff Policy, Competitiveness and Regulatory Framework

2.9.1 Generation cost is normally expressed as price per unit (KWh). Concept of Levelised Cost of Electricity (LCOE) allows calculation of real cost of solar electricity for comparison with other sources of electricity.

LCOE =	:	(CAPEX + NPV of OPEX) / NPV of total EP
CAPEX	:	Total Capital Expenditure
OPEX	:	Operation and Maintenance Cost
EP	:	Electricity Production (in KWh) over lifetime
NPV	:	Net Present Value (With suitable **Discount Factor-DF)** over life time of the Plant
DF	:	Discount Factor expressed as Weighted Average Cost of Capital

2.9.2 For solar PV systems the OPEX is very minimal, therefore, the LCOE of solar electricity is determined predominantly by its CAPEX. CAPEX per unit of installed capacity depends largely on the size of the Plant and the total demand. With increasing demand, the capital cost of solar PV systems has fallen rapidly. Between 2005 and 2015, a price decrease of 75% has been realised. Over next five years between 2015 – 20, further price decrease of 35 to 50% may be realised.

2.9.3 CERC issues broad guidelines for the estimated capital cost of Renewable Energy. In the Guidelines issued in March 15, downward trend of capital cost of Solar PV is maintained as under :

CERC Guidelines for Capital Cost of SPV

2012-2013	1000 Lac/MWp
2013-2014	800 Lac/MWp
2014-2015	691 Lac/MWp
2015- 2016	587 Lac/MWp

2.9.4 Large part of the solar PV market can be segmented in four categories depending on their installed capacity. **Solar PV capacity is specified as kilowatt peak (KWp), which indicates the power generating potential of the PV module under maximum sun irradiation.** Typical installed capacity for these categories are the following:

- Residential households : upto 5 KWp
- Commercial and Institutional buildings : 5 to 100 KWp
- Industrial Plants : 100 to 500 KWp
- Utility Scale Plants (ground–mounted) : Above 0.5 MWp

Note: Residential, Commercial, Institutional and Industrial systems can be grouped broadly under RTPV category, as these systems are installed on existing available land and structures within the organisations and do not require separate land procurement.

2.9.5 In India, various regulatory authorities have also worked out the LCOE under varying assumptions and for various categories. Some of these are summarised below:

S.No.	State / Entity	Date	Tariff (Rs / KWh Unit)		
			Solar PV	Solar Thermal	Small RTPV KW Scale
1.	CERC	27.03.12	9.35	11.22	12.46
2.	GERC	27.01.12	9.28	11.14	12.91
3.	RERC	30.05.12	8.42	10.45	11.95
4.	TNERC Consultative Paper	May 2013	5.78	8.35	8.15

Small RTPV tariff is about 40% higher than large scale ground mounted Solar PV.

2.9.6 In open competitive bidding for 500 MWp of Solar PV, contracts were awarded to 8 bidders from Rs 6.71 to 7.12 at a median price of Rs 6.95 per KWh by Karnataka and to 23 bidders from Rs 6.45 to 6.90 at a median price of Rs 6.70 per KWh by Telangana. Tariff for Solar PV is showing continuously falling trend and may achieve grid parity of Rs 5.50 per KWh by 2016-17.

2.9.7 Telangana, recently in May 2015, has floated a tender for 500 MWp of Solar PV with ceiling of Rs 6.32 per KWh and bid prices are expected to be even lower. In a recent tender by Govt of Rajasthan, it has been reported that price bids have fallen below Rs 6 per KWh.

2.9.8 LCOE tariff worked out by TNREC established near grid parity for large PV systems, based on equated financial and economic parameters. While for RTPV the tariff worked out is about 40% more, however, this does not include number of indirect benefits of RTPV for the entire society. Some major indirect benefits are listed below:

- **Reduction in Grid Losses**: In India, Transmission and Distribution (T&D) losses are very high. All India average is 26%, while in some States (Arunachal, J&K, Jharkhand), it is upto 50-60%. As RTPV is a distributed generation, where most energy is consumed locally, T&D losses can be reduced to zero. Financial value of reduced T&D losses will be about Rs1.1 to Rs 2.75 per KWh.
- **Reduction in Greenhouse Gas Emissions**: Major part of electricity generation world-wide is based on the use of fossil fuels (coal, oil and gas). With current mix of electricity generation, it is estimated that more than 600 gms/KWh of CO2 are emitted. In India, where coal is predominant fossil fuel used for electricity generation, the CO2 emissions are likely to be much more. PV systems have zero CO2 emission during their operational life time. The value of avoided emissions has been estimated as 10% of the present grid tariff in Europe. In India its value will be more than Rs 0.55 per KWh.
- **Energy Security**: Once installed, SPV system will produce electricity for at least 25 years at a fixed and known cost. Conventional power plants must deal with fluctuating prices for fossil fuels such as coal, oil and gas on the international markets. The certainty of being independent

from such fluctuations, considered as Hedging Value, has been assessed at 7 to 15% depending on assumptions of the oil, gas and coal prices evolution. Taking the median of 10% for Indian conditions Hedging Value towards energy security can be taken at Rs 0.55 per KWh.

- **Grid Parity for RTPV** : If the value of above quantifiable benefits are included, then RTPV tariff achieves grid parity even now (in 2016). Solar PV capital costs are falling and between 2010 and 2020 price decrease from 35 to 50% may be realised. Price decrease can be faster with faster implementation, bulk manufacture, procurement and installation throughout the world. By 2020, Solar energy will become the lowest cost source of electricity. India should lead this paradigm shift from Fossil Fuel to Solar.

2.9.9 Beside the quantifiable benefits as listed above, Solar PV systems offer many other benefits with large socio-economic gains. Some are listed below;

- **Industry Development**: PV requires industrial capacity, raw material providers, PV cell &module manufactures, machinery and equipment providers, installers and other associated O&M services linked to electricity systems. This generates added value for the community not only in terms of jobs but also in terms of industrial development and business growth.
- **Clean and Democratic Investment**: RTPV can be an alternative, widely spread, low risk investment with fair long term returns for all PV plant owners. Instead of investing in non-transparent financial funds, PV offers clean and sustainable investment opportunities. This investment opportunity has to be demonstrated by installation of model RTPV systems successfully delivering fair returns to public.

- **Climate Change Mitigation**: Use of fossil fuels for energy and transport to meet growth and development needs will create Greenhouse effect and lead to Climate Change. Reality of Climate Change is already visible in disintegration of polar ice and melting of glaciers, rise of sea water levels, and extreme weather events such as heat waves, droughts and floods. Solar energy should become the choice to protect the world from this Climate Change.
- **Water Consumption**: India's population is rising and may stabilise at 1.6-2 billion by year 2050. The demand for water will also increase by more than 50%. Unlike other technologies, PV systems do not require water during their operation. This makes PV a sustainable electricity source.
- **Rural Electrification**: Extension of conventional grid, to far-flung rural communities, remote isolated settlements and islands, is economically not viable. Solar PV systems with storage and hybrid power provide most economical and reliable source for these communities.

2.9.10 *Tariff Policy and Regulatory Framework*

2.9.10.1 To attract investments in Solar energy, regulatory framework for guaranteed off take of power by distribution companies and realisation of sale proceeds should be set up. CERC issued guidelines for fixing **Feed-in-Tariff (FiT)** of solar power. Under JNNSM, Ministry of Power and MNRE created a system of bundling of solar power with power out of cheaper unallocated quota of central stations, and selling this bundled power to State distribution companies. NTPC VidyutVyapar Nigam (NVVN), a subsidiary of NTPC, has been nominated as a nodal agency by Ministry of Power (MoP) for entering into Power Purchase Agreements (PPAs) with Solar Power Developers to purchase power fed to 33 KV and above grid, in accordance with the tariff and PPA duration as fixed by CERC. This arrangement was limited to utility scale solar power generated for maximum capacity of 1000 MW in the first phase of JNNSM.

2.9.10.2 Selection of Solar PV projects of 500 MW capacity was done in two batches open bidding. Under Batch-I, against CERC approved tariff for Solar PV of 1791 Paise/KWh, final tariff was realised between 1095 Paise/KWh to 1276 Paise/KWh. For Solar Thermal, tariff realised was 1049 Paise/KWh to 1224 Paise/KWh against CERC approved tariff of 1531 Paise/KWh. Average tariff for Solar PV was 1216 Paise/KWh which was 32% lower than CERC approved benchmark. For Solar Thermal average tariff of 1141 Paise/KWh was 25% lower than the CERC benchmark.

Under Batch-II for Solar PV, final tariff realised was 749 Paise/KWh to 944 Paise/KWh against CERC approved tariff of 1539 Paise/KWh. 350 MW worth SPV projects were awarded with an average tariff of 877 Paise /KWh which was 43% lower than benchmark tariff of CERC.

2.9.10.3 CERC set benchmark FiT similar to what was done in Germany, Italy and Spain, where FiT tariff set by regulatory agencies was implemented very successfully. In India, open bidding by NVVN resulted in heavy discounts over benchmark rates based on market conditions. Open and transparent bidding has led to continuous fall in FiT which is fast approaching grid parity.

2.9.10.4 JNNSM Phase-I included Rooftop PV and Small Solar Power Generation Programme (RPSSGP) linked distribution network (Below 33 KV). This was a State driven scheme to encourage States for grid connected projects focusing on distribution network and to strengthen the tail end of the grid. Under this scheme, State utilities purchase power from generation companies based on the tariff fixed/approved by the respective SERCs. Project size was limited to 2 MW and maximum 20 MW per State. The role of MNRE was limited to providing fixed Generation Based Incentive (GBI) to State utilities at a rate equal to the difference of CERC tariff and a reference tariff of Rs 5.5 per KWh. The projects were registered with nodal agency IREDA through web based process and projects were selected to set up 98 MW capacity projects from 12 States.

2.9.10.5 Under JNNSM Phase-I there was no initiative for promoting small RTPV programme, covering residential (1-5 KWp), commercial and institutional (5-100 KWp) and industrial (100-500 KWp) categories. No attention has been paid to create tariff policy and regulatory framework for these RTPV segments. In Europe this segment has contributed to more than 72% of total installed capacity. A paradigm shift in policy is needed to harness this potential in India. While it is difficult to accurately estimate the potential of this segment of RTPV in India, recent estimates indicate potential of 20 GW to 100 GW (Ref. 13 & 14).

2.9.10.6 Policy of Feed-in-Tariff (FiT) has led to rapid growth of solar energy in Europe. In India, CERC determined FiT acting as ceiling rate, large MW scale grid-connected projects were selected on the basis of competitive bidding. Small RPSSGP projects, were based on Generation Based Incentive (GBI). FiT and GBI, both, result in regular payments by utilities for the solar energy generated and supplied to the grid. These payment mechanisms will not be suitable for large number of small RTPV systems connected to grid spread widely over the entire coverage area of the distribution utilities. Financial condition of all State distribution companies (DISCOMs) in India is very bad and they may not have the capacity to administer and ensure regular payments to large base of RTPV systems.

2.9.10.7 Electricity generated by small RTPV systems can be used for self-consumption with Net-Metering approach. Net-Metering mechanism allows for two-way flow of electricity wherein the consumer is billed only for the net electricity (total consumption –own PV production) by the DISCOM. Such RTPV systems could be installed with or without battery storage, and with one integrated Net-Meter or two separate Meters, one for export to grid and one for consumption. Net-Metering laws which enable and incentivise self-consumption now exist in many countries, with Spain and Brazil adopting this approach most recently. Net-Metering is popular in USA where 43 States have adopted it and Energy Policy Act of 2005 further mandates all public utilities to make Net-Metering option available to all their customers. Similar policy initiative by CERC mandating grid connectivity to RTPV with Net-Metering and 305 capital subsidy announced by GOI will provide proper incentives for rapid growth of RTPV in India similar to its rapid growth in Germany.

2.9.10.8 To encourage large scale deployment of grid connected RTPV systems, tariff policy and regulatory framework for Net-Metering has to be formulated by CERC and SERCs.

Small RTPV offers additional advantages as under :

- Savings in Transmission and Distribution (T&D) losses
- Lower gestation period for installation and commissioning
- No need for additional land
- Improvement of tail-end voltages and reduction in system congestion with higher self-consumption leading to better grid stability
- Employment generation at local level

2.10 Energy Storage for Operating Reserve

2.10.1 Electricity produced by solar systems is dependant on solar irradiance. Solar radiation monitoring stations have been set up under India Metrological Department with finance from MNRE. Energy efficiency, averaged over long periods, have been worked out. Solar energy production shows daily variations in the form of half sine curve. Besides there are seasonal and weather related variations.

2.10.2 To ensure full reliability, operating reserves can be created, which can store surplus peak-time energy recycled during low/no sun time. Some energy storage systems are quite mature and used extensively, while technological advances are creating new efficient storage systems. Some of these are listed below:

- **Pumped Storage**: Surplus peak-time solar energy fed into Grid is used to pump up water to the water reservoirs at hydroelectric stations and reused to generate electricity during peak grid demand periods. 56 mega size pumped storage schemes (PSS) have been identified by Central Electricity Authority (CEA).Out of these, 12 PSS with total installed capacity of about 4500 MW are operational or under various stages of development. There is need for developing all potential PSS in view of large peaking requirements and availability of off peak Renewable Energy.
- **Thermal Storage**: Thermal energy in solar thermal plants can be stored in large underground tanks by storing molten salts at higher temperatures. Similarly, energy can be stored in super- heated compressed steam and used in heat cycle as per the demand
- **Battery Storage**: Batteries have been used for a long time to store electric energy and provide support for vital and critical systems. Technology has advanced with high capacity, long life batteries now being used to provide uninterrupted power to large installations. Batteries have been used to provide MW capacity grid storage systems.
- **Emerging Technologies**: Many innovative concepts, such as fly-wheels, hydrogen fuel cells, geothermal rock heat, etc. for energy storage are under development which may become the mainstay for storage and balancing of electricity generated by solar energy.

2.11 Solar Energy for Indian Agriculture:

2.11.1 In India, electricity supplied to Agriculture sector is highly subsidised. Share of agriculture in total sales of electricity is 22.5%, while the share of revenue from agriculture in total sales revenue is only 9%.Against average unit cost of 488 Paise/KWh average tariff for agriculture is 153 Paise/KWh. In some States, tariff for agriculture is almost zero. This is leading to a subsidy for Agriculture of more than Rs 45,500 crore per year.

2.11.2 Most of the energy supplied to Agriculture sector is used for irrigation pumps. India has an installed base of 25 million pump-sets, with 18 million electric pump-sets and around 7 million diesel pump-sets. Based on economics, the diesel based pump-sets can be largely replaced with solar RTPV powered pumps. This will lead to a potential of upto 15 GWp of solar RTPV.

2.11.3 Solar RTPV is ideally suited for energising agriculture pumps, as the pumping requirement is not of continuous nature. Pumps can be used in day time when there is maximum solar radiation. As agriculture pumps are not used for all the days of the year, RTPV energy generated, during non-use days, can be fed back to the grid. If the annual subsidy of about Rs 25,000 per annum/pump is capitalised and the capitalised value of energy pumped back to the grid is added, it will make good economic proposition for

RTPV vis-a-vis all electric pumps. This will provide a potential of up-to 50 GWp for solar RTPV. When equipped with Net-Metering earnings from surplus solar PV energy generated during idle periods will partly meet financing cost for RTPV.

2.11.4 All lift irrigation schemes of State irrigation departments should be provided with RTPV of adequate capacity to run these during day time sunshine hours.

2.12 Railways, Central and State Public Sector Undertakings

2.12.1 Railways require uninterrupted power at Stations for signalling, safety and operations. In non-electrified territories where grid power is not reliable, diesel generators have to be provided. Providing RTPV will be economical. Further, Railways being a large consumer of electricity for non-traction general use, it should be given a solar RPO of 10% of energy consumed for non-traction use. This can be easily met by providing 25-50 KWp solar RTPV systems at each station, administrative and field offices, workshop and sheds, production units and other associated establishment. This will provide RTPV potential of about 1000 MWp. Similarly all Government & Quasi government institutions, PSUs under Central and State governments should be given solar RPO of 10% of the energy used. This will give a combined potential of 10 GWp for RTPV.

2.12.2 Government of India - MNRE have sanctioned a scheme for setting up of **1000 MW of Grid- Connected Solar PV** power projects by CPSUs including the Indian Railways, with an estimated Central Financial Assistance (CFA) of Rs 1000 crore towards Viability Gap Funding (VGF). (Source – MNRE notification)

2.12.3 Indian Railways have made plans for installation of 1000 MWp of solar energy in next five years which include 200 MWp under the scheme sanctioned by MNRE by availing CFA towards VGF. Other CPSUs should come forward and plan Solar RTPV to cover 10% of their energy consumption.

2.13 Defence Establishments and Para Military Forces:

2.13.1 MNRE has sanctioned a similar scheme for setting up over **300 MWp of Grid connected and off-Grid Solar PV projects** by Defence Establishments under Ministry of Defence, and Para Military Forces under Ministry of Home Affairs, with VGF support of Rs 750 crore under JNNSM, in five years period of 2014-2019. Government has also given permission for right to use Defence land by chosen developers by way of lease. (Source- MNRE Notification)

2.13.2 All Central / State establishments including Defence/Paramilitary /Police/Industrial and Civil should have Solar RTPV obligation of 10% of their energy consumption.

2.14 Solar Cities

2.14.1 MNRE launched a comprehensive plan for 60 cities called "Solar Cities Initiative", which aims at minimum 10% reduction in projected demand of conventional energy at the end of five years, through a combination of enhancing supply from renewable energy source of SPV and SWH and other energy efficiency measures. Under this plan a total of 60 cities/towns are proposed to be supported for development as Solar Cities during 12^{th} Plan period, with at least one city in each State with a maximum of five cities in a State.

2.14.2 Under this plan RTPV is proposed to be provided in public buildings/offices, shopping malls, schools / colleges, hostels/hotels, hospitals, local industries, water pumping stations, sewage treatment plants etc.

2.14.3 This plan must be extended to all cities with a population more than one lac. To encourage private participation, all buildings on more than 500 sq meter plot area and all consumers with more than 500 KW of load should be mandated to have 10% SPV purchase obligation.

2.14.4 To include small homes liberalised subsidies as done by Kerala and Tamil Nadu States should be provided for upto 2 KWp SPV plants. Growth of small residential RTPV 1-5 KWp can remain subdued due to high upfront costs. Some innovative lease model can improve market attractiveness for consumers by avoiding high upfront costs and reducing monthly bills. Presently high-end metro consumers are charged high tariff of Rs 6-7/KWh. By installing 1-2 kW system to reduce marginal power consumption, they can reduce monthly bills by upto Rs. 1200 for 25 years, by leasing the plant and paying an EMI of Rs 2000 for 5 years.

2.14.5 Many industries use Diesel Generators to ensure reliable uninterrupted power for their production process. Solar RTPV with storage offers an economical and reliable alternative. Industry must be encouraged to shift to RTPV, with some capital subsidy in the form of viability gap funding (VGF).

2.14.6 CERC notified tariff policy, requires State electricity regulators to fix a percentage of energy purchase from solar power with 0.25% by year 2013, and increasing trajectory of 0.25% each year up-to 1.5% by year 2017 and 3% by year 2022.The requirement of solar capacity to fulfil the solar RPO of 1.5% by 2017 works out to 9 GW. This implies that with compliance to solar RPO by State utilities, it will not be difficult to accomplish ambitious solar power capacity target of 100 GWp by year 2022. This can be implemented by States just by following the reverse bidding process established under JNNSM. As the cost of SPV plants are falling, VGF funds requirement will be much smaller and may even become nil by the year 2017.

2.15 Solar Power in India – At a Glance (Ref. 24)

2.15.1 *General*

Both **solar photovoltaic (SPV)** and **concentrated solar power (CSP)** technologies are suitable for our conditions. Unlike SPV technology which works on global irradiation, the CSP technology works only on direct normal irradiation (DNI) and is thus limited only to places with high DNI.

SPV technology has grown phenomenally throughout the world with cumulative installation of over 100 GW (Dec. 2012) with Germany, Italy and US leading the charge. India also targets 20 GW by 2022 from the present level of 2.08 GW. **This target has been enhanced by five time i.e. to 100 GW through Government of India announcement in June 2015.**

CSP technology is at a nascent stage globally with only 2.5 GW of installed capacity. In India, there are 15 projects in various stages of development and some of these are pilot projects. Besides, one 50 MW CSP plant is currently in operation.

2.15.2 *Decentralised Solar Power and Rooftop Photovoltaic (RTPV) Power*

Decentralised solar energy applications are attractive since these generate solar power close to the load centre and have minimum transmission losses. Based on national census surveys and GIS (Geographic Information System) analysis, the potential of RTPV power in the country (commercial, residential, industrial rooftops; and rooftops of airports, railway stations, metro stations and bus stations) has been estimated to be in the range of 60 GW to 94 GW (Ref. Planning Commission – April 2014. – Ref. 29).

Solar Home Lighting Systems (SHS) were provided by Chhattisgarh Renewable Energy Development Agency (CREDA) in 500 villages in the year 2003. The SHS is an assembly of 37 Wp (Watt-peak) solar panels, cables, an inverter, a battery and two 11 Watt CFLs. Due to thefts and other problems CREDA opted for **solar micro-grids**. The capacity of solar micro grids varied from 1 KWp to 10 KWp (1KWp suitable for 10 households; 10 KWp suitable for 100 households). As of June 2013, 1476 remote villages including 622 hamlets, in Chhattisgarh, had received electricity through micro-grids. The total capacity (including micro-grids, solar-powered water pumps and street lights) adds up to 3,066 KW serving about 58,000 households in the State.

Solar Water Pumps are available from 1 HP to 5 HP pump capacities. A 3 HP pump needs a solar panel of 2700 Wp (Watt-peak) and the cost of total system is about Rs. 4.5 lac and it has negligible recurring cost, while a 3 HP diesel pump (cost Rs. 70,000), assuming it runs for five hours a day, has an annual recurring cost of Rs. 80,000. The cost of Solar pump can be recovered in four years, while for Diesel pump the spending never ends.

2.15.3 *Solar Photovoltaic Power Plant over Sardar Sarovar Canal*

Gujarat State Electricity Corporation (GSECL) runs a 1 MW SPV power plant on 750 metre stretch of the Sardar Sarovar Canal System. Its location meant that the project did not require any land acquisition. The project costed Rs. 17.1 crore as it required steel structure. This pilot project was commissioned on March 28, 2012 and preliminary studies show :

(a) The project will save 9 million litres of water of canal from getting evaporated every year.
(b) Due to water cooling effect the plant's yield will be 2.47% higher than the conventional SPV plants.

This project is a precursor to other solar utility projects on Sardar Sarovar Canal. It is estimated that 2,200 MW of solar power generating capacity can be installed by covering only 10 percent of the 19,000 km canal network with solar plants. This will also mean that 4,400 hectares of land is conserved and about 20 billion litres of water saved every year.

2.15.4 *Ultra Mega Solar Photovoltaic Power Plants*

On January 29, 2014 Ministry of New and Renewable Energy (MNRE) announced the setting up of the first Ultra Mega Solar Power Project (UMSPP) in Sambhar, Rajasthan. This is the first of the four such 4,000 MW projects that MNRE plans to install. The other three would come up in Khargoda in Gujarat, and Ladakh and Kargil in Jammu & Kashmir.

The rationale is that investing in big plants will reduce the cost of solar photovoltaic (SPV) power from the current level of Rs. 7-8 per KWh to Rs. 5 per KWh over the next 7-10 years. The Sambhar plant will be built on 8,000 hectare of surplus land in a period of about seven years and will cost Rs. 30,000 crore.

2.15.5 *Concentrated Solar Power (CSP) Plant*

On August 13, 2013 Godawari Green Energy Limited (GGEL) commissioned 50 MW Parabolic Trough concentrated solar power (CSP) plant in Rajasthan's Jaisalmer District under Jawaharlal Nehru National Solar Mission (JNNSM). Some salient details of the plant are :

â Capacity	50 MW
â Solar Collectors	480
â Project Cost	Rs. 800 crore
â Land Used	160 hectare
â Time of Construction	29 month
â Effective PLF	25%

2.16 Conclusions / Recommendations

2.16.1 To eradicate extreme poverty, India has to maintain high GDP growth of more than 7.5% per year over a long period of 10-15 years. For sustainable development, energy needs of the growing economy should be met from fossil fuel free renewable energy sources. Solar energy provides ideal long term and secure solution for India's energy needs.

2.16.2 Jawaharlal Nehru National Solar Mission (JNNSM) was launched in 2010 to promote sustainable growth while addressing India's energy security challenge. Target of creating solar installed capacity of 1GWp in Phase-I (2010 to 2013) has been achieved. For Phase-II (2013 to 2017) target of 10 GWp (cumulative) has now been superseded by highly ambitious target of 100 GWp by 2022.

2.16.3 CERC has notified Solar Renewable Purchase Obligation (RPO) of 1.5% by 2017 and 3% by 2022, for the States. Requirement of solar capacity in compliance to solar RPO obligations works out to 20 GWp. JNNSM Phase-I has established transparent reverse bidding process to award large ground mounted grid connected utility scale solar projects. States can replicate the process to finalise all future projects to fulfil their targets.

However, the financial position of State power sector poses a risk to the development of utility-scale solar projects. Central Government will have to play an enabling role in supporting the solar power projects in States. National Clean Energy Fund (NCEF) has been created through a coal cess and currently supported by levies which are ultimately paid by consumers/state utilities. This fund can be used to compensate the States for supporting solar power. States may be supported for solar projects to meet their targets of solar RPOs of 1.5% by 2017 and 3% by 2022.

2.16.4 Small Solar Roof Top Photo-Voltaic (RTPV) systems form more than 72% of total solar capacity installed in Europe, a global leader. In India too, there is huge potential for RTPV estimated between 20-100 GWp. Under Phase-II of JNNSM, a paradigm shift is needed, in implementation strategy, to provide a thrust to promote RTPV. For RTPV, additional target of 20 GW may be included under new solar policy and separate subgroups may be formed at the Centre and States to implement this segment.

2.16.5 All India Guidelines may be formulated for RTPV similar to the policy framed by Haryana.

2.16.6 Guidelines for Grid connectivity may be issued for all States similar to those issued by DERC.

2.16.7 Many States and Centre have issued progressive policy directives to promote

RTPV. Tamil Nadu Solar Energy Policy 2012 is a comprehensive document that includes good features of innovative steps taken by other States earlier. For promotion of RTPV, this document has laid down specific target of 350 MW and policy directives for implementation.

Some policy directives of Tamil Nadu (as under) may be notified under Central directives and implemented in all States (Ref. 16) :

- Generation Based Incentive has been provided for RTPV
- Net-Metering has been notified for all RTPV systems
- Solar Purchase Obligation (SPO) at 3% upto December 2013 and 6% from January 2014 have been mandated for all HT consumers and high tariff LT commercial consumers.
- 10,000 homes have been granted subsidy of Rs 20,000/KWp

2.16.8 Solar Energy Corporation of India, GOI enterprise under MNRE, has finalised contracts for RTPV in six cities. Gujarat government has finalised similar contract for Gandhi Nagar, which provides payment of roof rent of Rs 3/KWh to be paid to the roof owner. Solar City scheme has been promoted for 40 cities by MNRE. Similar Solar City programmes may be notified for all cities and towns with more than one lakh population.

2.16.9 RTPV of adequate capacity should be provided for all pumping installations under water works and sewage disposal units of municipal authorities.

2.16.10 Agricultural pumps are ideally suited for RTPV. Replacement of diesel pumps with RTPV powered electric pumps is justified on economic considerations. Provision of RTPV systems for electric irrigation pumps will cut down huge subsidy for agriculture sector and some surplus power will be pumped back into the grid during no-use period. Innovative financing scheme for lease and EMI payments to be realised from savings of energy charges can be considered.

2.16.11 Indian Railways (IR) should install Solar RTPV at Railway stations that require assured power for Operations, Safety and Signalling.

2.16.12 All Central and State Public Sector units including IR may be given Solar Power Purchase obligation of 10% of their energy demand. Similar guidelines may be issued for Army and Paramilitary forces.

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Abbreviations

ARES	Advanced Rail Energy Storage
BOS	Balance of System
CAES	Compressed Air Energy Storage
CAETS	Council of Academies of Engineering and Technological Sciences
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CERN	European Council for Nuclear Research
CFA	Central Financial Assistance
CIIE	Centre for Innovation Incubation and Entrepreneurship (Ahmedabad)
CPSU	Central Public Sector Undertaking
CPV	Concentrator Photo Voltaic
CREDA	Chhattisgarh Renewable Energy Development Agency
CSIR	Council of Scientific and Industrial Research
CSP	Concentrated Solar Power
CSTP	Concentrated Solar Thermal Power
CWET	Centre for Wind Energy Technology
DISCOM	Distribution Company
DNI	Direct Normal Irradiance
EPIA	European Photovoltaic Industries Association
FiT	Feed-in-Tariff
GBI	Generation Based Incentive
GDP	Gross Domestic Product
GHGs	Green House Gases
GIS	Geographical Information System
GOI	Government of India
GSECL	Gujarat State Electricity Corporation Limited
GW	Giga Watt
GWp	Giga Watt (Peak)

IEA	International Energy Agency
IEP	Integrated Energy Policy
IMD	Indian Metrological Department
INAE	Indian National Academy of Engineering
IREDA	Indian Renewable Energy Development Agency
ISA	International Solar Alliance
ITER	International Thermonuclear Experimental Reactor
JNNSM	Jawaharlal Nehru National Solar Mission
KV	Kilo Volt
KW	Kilo Watt
KWh	Kilo Watt Hour
KWp	Kilo Watt (Peak)
LCIG	Low Carbon Inclusive Growth
LCOE	Levelised Cost of Electricity
MDGs	Millennium Development Goals
MNRE	Ministry of New & Renewable Energy
MoP	Ministry of Power
Mtoe	Million Tonnes of Oil Equivalent
MW	Mega Watt
MWp	Mega Watt (Peak)
NAPCC	National Action Plan on Climate Change
NCE	National Centre for Excellence
NCEF	National Clean Energy Fund
NHPC	National Hydroelectric Power Corporation
NISE	National Institute of Solar Energy
NSM	National Solar Mission
NTPC	National Thermal Power Corporation
NVVN	NTPC Vidyut Vyapar Nigam
OPEX	Operating Expenditure
PHS	Pumped Hydraulic Storage
PLF	Plant Load Factor

PPA	Power Purchase Agreement
PPP	Public Private Partnership
PSS	Pumped Storage Scheme
PSU	Public Sector Undertaking
PV	Photo Voltaic
PVPS	Photo Voltaic Power System
REC	Renewable Energy Certificate
RETs	Renewable Energy Technologies
RPO	Renewable Purchase Obligation
RPSSGP	Rooftop PV and Small Solar-power Generation Program
RTPV	Roof Top Photo Voltaic
SECI	Solar Energy Corporation of India
SERAC	Solar Energy Research Advisory Council
SERC	State Electricity Regulatory Commission [D for Delhi; G for Gujarat; R for Rajasthan; & TN for Tamil Nadu in place for S]
SPO	Solar Purchase Obligation
SPV	Solar Photo Voltaic
SWH	Solar Water Heating
T&D	Transmission & Distribution
TRAI	Telecom Regulatory Authority of India
UMSPP	Ultra Mega Solar Power Project
UNFCCC	United Nation's Framework Convention on Climate Change
VGF	Viability Gap Funding
W	Watt
Wh	Watt Hour
Wp	Watt (Peak)

Chapter 3

Mass Transit Systems

3.1 Demographic Transition in India

3.1.1 The entire South Asian sub-continent is undergoing very significant demographic changes which will have a major impact on the future of the Sub-continent; and how competently decision makers frame appropriate policies to take these changes into account will affect the economic growth rates and the quality of life of citizens, particularly those residing in Urban Agglomerations and Cities, in the years ahead. The changes in India include a decline in the Infant Mortality Rate from 160 per 1000 live births in 1950 to about 41 in 2013. Similarly there has been a drop in Fertility Rate i.e. children per woman from about 6 in 1950 to about 2.5 in 2013 and the UN predicts a decline to 2.1 by 2025 which is about the replacement level. Life expectancy which is currently at about 66 years is likely to increase to around 75 years by 2040. Although these figures show a positive transition in demographic terms they are way behind what has been achieved in other developing economies such as Brazil and China. However, the key emerging trend in India is the ratio between working age (15 to 64 years) and non-working age (below 15 and 65+ years) population. This ratio is presently around 1.8 i.e. 1.8 persons are in the working age group for every 1 dependent. This ratio is expected to steadily grow over the next quarter of a century to peak at about 2.2. This large proportion of the population coming into the working age group is often described as the **demographic dividend**.

3.1.2 However, in order to derive the full benefits of demographic dividend there are a number of prerequisites that need to be fulfilled. Government will need to ensure that there is an enabling policy and institutional framework. This requires strong Government institutions and a legal framework for new job creation and ease of doing business in the country. Moreover, appropriate labour reforms will need to be implemented to encourage investment in diverse areas including manufacturing, services and agriculture, to promote employment at all skill and academic levels. It is important that suitable educational policies are implemented at primary, secondary and university levels apart from vocational training and a focus on skill development so that employment needs of all sectors and segments of the economy can be catered to. The overall management of the economy is also critical for success, such as keeping a control on inflation, targeted investments without excessive borrowing, and promoting trade including diversifying the goods and services exported by the country.

3.2 Trends in Urbanisation

3.2.1 The urban population of India in 1901 was 25.85 million and constituted 10.84% of the total population of the country and in 2011 was 377.1 million or 31.2% of the total population. The growth in urban population as recorded in the Decadal Population Census is given in Chart 3.2.1(A). However, India still continues to be primarily a rural country in population terms as 68.8% of the population resided in rural India in 2011. The rate of growth of the urban population in the country as a percentage of total population has also been extremely slow at about 2% to 3% per decade. The proportion of urban population to total population as enumerated in the National Population Census since 1901 is given in Chart 3.2.2(B)

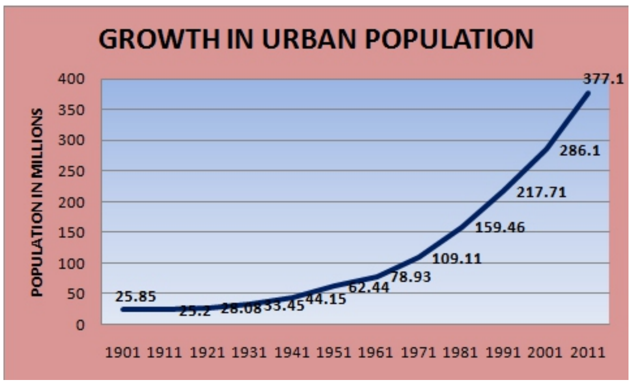

Chart 3.2.1(A): Growth of Urban Population in India

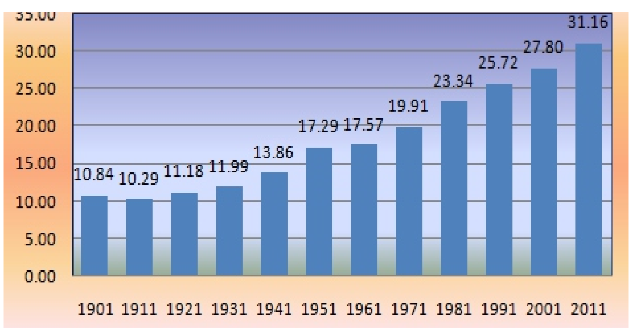

Chart 3.2.2(B): Change in Urban Population as a percentage of Total Population

3.2.2 However, in the next few decades urbanization is expected to grow, and the rate at which urban population will increase is also expected to accelerate. The main reason for this is that although about two-third of the population resides in rural areas, the actual growth is taking place in urban centres. The share of Agriculture in GDP growth which was 34.4% in 1981 has progressively declined to 29.6% in 1991, 23.2% in 2001 and 18% in 2013. The contribution to GDP growth comes primarily from the Services sector and from Industry and Manufacturing sectors and a major portion of these are located in urban areas. As a result with declining job opportunities in rural areas there is bound to be a migration towards the urban centres where new job creation is expected to take place. McKinsey & Company who had developed an India Urbanization Econometric Model had in their Study a few years back estimated that by 2030, firstly, urban India will account for nearly 70% of the GDP and secondly, the urban population would be 40% of the total population of 1.47 billion or 590 million against 377 million recorded in the 2011 Census. This means our urban agglomerations / cities will have to cope with approximately an additional 200 million people in the next 15 years. The Study also projected that 70% of all new jobs will be created in urban areas. Our city planners will therefore be hard pressed to provide for infrastructure and other services such as water, sewerage, solid waste disposal, affordable housing, education, health care and transport.

3.2.3 Urban Agglomerations (Cities / Towns) in India are categorised into six categories depending on their population. Agglomerations with a population of over 1 lakh have been classified as Class I Cities which are of primary concern with reference to Mass Transit / Public Transport. The Total Urban Agglomerations recorded in the 2011 Census were 7935 out of which 468 were Class I Cities with a population of over 1 lakh. These constitute 70% of the total urban population. 53 Cities out of the 468 Class I Cities were having a population exceeding one million, up from 35 in 2001 (Table 7.2.3 below) and constituted 42% of the total urban population.

No. of Class I Cities			
Category	**Population of Towns**	**2001**	**2011**
Class I (Total)	Population 1 lakh and above	393	468
Class I > 1 Million	Population more than 1 million	35	53

Table 3.2.3 : Number of of Class I Cities in India – Census 2011.

Out of 468 Class I Cities, 3 have a population of over 10 million, 5 between 5 million and 10 million, 11 between 2 and 5 million, 34 between 1 and 2 million, 42 between 0.5 million and 1 million and the balance 373 between 1 lakh and 5 lakhs.

3.2.4 By 2030 it is projected that 5 States are expected to have more than 50% of their population residing in cities. These are Tamilnadu, Gujarat, Maharashtra, Karnataka and Punjab. By 2030 there would be about 68 cities with a population of over a million up from 53 in the 2011 census. The cities with a population of over 1 million in 2011 are given in Table 3.2.4.

	City	Population 2001	Population 2011		City	Population 2001	Population 2011
1	Greater Mumbai	16.37	18.41	28	Ludhiana	1.40	1.61
2	Delhi	12.79	16.31	29	Nasik	1.15	1.56
3	Kolkata	13.22	14.11	30	Varanasi	1.21	1.44
4	Chennai	6.42	8.70	31	Madurai	1.19	1.46
5	Bangalore	5.69	8.50	32	Meerut	1.17	1.42
6	Hyderabad	5.53	7.75	33	Vijayawada	1.01	1.49
7	Ahmedabad	4.52	6.35	34	Faridabad	1.05	1.40
8	Pune	3.75	5.05	35	Rajkot	1.00	1.39
9	Surat	2.81	4.59	36	Jamshedpur	1.10	1.34
10	Jaipur	2.32	3.07	37	Jabalpur	1.12	1.27
11	Kanpur	2.69	2.92	38	Srinagar		1.27
12	Lucknow	2.27	2.90	39	Asansol	1.09	1.24
13	Nagpur	2.12	2.50	40	Vasai-Virar		1.22
14	Ghaziabad		2.36	41	Dhanbad	1.06	1.20
15	Indore	1.64	2.17	42	Allahabad	1.05	1.22
16	Coimbatore	1.45	2.15	43	Aurangabad		1.19
17	Kochi	1.35	2.12	44	Amritsar	1.01	1.18
18	Patna	1.71	2.05	45	Jodhpur		1.14
19	Kozhikode		2.03	46	Ranchi		1.13
20	Bhopal	1.45	1.88	47	Raipur		1.12
21	Thrissur		1.85	48	Kollam		1.11
22	Vadodara	1.49	1.82	49	Gwalior		1.10
23	Agra	1.32	1.75	50	Durg-Bhillainagar		1.06
24	Visakhapatnam	1.33	1.73	51	Chandigarh		1.02
25	Mallapuram		1.70	52	Tiruchirappali		1.02
26	Thiruvananthapuram		1.69	53	Kota		1.00
27	Kannur		1.64				

Table 3.2.4: India's Cities with a population of over a million (Figures in millions)

3.3 Transport in Our Cities

3.3.1 Our towns and cities as a result of rapid urbanisation face a number of challenges owing to inadequate infrastructure and poor delivery of services. Problems are faced in water supply, sewerage and sanitation, solid waste management and in Urban Transport. Moreover there are serious constraints in Urban Governance owing to a weak institutional framework, lack of expertise, and inadequate investment. It is only if we are able to effectively cope with all these issues that as a nation we will be able to deal with the massive growth in urbanisation over the next few decades. With respect to Urban Transport, public transport availability is grossly inadequate and services are of poor quality. The number of trips made by public transport in all categories of cities over the last few decades have been declining. For example, in cities with a population between 2 to 4 million, a MOUD Study in 2008 estimated that Public transport share which ranged from 35.6% to 45.8% in 1994 had declined to between 0.2% and 22.2% in 2007. Similarly in cities with a population over 8 million it had declined from 59.7%-78.7% to 35.2%-54%. There is also a shortage of road space and condition of roads is poor, they are encroached by vendors and commercial establishments, and maintenance is a problem. The most serious problem over the last decade or so has been accentuated owing to the very rapid growth in personalised private transport, both four wheeler and two wheelers. Table 7.3.1 gives the trend in Domestic sales of Automobiles over the last six years. With this pace of growth, the problem of congestion on roads and pollution in our cities is going to further worsen. The growth in domestic sales which had been over 25% in 2010-11 has declined considerably over the last few years owing to a slowdown in the economy; however, the growth was still 7.2 % in 2014-15 as compared with 3.5% in the previous year. India in 2012-13 had an installed capacity for manufacturing 6.59 million Four-Wheelers and 20.74 million Two & Three-Wheelers. A small portion of the production is also for export.

Category	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**
Passenger Vehicles	19,51,333	25,01,542	26,29,839	26,65,015	25,01,509	26,01,111
Commercial vehicles	5,32,721	6,84,905	8,09,499	7,93,211	6,32,851	6,14,961
Three Wheelers	4,40,392	5,26,024	5,13,281	5,38,290	4,80,085	5,31,927
Two Wheelers	93,70,951	1,17,68,910	1,34,09,150	1,37,97,185	1,48,06,778	1,60,04,581
Grand Total	**1,22,95,397**	**1,54,81,381**	**1,73,61,769**	**1,77,93,701**	**1,84,21,223**	**1,97,52,580**

Table 3.3.1: Domestic Sales of Automobiles in India 2009-10 to 2014-15

(Source: SIAM)

3.3.2 With the rising population, there has been a rapid growth of urban sprawl in virtually all our large cities without any conscious effort to integrate the Transport Network with Land Use at the planning stage. Modal share of Public Transport varies from City to City depending on its quality and availability. Several large cities have virtually no Public transport, for example Raipur, Patna and Bikaner. With declining Public transport the role of Intermediate Para Transit and Private vehicles is increasing at a fast pace. A Study conducted by M/s Wilbur Smith (2007) projected for 2031 that if nothing is done the share of Public transport will decline from about 18% to under 10% and the Network speed will slow down from 22 kmph in 2007 to 9 kmph.

3.3.3 **National Urban Transport Policy (NUTP) 2006**: With the realisation of the severe transport constraints Indian cities would face in the future owing to unprecedented levels of migration from rural areas to cities, the Government came up with a National Urban Transport Policy (NUTP) in 2006. The Policy projected urban population to grow to 473 million in 2021 and 820 million by 2051. In its vision it recognised the need to bring citizens in the centre-stage and initiate policies that would be to their benefit. It highlighted the need to make cities more liveable and transform them into engines of growth. It also stated that cities need to evolve into an urban form best suited to their unique geography and in order to best support social and economic activities that take place in the city. It set out a long list of objectives which amongst others included due importance to urban transport at the planning stage; the need to integrate land use and transport planning in order to minimise travel distances for livelihood, education and social purposes; encourage use of public transport; address concerns of safety; establish efficient multimodal public transport; introduce appropriate regulatory mechanisms; reduce pollution through change in practice and inducting technology etc.

3.3.4 In order to achieve these objectives the Policy set out a course of actions viz. (i) The need for integrating land use and transport planning towards which Government of India agreed to share 50% of the cost with State Governments for developing such Master Plans for urban areas. (ii) Promote a more equitable allocation of road space as far too much of the road space was taken up by private motorized modes, at the cost of non-motorized modes and public transport, placing the urban poor at a disadvantage. (iii) Prioritize public transport and here again Government of India would share 50% cost of preparing comprehensive City Transport Plans as well as 50% of project development costs in PPP projects and provide equity support and viability gap funding up to 20% in PPP projects. (iv)It acknowledged the market segmentation that exists where on the one hand transport for the poor required to be subsidized while on the other hand for premium customers full cost recovery needs to be made and good quality service provided. (v) It listed the range of public transport options that existed from Metro Rail to City Bus services and other modes in between to meet various demand patterns. (vi)It recognised the need for integration between different urban public transport modes even when there are different operators and (vii) it suggested various financing options and clearly stated that the Central Government would encourage high capacity systems being set up through Special Purpose Vehicles. The policy document touches upon a number of other aspects such as the role of 'Para Transit', priority for non-motorized modes, parking, legal and administrative matters, need for a greater role by State Governments in capacity building, and the use of cleaner technologies. Another underlying feature is the need for the private sector to play a greater role in Urban Transport. Under the National Urban Renewal Mission some progress has been made in strengthening transport services and infrastructure in some of our cities. The NUTP 2006 did help in focussing attention on Urban Transport problems and has provided a basic framework for moving ahead.

3.3.5 **Report on Indian Urban Infrastructure and Services (2011)**: In order to estimate the investment requirements for Urban Infrastructure and Services, the Government of India appointed a High Powered Expert Committee (HPEC) with Dr. Isher Judge Ahluwalia as Chairperson. The Report of the HPEC examines a number of urban issues viz. Water Supply, Sewerage, Solid Waste Management, Storm Water Drains, Street Lighting, Urban Roads, Urban Transport and Traffic Support Infrastructure. The Report brings out some interesting facts. It highlights the severe constraints on road space owing to the encroachments by commercial establishments, street vendors and on-street parking. It mentions that whereas between 1951 and 2004, motor vehicle population increased a 100 times, road network only expanded 8 fold. It points out that whereas Urban Public Transport in India in 2008 accounted for only 22% of total urban transport while in several lower middle income countries it was 49% like Philippines, Venezuela and Egypt, and 40% in upper middle income countries like South Africa, South Korea and Brazil. The share of Buses in the vehicle fleet has been progressively declining from 11% in 1951 to 1.1% in 2001. It also mentions that out of 85 cities with a population of over 5 lakh only 20 have a City Bus Service. All City Bus Services run at a loss except for Hyderabad and Bangalore. There are very few examples in India where Public Transport has improved. The only examples it states are Delhi MRTS, Ahmedabad & Bhopal BRTS and new privately operated Bus Services in Indore and Surat. The Committee recommended an Urban Infrastructure Investment of Rs 39.2 lakh crore over next 20 years of which 44% was in Urban Roads, and 14% in Transport and Traffic Support Infrastructure.

3.4 Mass Transit Modes

3.4.1 In order to cater to the transport needs of our burgeoning cities Urban Mass Transit Systems will progressively need to play a much greater role in fulfilling the mobility requirements. Mass Transit Systems like a Metro are common carrier passenger transportation systems, accessible to everyone and run on fixed routes and on notified schedules, and have an established tariff structure. Mass Transit covers a whole range of modes of Passenger Transport from Commuter / Suburban Rail, Metro Rail, Light Rail Transit, Tramways, Monorail, Guided Bus, Bus Rapid Transit (BRT), Trolley Bus, Articulated Bus and Maglev. These could be broadly placed in three categories viz (i) High Capacity Systems which include Commuter/Suburban Rail and Metro Rail, (ii) Medium Capacity Systems which would include Light Rail Transit, BRT and Monorail and (iii) Low Capacity Systems such as normal buses of various kinds moving in mixed traffic conditions. Each one of these categories is appropriate for different traffic demand levels and has its own technical characteristics. A major city may have one or more of these transport modes in its transport network. The focus in India has been primarily on building Metro Systems amongst high capacity systems and Bus Rapid Transit (BRT) Systems in case of medium capacity systems.

3.4.2 The characteristic of the different modes of Mass Transit are given in Table 7.4.2. A key element is the peak traffic volume that the mode can handle measured in terms Peak Hour Peak Direction Trips (PHPDT) i.e. the number of passengers that can be transported in one hour, in one direction, during the peak hour. The maximum capacity is that of Commuter & Metro Rail and the lowest is that of a conventional Bus in mixed traffic.

Mode	Capacity (PHPDT)	Grade Separation	Speed kmph	Radius of Curvature	Gradient
Metro Rail	>30,000	Separated	30-40	300M	3%
Commuter Rail	>50,000	At Grade	40-50	300M	3%
LRT At Grade	15,000	At Grade	30	25M	6%
Mono Rail	20,000	Separated	30-40	70M	6%
Bus Rapid Transit (BRT)	10,000	At Grade	15-20	25M	3%
Bus Lane	5,000	At Grade	15	-	-
Bus / ETB	3,000	At Grade	10	-	-

Table 3.4.2: Some characteristics of various Mass Transit Modes

3.4.3 With more and more cities seeking the construction of Metro Systems the Government of India has laid down guidelines for Metro based systems. These guidelines lay down four criteria (i) The Peak Hour Peak Direction Trips (PHPDT) should be more than 20,000 for at least 5 km of continuous length by 2021, (ii) the city should have a population of over 2 million as per the 2011 Census, (iii) the average trip length for motorised trips should be more than 7-8 km and (iv) there should be at least 1 million ridership per day on organised Public Transport. However, the Government has also stated that in the first instance, feasibility of relatively cheaper options should also be examined as it may not be possible to provide for Metro systems for all the cities even where these criteria are met.

3.4.4 Over the last several decades since Independence, we in India have not invested in Mass Transit for our cities. As a result until very recently no new Suburban Rail or Metro Rail System had been built (except the Kolkata Metro) and Bus services were grossly inadequate or non-existent. This has resulted in investments going towards creating road infrastructure to cater to the private vehicles leading to congestion and pollution, and the problem of urban mobility getting worse day by day. To meet the inadequacy in public transport modes, Intermediate Para Transit (IPT) modes such as the auto-rickshaw, shared 'tempo' rickshaws and cycle-rickshaws have had to fill in the gap, which has further added to the chaos in our cities. As a result our cities are fast becoming cities for cars, not for the people. An interesting case in point of how planners decide in favour of the private car rather than Public Transport despite its obvious benefits is the Bus Rapid Transit (BRT) corridor in India's Capital viz. New Delhi, which is now being closed down instead of making necessary corrections to make the BRT succeed. Another major problem in all Indian cities is the lack of integration between different urban transit modes. A classic case is the Circular Commuter Rail Line built at the time of the Asian Games in Delhi in 1982. Patronage of the Line continues to be poor 30 years later because of faulty planning. What Delhi, because of its land use pattern required was a 'wheel & spoke' network and not a circular one? However, the problem could have been overcome if there were radial links to the City Centre through suitable interchange facilities and scheduled Bus connections but no effort was made in this direction.

3.5 Role of Para Transit and other Modes of Transport

3.5.1 While discussing the development and role of Mass Transit it is appropriate to mention the part played by other mobility options in Urban Areas. Apart from the various organized modes of 'Public Transport' and motorized modes of personalized 'Private Transport' (4-wheelers and 2-wheelers), there are a number of 'Para Transit' modes, including what may be termed as 'intermediate', 'informal' and 'non-motorized' modes of transport in extensive use in Indian cities and towns. Such 'Para Transit' modes, which are widely used in Indian cities and towns may be listed as below:

Motorized modes

- Mini-buses, shared autos and taxis, e-rickshaws
- Hired taxis and autos (personal use)

Non-motorized modes

- Cycle rickshaws
- Bicycles
- Pedestrians (walking)

It is necessary to bring some order into the present chaotic and unnecessarily extensive presence of various para transit modes in the Indian cities and towns and, through adequate provision of Mass Transit, to prune their presence. However, while doing so, following points should be kept in view:

a) Even with adequate provision of 'Mass Transit' systems, certain organized provision of 'Para Transit' modes remains essential to provide for feeder services and 'first/last mile' connectivity for the Mass Transit modes, and for short lead and local transportation.

b) Out of non-motorized transport (NMT) modes, while cycle rickshaws do not exist in developed countries and in India too it may not be necessary to provide for their presence in the long run, for the present and foreseeable future these are likely to continue to operate, may be on a progressively reduced scale.

c) Regarding the other NMT modes, i.e. bicycles and walking, these are bound to persist and even need to be encouraged. Hence, adequate and safe infrastructure has to be provided for bicycles and pedestrians. Even in developed countries walking remains an essential mode of local transit. For a sustainable and inclusive public transit system, it is necessary to promote NMT modes for short and medium size trips, and for local mobility.

d) Autos and taxis will also remain as a necessary component of urban transport in India, corresponding to the presence of taxis in developed countries.

e) Organized urban transport institutions usually limit their concern to the formal modes of transport, both public and private. Thus, 'para transit' modes, being Informal/ NMT, are left outside their purview. It is essential that such institutions function as unified urban transport agencies covering also 'para transit' modes including NMT.

3.5.2 It is important to highlight the key role of Para Transit in Developing countries, as a very large portion of the population is constrained to use para transit, as public transport is inadequate and private transport is unaffordable. Travel by foot in India is still significant. However, with the rapid expansion of population and urban sprawl this option is now progressively diminishing although it is still promoted on health considerations. Further, under the kind of urban development taking place, at present, it is becoming impractical / difficult to travel by foot. Cycling was also a mode popular with the urban poor and lower middle class until a few decades ago. However, with growing distances, congested roads, non-availability of bicycle lanes it is also declining and being replaced by the private scooter and motorcycle. For short distances particularly in old cities, the cycle rickshaw is still a popular mode. The auto rickshaws, fixed route motorised rickshaws, minibuses are the 'para-transit modes' that have been rapidly growing in the Indian Urban Environment. They fill an important gap created by the absence of Public Transport/Mass Transit options.

3.5.3 The role of various modes of transport is reflected in the recently published data of the Census of India 2011 regarding how rural and urban workers travel to work. The overall nationwide figures for mode of travel of 'Urban Workers' are depicted in Chart 7.5.3. The mode of travel for major cities is given in Table 7.5.3. Both sets of data highlight the low level of use of Public Transport / Mass Transit and the higher percentage of travel by other modes viz., on foot, bicycle, para-transit, two wheelers and private cars. The large Metro cities still have significant travel by public Bus whereas urban Rail travel is important in Mumbai. Percentage of travel by private two wheeler (scooter/motorcycle) and four wheelers is high in Delhi.

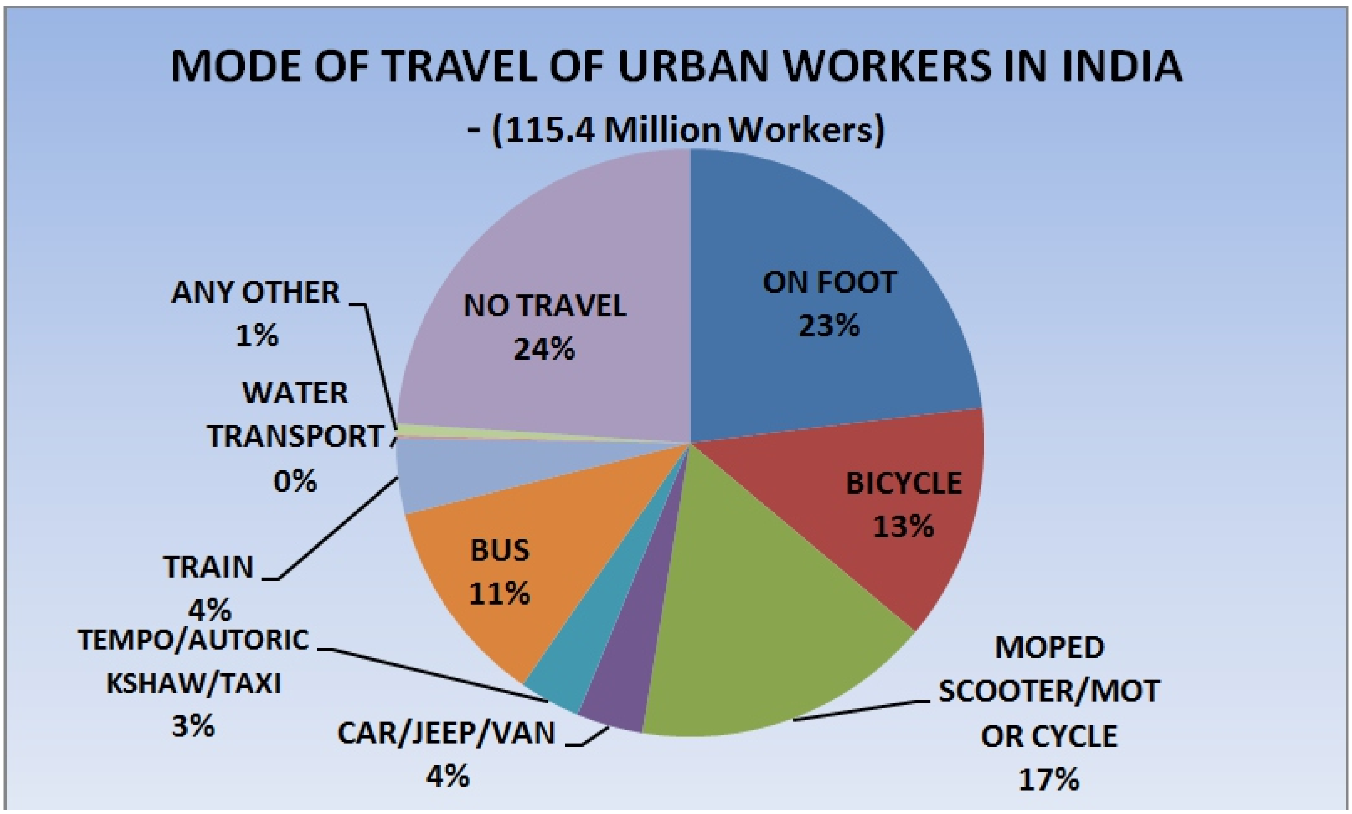

Chart 3.5.3: Mode of Travel of Urban Workers in India based on Census of India 2011 data

MODE OF TRAVEL	MUMBAI	DELHI	KOLKATA	CHENNAI	BENGALURU
NO OF WORKERS	**4806459**	**5332324**	**1698875**	**1751824**	**3944496**
ON FOOT	1200289	1179205	465797	280089	948465
BICYCLE	57692	479369	118142	171917	170400
MOPED SCOOTER/MOTOR CYCLE	214497	749366	65152	401928	700627
CAR/JEEP/VAN	230165	575757	63824	107691	319585
TEMP/AUTORICKSHAW/TAXI	150916	122700	49929	37835	107465
BUS	788330	1162768	375345	339495	933567
TRAIN	1189633	157266	57314	52591	33873
ANY OTHER	23615	60429	10303	8343	16762
MODE OF TRAVEL	**TRAVEL PERCENTAGE BY EACH MODE**				
ON FOOT	24.97%	22.11%	27.42%	15.99%	24.05%
BICYCLE	1.20%	8.99%	6.95%	9.81%	4.32%
MOPED SCOOTER/MOTOR CYCLE	4.46%	14.05%	3.84%	22.94%	17.76%
CAR/JEEP/VAN	4.79%	10.80%	3.76%	6.15%	8.10%
TEMP/AUTORICKSHAW/TAXI	3.14%	2.30%	2.94%	2.16%	2.72%
BUS	16.40%	21.81%	22.09%	19.38%	23.67%
TRAIN	24.75%	2.95%	3.37%	3.00%	0.86%
ANY OTHER	0.49%	1.13%	0.61%	0.48%	0.42%

Table 3.5.3: Mode of Travel of Workers in selected Metropolitan Cities
(Source: Census of India 2011)

3.5.4 The importance of Para Transit may be gauged by looking at two cases. In Chennai for example according to a 2013 estimate by the Centre for Public Policy and Research, Para Transit modes (shared taxi and maxi cabs) contributed 1.8 million journeys which is the second largest mode of transport next only to the Bus system and very much higher than the MRTS. In a mid-sized city like Amritsar where Public Transport is grossly deficient, majority of the main urban transport needs of the city are provided by Para Transit modes such as the 'auto rickshaw' and 'minibus'. Amritsar, in the core old city and in the Inner periphery areas the dominant mode is the cycle rickshaw, in the outer periphery it is the auto rickshaw and in the periphery or areas that have come up in the last 3 to 4 decades, the minibus carries a major share. It has been estimated, in Amritsar that 23% of education trips are by cycle rickshaws, 28% of senior citizens and 58% of women also use cycle rickshaws. The very diverse modes of Para Transit modes that have grown in an unplanned manner in Amritsar and many other cities have resulted in a range of problems such as distortion in land use patterns, congestion, accidents, pollution, unauthorised parking and encroachment on road space. With the Public Mass Transit infrastructure and modes not able to keep pace with demand, Para Transit is here to stay. This segment also provides livelihood to a large section who have over time built strong political lobbies.

3.6 Mass Transit and Land Use Integration

3.6.1 There is a growing realisation all over the world of the need for integrated planning of Mass Transit facilities and the Land Use in order develop more sustainable cities. This is complex though important component of urban development. Such integration can reduce the need for travel by private motorized transport, reduce local pollution and greenhouse gas emissions, reduce travel distance, and create more compact and environmentally and citizen friendly cities. What this implies is that urban planners, at an early stage, need to conceptualize the shape the city will take in future, and integrate Transit related development with Land Use plans. Experience has shown that in Developing countries this process is often extremely difficult in view of a number of hurdles such as (i) Lack of coordination at a local City Government level between different wings such as land use, infrastructure investment, urban services owing to various reasons such as limitations of jurisdiction, regulatory factors etc. (ii) Non availability of requisite level of skills and expertise in combining the knowledge of urban land-use planning and nuances of Mass Transit as these are often not found in one individual or even in one organisation. (iii) Effective integration of Transit and Land Use should result in mixed land use neighbourhoods with office, residential and retail developments in close proximity around transit nodes. This leads to relatively densely populated compact cities. However, there is often a resistance to this amongst city leaders who often encourage city sprawl which results in much longer distances over which civic services have to be provided, increasing cost and journey distances. (iv) There are sometimes restrictive laws or rules which impact land transactions such as the Urban Land Ceiling Act 1976 (which had to be withdrawn in 1999), which limited the size of land parcel an individual or builder could own (v) There is also inadequate policy and legal framework to support redevelopment of built up areas. The Government and Planners in India are beginning to realise these constraints and action is being initiated to overcome some of these.

3.6.2 Therefore, it is important that, particularly in the case of our second and third rung cities which are expected to grow rapidly, our urban planners conceptualise the shape in which they want Land use and Transit oriented development to take shape and develop strategic plans accordingly. The institutional framework of our Urban Local Bodies such as Corporations and Municipalities also needs to be strengthened and appropriate guidance and support must be available to them from the Central and State Governments. It is also important that for optimum benefit, high population densities (Densification of Population) are planned along high density corridors. These high density corridors should have diverse land use, i.e. office, residential, retail etc. and high quality public spaces and pedestrian friendly layouts. It will also be necessary to develop well organised efficient feeder systems into the main arterial Mass Transit routes. Financing schemes will be crucial for this Transit oriented development. It is important that Land value capture is used to generate revenue to partially fund new development. This has been done very successfully in Hong Kong and Tokyo. In India also a beginning has been made and in Mumbai capacity building works on the Suburban Commuter lines being executed by Mumbai Rail Vikas Corporation (MRVC) are being partially funded by surplus Real Estate development on a surplus plot of land with Indian Railways at Bandra, for which a higher FAR has been permitted by the State Government. In Japan, private Railway Companies, many of which manage the Urban Mass Transit Systems have been involved in Real Estate development to the extent that a significant percentage of their total revenue comes from Real Estate. For example, the Tokyu Rail gets 17% of its revenue from Real Estate and 45% from Retail business.

3.7 Global Trends in Mass Transit Usage

3.7.1 *Metro Rail*

3.7.1.1 Metros are the most significant Mass Transit Systems in the world as these are capable of transporting very high volumes of traffic. There are 148 cities in the world of various sizes with Metro Rail Transit Systems and there are about 540 different lines in these Metro systems. The total passengers carried over all these Metro systems are about 150 million passengers per day. The ten largest Metro Rail Transit Systems are given in Table 7.7.1.1 along with the number of annual passenger trips. Metro Rail Systems were introduced progressively since the mid eighteenth century for example London (1863), Chicago (1892), Paris (1900), New York (1904), Tokyo (1927) and Moscow (1935). In recent decades the number of cities with Metro Rail Systems has been growing rapidly with 45 systems having been opened since 2000. More new Metros are now being opened in Asia than elsewhere although there is also growth in the Middle East and South America. Metro systems in Asia carry over 70 million passengers a day which is almost half the volume carried in the world. It must be noted that Metro systems are distinct from Commuter or Suburban Rail Systems data for which is not included here.

	CITY	ANNUAL PASSENGER TRIPS (IN MILLIONS)	REMARKS
1	Tokyo	3,294	Multiple Operators
2	Seoul	2,467	Multiple Operators
3	Moscow	2,464	
4	Beijing	2,460	
5	Shanghai	2,269	
6	Guangzhou	1,841	
7	New York City	1,661	
8	Mexico city	1,609	
9	Paris	1,541	
10	Hong Kong	1482	
	Delhi	*876*	

Table 3.7.1.1: The 10 largest Metro systems in terms of Annual Passenger Trips
(Source www.uitp.org)

3.7.1.2 In terms of Metro Infrastructure there are about 11000 km of Metro lines, 9000 stations and an average line length of 20 km. The largest system in terms length is Shanghai with over 500 km followed by Beijing, London and Seoul with over 400 km. The average distance between stations is 1.2 km which tends to be longer in the Asia Pacific region and shorter in Europe. The total length covered by Delhi Metro in Phase I & Phase II is 189 km. The average distance between stations for example on the Central Secretariat to HUDA City Centre line is 1.5 km.

3.7.2 *Light Rail Transit and Tramways*

3.7.2.1 The UITP defines Light Rail transit as "a Public Transport System permanently guided at least by one rail, operated in urban, suburban and regional environment with self propelled vehicles and segregated or not segregated from general road and pedestrian traffic." This covers a fairly wide range between classical Tram and Metro. In a UITP study for Europe carried out in 2009, it was estimated that at that time 10.4 billion passengers per year travelled by Light Rail Systems whereas 9.9 billion passengers a year travelled by Metro systems. At that time there were 189 LRT networks and 45 Metro networks in Europe. The number of passengers per Network km was 1.57 for Metro against 1.36 for LRT. What this reveals is that Light Rail Transit in a European context is a very important mode of Mass Transit. In 2012 the overall modal share of Urban Public Transport was 14% by LRT, 14% by Suburban Rail, 16% by Metro and 56% by Bus. In the same year, 49.5 billion journeys were undertaken by Public Transport.

3.7.2.2 The largest number of LRT systems in 2009 were in Germany (56) followed by France (19) and Spain (14). There were average 6.5 lines per System with an average length of 12.8 km. The Right of Way on average is separated on 75% of the length with a few countries like Greece having 100% segregation whereas elsewhere it was to a much lesser extent.

MODAL SHARE OF PUBLIC TRANSPORT JOURNEYS IN EUROPE IN 2012

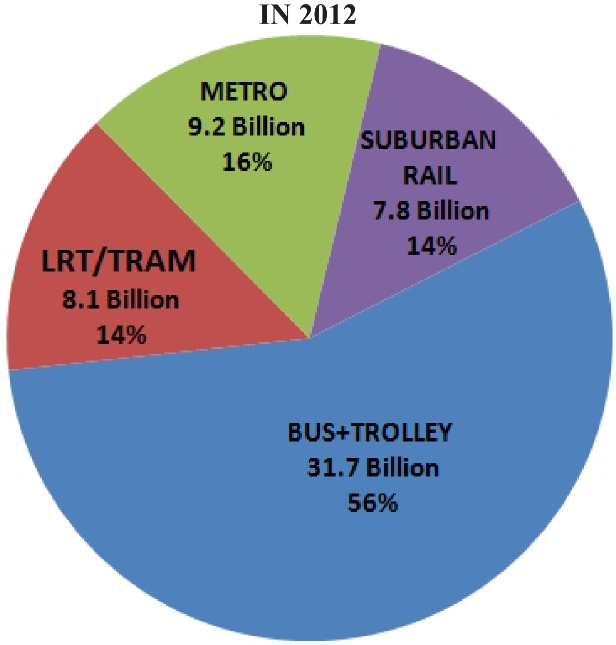

Chart 3.3.2.2 (A): Modal Share of Public Transport Modes in Europe 2012 (Source: UITP)

MODAL SHARE OF PUBLIC TRANSPORT JOURNEYS IN USA IN 2012

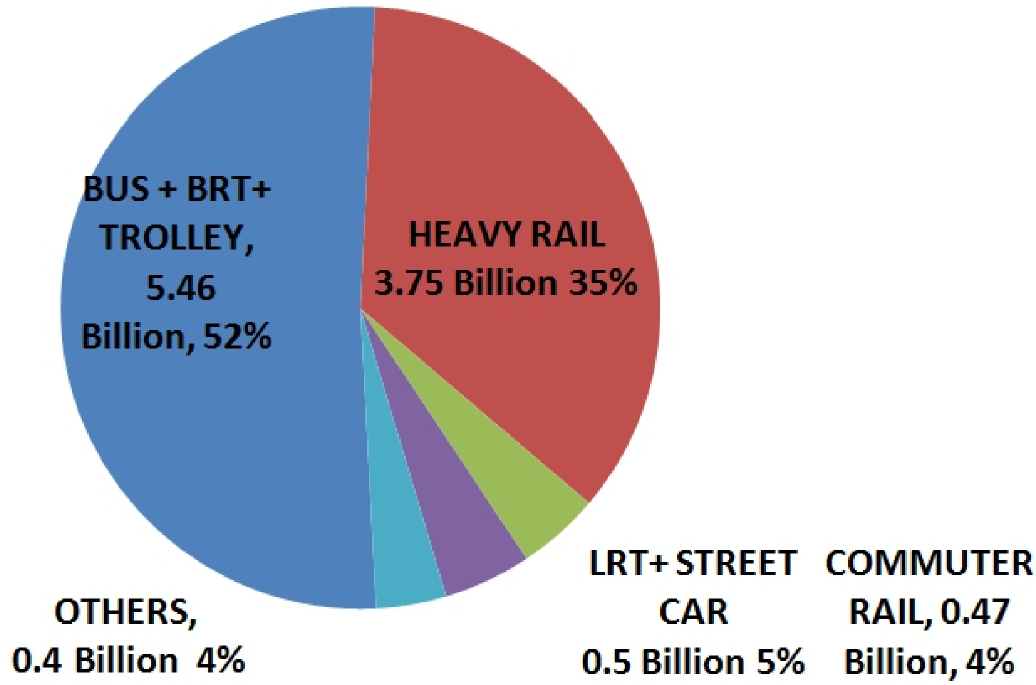

Chart 3.3.2.2(B): Modal Share of Public Transport Modes in Europe 2012 (Source: APTA)

3.7.2.3 In the United States on the other hand, out of 815 Public Transport Systems, 27 are described as Commuter Rail, 15 Heavy Rail, 4 Hybrid Rail, 25 Light Rail, 2 Monorail, 10 Streetcar, 699 Bus and 4 Bus Rapid Transit amongst other categories. In 2012, out of 10.5 billion passenger journeys undertaken by Public Transport those by Bus were 50.1%, Heavy Rail (Metro) 35.4%, Commuter Rail 4.5% and Light Rail 4.2%. Public Transport plays a much smaller role in North America as may be seen by the passenger journeys undertaken. Light Rail Transit though important in several cities carries much lower volumes. Total LRT mileage is 1418 miles (2268 km) against almost 15000 km in Europe. However, it is worthwhile to note that Transit Passenger Miles in the USA have been growing much faster than population growth i.e. Public Transport usage is improving. The largest Transit agencies in the USA in 2012 were New York City Transit (MTA) with 3.38 billion trips annually, Chicago Transit Authority (CTA) with 545 million trips per year, Los Angeles Country Metropolitan Transport Authority (LACMTA) 465 million trips followed by the Washington Metropolitan Area Transit Authority (WMATA) with 424 million trips. However, the largest urbanized areas with maximum Transit travel are New York-Newark- New jersey, Los Angeles-Long Beach-Anaheim, Chicago, Washington D.C. and San Francisco-Oakland.

3.7.3 *Bus Rapid Transit (BRT) Systems*

3.7.3.1 Bus Rapid Transit system is a high capacity, low cost, transit solution that can significantly improve urban mobility. The BRTs have their own lanes on City Roads and use Bus stations rather than conventional bus stops. The Bus station has the advantage that tickets can be purchased before boarding, and entry and exit into the Bus is at the same level without having to climb steps as the stations have elevated boarding platforms.

Moreover, electronic signage provide information regarding the next Bus. In view of its low cost and convenience many cities the world over are opting for BRT systems. Building a Rail based system could cost several times more than a BRT system. There are number of cities both in the developed world as well as developing countries where BRT has been introduced. These include Sydney, Adelaide and Brisbane in Australia, Bogota in Colombia, Curitiba in Brazil, Quito in Ecuador, Phoenix, Arizona in the US and Istanbul in Turkey.

3.7.3.2 China has developed BRT systems in several of its cities. These include Hangzhou, Beijing, Kunming, Changzhou, Xiamen, Suzhou and Urumqui to name a few. Many cities have more than one route, for example Suzhou has five with 106 stations and a route length of 95 km. An interesting case is of Guanghzou with a single BRT route opened in 2010 with 26 stations and 22.5 km length which caters 1 million passenger trips per day with a peak hour flow of 26,900 PHPDT. It has long stations and a Bus frequency that can reach 350 Buses per hour. Some of the integrated planning aspects are worthy of note such as the land use along the route which serves well developed areas, retail complexes and new residential areas. Large stretches of green areas have been developed along the corridor with a view to upgrade public spaces. An interesting feature is that Buses operate on an open system serving both the BRT corridor as well as areas outside it. It also provides a connection to the Metro. Moreover a number of operators are permitted to provide service on the route.

3.7.3.3 Another remarkable Bus Transit System is the TransMilenio in Bogota, Colombia which in the year 2008 carried 1.4 million passengers per day. It was planned in three phases with 84 km built in Phase I and Phase II along the Trunk Corridor with 114 stations and a fleet of 1071 buses plying at an average speed of 27 kmph. An additional Phase III of 28 km was under construction apart from 200 km of feeder routes. The BRT operates both stopping at all stations and limited stop Express Services. The Station entry is through use of Intelligent Contact less Cards. The movement and fleet control is through continuous voice and data communication with the Control centre. The success of BRT in Bogota has been the result of good city leadership. A number of Transportation Demand Management (TDM) measures had been put in place such as development of 344 km of bicycle routes, pedestrian paths, regulation of private automobile use during peak hours, and introduction of car free days. Creation of public spaces and pedestrian precincts has also encouraged use of non-motorized transport. Affordable housing has also been built under a PPP framework for low income groups along the TransMilenio facilitating their commuting needs. One area where Bogota has not been able to implement change because of coordination and planning related constraints is increasing the FAR along the BRT route which is essential for Transit oriented development. What Guangzhou and Bogota establish that a Bus Rapid Transit Corridor, if properly planned and implemented, can carry very high volumes of traffic.

3.8 Mass Transit in Selected World Cities

3.8.1 LONDON: London is a very good example of a totally integrated Public Transport System under Transport for London (TfL) managed by the Mayor of London. The various public transport companies and modes that come under Transport for London are the London Underground Ltd. (Tube), London Rail, Docklands Light Rail, London Buses and London Trams. In addition, TfL also regulates taxis, private hire cars, major roads, London river services etc. The institutional arrangement ensures integrated planning, scheduling and delivery of services in a very coordinated way. It also ensures fare integration through Zonal system following six concentric circles. Prepaid Smart Cards facilitate seamless transfer from one mode to another. There is also excellent physical integration between modes with well planned interchanges, with well designed signage ensuring unimpeded movements and reduced dwell times. There is also a common watchdog organisation for all modes called London Travel Watch to which users of all services could approach with complaints and suggestions. Recently even some over ground services out of London are also coming under the ambit of TfL. Clearly this is a good model to emulate.

3.8.2 SINGAPORE: This City Nation State has taken some of the finest initiatives in promoting Mass Transit, integrating Transit and Land Use, and initiating Transportation Demand Management (TDM) measures. As early as 1971, in a Conceptual Plan for Mass Rapid Transit System it adopted a plan for 'Land Banking' i.e. identifying areas for development of residential complexes which were to be connected by Public Transport. In 1991, the Government prepared a Concept Plan for high-rise development around the MRT which was operational since 1987. Land use plans not only ensured that public transport would cater to residential areas but also the commercial centres, industry and housing were placed in close proximity to each other to minimise travel. The Mass Transit network was very thoughtfully conceptualised with radial lines from the CBD linking to circular line on the city's periphery.

As early as 1975, an Area Licensing Scheme had been introduced under which private road vehicles were charged for entry into the CBD or defined Zone in order discourage use of private vehicles. This was subsequently replaced by an Electronic Road Pricing Scheme where a charge is automatically levied for road usage in congested Zones with the help of electronic sensors fitted to vehicles. The Mass Rail Transit is now run by SMRT Corporation. The North-South and East-West Lines, with 53 stations and 93.2 km length, are the high density routes carrying 1.6 million passengers daily. There is also a circle line with 30 stations which is 35.4 km long. The same Company also runs a 7.8 km long LRT system with 14 stations. SMRT also runs Buses, has a fleet of 1050 buses which operate from 5 interchanges and had a ridership of over 326 million in 2012. The company also operates 3000 taxis and 70 chartered buses. The SMRT Corporation have also leveraged property at Stations and Interchanges for retail business, event management etc.

3.8.3 SAN FRANCISCO (BAY AREA): The Bay Area Rapid Transit (BART) is an important Mass Rapid Transit System in the United States and has contributed towards significant increase in Public Transport ridership in the area. It consists of a length of 167 km with five lines viz A-Line from Fremont to Lake Merritt (38 .3 km); the M,W and Y-line from Oakland West to Millbrae (43.4 km); the R-Line from Richmond to MacArthur (17 km); the C-line from Pittsburg/Bay Point to Rockridge (47.1 km) and the L-Line from Dublin/Pleasanton to Bay Fair (16 km). The lines are partially underground, on the surface and elevated. There are 44 Stations of which 16 are on the surface, 13 elevated and 15 underground. Interestingly it has a Broad Gauge (5'6”) track similar to India. The average weekday ridership of BART has grown from about 310,000 in 2000 to 410,000 in 2014 with annual growth varying from -6% to +7%. It is the fifth busiest Metro system in the United States. Its significant feature is linkages with other Transit facilities in the Region such as Caltrain, Altamount Commuter Express, AC Transit, Amtrak's Capitol Corridor, Santa Clara Valley Transportation Authority Light Rail etc. Transit interchanges are convenient, the effort being to provide direct and uninterrupted connections, good lighting, shelter, seating and service information and integrated fares. With growing ridership, expansion of the System is planned and additional rolling stock is being procured. BART is also seeking Federal support for its growth plan.

3.8.4 HONG KONG: Hong Kong was initially served by two Mass Transit Operators viz. the MTR Corporation and the Kowloon Canton Railway Corporation (KCRC). Whereas MTRC operated 7 lines, KCRC ran 3 suburban lines and one LRT system. Since 2007, all operations have been transferred to a single entity, the Metro Transit Railway Corporation Limited (MTRCL). Brief details of the MTRCL lines are given in Table 7.8.4.

	Name of Line	Year of Opening	Length	Stations	Gauge	Traction supply
1	Kwun Tong Line	1979	15.8	15	1432 mm	1500V DC
2	Tsuen Wan Line	1982	16.9	16	1432 mm	1500V DC
3	Island Line	1985	16.3	17	1432 mm	1500V DC
4	Tung Chung Line	1998	31.1	8	1432 mm	1500V DC
5	Tseung Kwan O Line	2002	15.5	8	1432 mm	1500V DC
6	Disneyland Resort Line	2005	3.5	2	1432 mm	1500V DC
7	Airport Express	1998	35.3	4	1432 mm	1500V DC
8	East Rail*	1910	34	13	1435 mm	25 KV AC
9	Lok Ma Chau Spur*	2007	7.4	1	1435 mm	25 KV AC
10	West Rail*	2003	35	12	1435 mm	25 KV AC
11	Ma On Shan Rail*	2004	11.4	9	1435 mm	25 KV AC

*Old KCRC Portion

Table 3.8.4: Metro & Suburban Lines in Hong Kong

Apart from Heavy Rail Line, Hong Kong has a 36 km long LRT system with 68 stops in its North Western District. The LRT has interchange facilities with the West Rail system. This apart, in the Downtown there is an over 100 year old Tramway system running from east to west along the northern shore of Hong Kong Island. The Tramway is at grade and operates in mixed traffic conditions. The Public Transport System of Hong Kong that includes Railways, Trams, Buses, Minibuses, Taxis and Ferries carries over 12 million passengers per day. This includes 4.62 million by Rail (9 lines excluding Airport line)), 41,400 on the Airport line, 479,000 on LRT, 1.5 million on fixed route Minibuses and 349,000 on Minibuses free to operate on any route, and 184,000 on Trams. Hong Kong is a remarkable example of planning and development of Mass transit. The Special Administrative Region has a land area 0f 1,108 sq. km., 24% of which is built up, a population of seven million amongst the most heavily used road network in the world with 630,000 vehicles on 2086 kilometres of road. Public Transport usage is an astonishing 90%. In order to ensure viability of the Mass Transit system the

MTRCL borrowed from the Japanese experience of Rail cum Property development both in case of Green field and Brown field projects. For example on the New Airport Line above Tsing Yi Station, MTRCL developed Maritime Square a massive high rise development with shopping, residential, recreational and rail interchange facilities, all in a single complex. The station platforms and lines along with shopping and station facilities are located on the second and third floors, residential parking and park and ride on 4^{th} & 5^{th} floors with residential floors above them.

3.9 Mass Transit Developments in Selected Indian Cities

3.9.1 **MUMBAI:** The Suburban/Commuter Railways have played a key role in the development of the City. In fact, the introduction of Suburban rail services in the 1920's along the Western and Central Railway Lines, led to development of residential suburbs along them such as Bandra, Andheri and Borivili along the Western Railway line, and Byculla, Dadar, Ghatkopar and Kurla along the Central Railway Line. These lines also linked these suburbs to industrial zones such as Parel and the Central Business District in South Mumbai. On the Western Railway (WR) the first suburban train was introduced in 1928 between Churchgate and Andheri. Today the Western and Central Railway Systems together carry approximately 7.5 million passengers a day. Under the Mumbai Urban Transport Project (Ph. I & Ph. II) additional rail corridors are being built, new rolling stock acquired with support from the World Bank on a cost sharing basis between the Central and State Governments. A beginning has also been made in exploiting air rights and capturing land value in order to fund the project. Bus Transport also plays a very important role in the City of Mumbai with services provided by the Brihanmumbai Electric Supply and Transport (BEST) Company which operates over 4,680 buses and transports over 5 million passengers daily. In addition other Bus operators also i.e. Navi Mumbai Municipal Transport, Kalyan – Dombivali Municipal Transport, Thane Municipal Transport etc also provide public transport services in the Greater Mumbai Region.

With the rapidly growing demand for mobility in the City of Mumbai and constraints in East-West movement across the original Mumbai Island and across the Thane Creek to Navi Mumbai, a number of new Mass Transit Projects have been envisaged. These include three Metro Corridors (i) Mumbai Metro Line 1 from Versova to Ghatkopar via Andheri 11.40 km long with 12 stations on an elevated alignment. This links the Eastern and Western suburbs, links with Suburban lines and reduces journey time by 50 minutes. The line was operational in 2014 and is expected to have a ridership 6,65,000 by 2021. (ii) Metro Line 2 from Charkop to Mankhurd via Bandra. This is a 31.87 km long line with 27 stations from the Northern Suburb of Charkop to Mankhurd in the East and (iii) Metro Line 3 connects Colaba to SEEPZ via Bandra. This is a 32.50 km line with 27 stations, wholly underground which will link the CBD of South Mumbai to the new CBD at Bandra Kurla Complex and shall also link both the Domestic and International Airports as also industrial areas of MIDC and SEEPZ. It is projected to have by 2021 a ridership of 1.3 million with a PHPDT of 39000. Two Mumbai Trans Harbour Links are being planned to Navi Mumbai/ Mainland with a view to decongest Mumbai. One is a highway connecting Sewri with Nhava Shiva by a 22.5 km long six-Lane carriageway. The second is a Metro Trans Harbour Link 49.60 km long from Siddhivinayak –

Dhutam - Dushmi which will be partially at grade, partially elevated and small section of 3.9 km underground. In view of narrow roads and constraints on bus speeds Mumbai has also opted for Monorail. The Mumbai Monorail Project consists of two phases. Phase I from Wadala to Chembur (8.93 km) and Phase II from Sant Gadge Maharaj Chowk to Wadala (11.20 km). Phase I is operational and has a fairly good capacity with each 4 car unit capable of carrying 562 passengers at a headway of 3 minutes and speed of about 30 kmph. There are a few other projects also in the Master Plan such as a Metro from Thane to Kasarvadavali, Thane-Bhiwandi-Kalyan Monorail which probably will take time to fructify. Land value capture to fund some of these projects is an integral component. One major weakness in Transit development in Mumbai is the lack of integration between Transit modes in terms of ticketing, scheduling and transfer facilities for which closer coordination between various agencies will be necessary.

3.9.2 **DELHI**: Some basic facts about the Transport network in Delhi include a motor vehicle population of 88.27 lakh on 31st March 2015, the highest in India, which is 6.4% higher than the previous year, the Delhi Transport Corporation (DTC) bus system caters to a daily ridership of 3.9 million passengers and has a DTC bus fleet of 3781 low floor AC and non-AC CNG buses & 924 Standard floor buses. In addition 1406 privately run cluster buses operate in 9 clusters and a Metro system that transports 2.4 million passengers daily (2014-15). The introduction of CNG for buses and three wheelers did contribute to reducing pollution; however, the benefit is fast being lost owing to the rapid growth in four wheeler and two wheeler populations. While Delhi has the distinction of having the nation's highest road density, the advantage is again being lost because of the growth in road vehicles as despite massive investments in the Metro system, the Mass transit system has not been able to keep pace with the demand. Once phase III of the Delhi Metro is completed, the daily ridership of the Delhi Metro is expected to increase to 4.0 million. An interesting recent development is the Delhi Government's Budget proposal for acquisition of 10,000 buses including 1,380 semi low floor DTC buses and 1000 cluster buses. There appears to be a problem regarding identifying 500 acres of land for accommodating these buses. It is hoped that the Central and State Governments will be able to work together on this proposal, as despite Metro development, expansion of the bus network and developing new BRT routes is essential to give the Capital City a Mass Transit system that caters to its needs. Every possible endeavour needs to be made to curb the accelerated pace of growth of private road vehicles in the City. There is also a proposal for integrating ticketing on various modes.

The major success in Delhi in the new millennium has been the development of the MRTS or Delhi Metro. The project was approved in September 1996; the Phase I of 65.05 km was commissioned between 2002 and 2006 and Phase II of 124.63 km was commissioned between 2008 and 2011. Phase III which will add 117 km to the network is at present under implementation. The project, the first of its kind, in the country was implemented on time and is held out as a model for good project management. Monitoring progress at the highest level and cooperation and support from all quarters apart from capable leadership contributed to successful implementation. The Delhi Metro Rail Corporation (DMRC) is today advising and implementing projects in many cities.

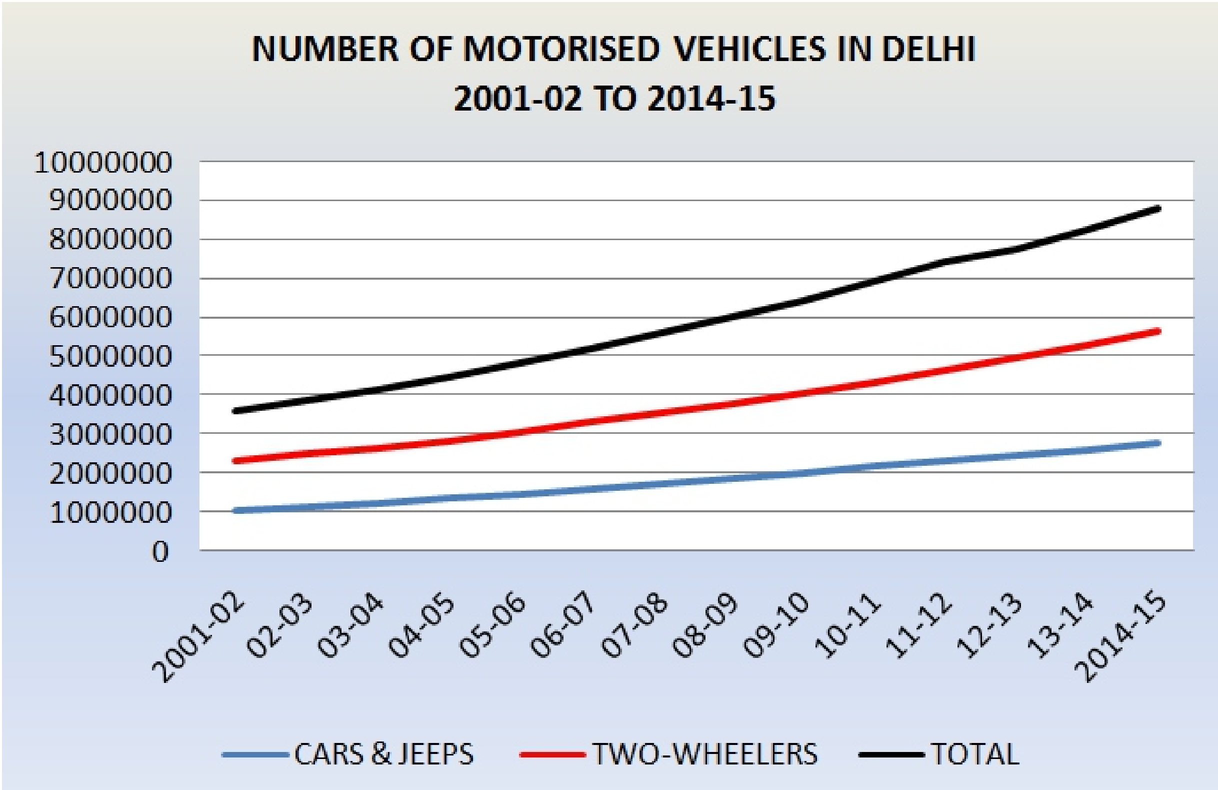

Chart 3.9.2: Growth in Motor Vehicle population in Delhi causing rising pollution & congestion on roads. Improving Mass Transit is the only solution (Source: Economic Survey of Delhi 2014-15)

The urgency for strengthening Public Transport infrastructure has recently been highlighted by the fact that Delhi had the dubious distinction of being declared as the most polluted city in the World with poor air quality likely to have severe impact on public health. With a view to control the problem, the Government, as an experimental measure for a 15 day period (in January 2016), introduced vehicle restrictions by allowing odd numbered private vehicles on odd Dates and even numbered vehicles on even Dates. This resulted in reducing road congestion though its impact on pollution was marginal. Many bold initiatives of this type are necessary. However, the long term solution is building a strong Mass Transit Infrastructure and weaning away people from Private Motorized Transport.

3.9.3 **HYDERABAD:** One of the unique development in Hyderabad is that under the aegis of the Hyderabad Metropolitan Development Authority, they have created a Unified Metropolitan Transport Authority (UMTA) and have initiated Mobility Studies and a Comprehensive Transportation Study for the city of Hyderabad. According to this Study, the transportation needs of the City are met by various modes i.e. Private vehicles (2&4 wheelers) to the extent of 48.5%, Bus transport 42%, Rail-based Multi Modal Transport System (MMTS) 1.55% and Auto Rickshaws (3 & 7 seater) 8%. The transit developments have been on several fronts e.g. the State Government was able to persuade the Ministry of Railways to introduce Heavy Rail based Transit system in Hyderabad by segregating it to the extent possible from the Main Line system and inducting new rolling stock. The road infrastructure has been improved in recent years with development of Inner and Outer ring roads and, radial roads which has relieved congestion. However, the most significant project is that of the Hyderabad Metro which is being carried out under a Public Private Partnership framework and is said to be the largest PPP project of its kind in the world

Hyderabad, one of India's leading cities has rapidly grown into a major commercial, industrial, administrative, educational and IT hub in Southern India. With rising urban mobility, and congestion on roads, the development of an Urban Metro Rail system was an urgent need. With this background the Government of Andhra Pradesh decided on the development of the Hyderabad Metro Rail system. The project envisaged development of three corridors (72 km.) viz. Miyapur – L.B. Nagar (29 km./27 stations), Jubilee Bus Station – Falaknuma (15 km. / 16 Stations) and Nagole – Shilparamam (28 km. / 23 stations). It was planned to provide interchange facilities with existing rail terminals, the MMTS stations and Bus terminals. In order to provide 'seamless' travel between the Metro Rail and the catchment area it was proposed to provide air-conditioned bus services on the Metro Ticket between the stations and the suburban areas. The project was planned as an urban rejuvenation and redesign initiative in order to transform the City into a people friendly and green city.

The Project is based on the Design, Build, Finance, Operate & Transfer (DBFOT) model. The Concessionaire selected by International Competitive Bidding was L&T Group (L&T MRHL). The Company won it on the basis of the least requirement of funding support (grant) of Rs 1458 crore from the Government. The Concession Agreement was signed on 4th September 2010 and Financial Closure was achieved on 1st March 2011. The total Project cost initially accepted by the State Govt. was Rs 12132 crore. However, as a result of price escalation and taking into account the cost of acquisition of Real Estate, total Project cost went up to Rs 16375 crore. The Funding Pattern of the Project consisted of Senior Debt, Subordinate Debt, Equity and a Government of India Viability Gap Funding. Construction of the Project has moved rapidly, despite problems owing to bifurcation of the State of Andhra Pradesh, and the first section is expected to be opened in 2015. What this project shows is that if there is a strong support from the local State Government much can be achieved and private entities will be willing to participate.

3.9.4 **JAIPUR:** Jaipur City had a population of 3.07 million in 2011 with a total population of about 4.4 million in the Greater Jaipur Region. This population is expected to grow to 6.4 million by 2021 and 9.3 million by 2031. The urban transport infrastructure and services in the City are rudimentary. There are about 250 city buses, 1800 private minibuses and various categories of intermediate Public Transport such as auto rickshaws, cycle rickshaws etc. Route rationalisation and quality of service is poor. The share of public transport was declining and it was estimated that over a decade the share of Public transport had declined from 26% to 19%. With rapid economic growth and urbanization, building a more sophisticated and developed urban transport system was a priority. Various options were examined and it was decide to fast track a Metro Project in the City. Two corridors were proposed which are given in Table 7.9.4 below.

	From	To	Distance	
Phase 1: Corridor I (East-West)	Mansarovar	Badi Chaupar	12 km	**9.2 km Elevated 2.8 km Under Ground**
Phase 2: Corridor II (North-South)	Sitapura	Ambabari	23 km	**18 km Elevated 5 km Under Ground**

Table 3.9.4

Phase I was further divided into Phase 1A from Mansarovar to Chandpole (9.13 km) an entirely elevated section and Phase 1B the remaining section which is underground. It is a remarkable achievement that the construction of Phase IA has been completed in a short span of 51 months and it was opened in early June 2015. In addition to the Metro, Jaipur is also building a Bus Rapid Transit System and a 7.1 km stretch was started as a pilot project from C-Zone Bypass near Harmada to Pani Pech. Additional BRTS corridors are also being planned and a total length of 26 km has been sanctioned. These are parallel to the Metro alignment and also as feeder routes to the Metro. Under the JNNURM, 400 new low floor buses are also to be acquired. With the proposed Metro Transit lines and the BRTS, hopefully the mobility needs of Jaipur citizens will improve.

3.9.5 **AHMEDABAD**: Ahmedabad had a population of 5.5 million in the 2011 Census and is considered one of the fastest growing cities in the world. It has about 1.5 million road vehicles growing rapidly and congesting the road network. The only public transport mode used to be Bus apart from various Intermediate Transit Modes. However, Ahmedabad decided to go in for Bus Rapid Transit in order to tackle the City's transport problems. Today about a million passenger journeys are undertaken by Bus everyday of which 860,000 are by conventional City bus and 140,000 on the BRT. The first BRT route was opened in 2009 and the total network planned is 88 km with about 45 km in Phase I. Ahmedabad has, perhaps, been the most successful experiment in Bus Rapid Transit in India. Some of the key innovations include a focus on the network rather than corridors, specially designed comfortable Buses, safe and accessible Bus stations, use of Intelligent Transportation systems, extensive public outreach and use of PPP in operations. The entire project is run by an SPV created by the Ahmedabad Municipal Corporation. What it has achieved is an average bus speed of 25 – 30 kmph, headways of 3-4 minutes on important routes and provided access to this Transit mode to about 20% of the population who reside within 1 km of the BRT routes. However, an important aspect that has not been impacted is Land Use patterns or the growth of the city. The Local and State Governments have not been able to incentivise development of residential or commercial complexes along these routes, through FSI relaxations, as has been done elsewhere in the world. Although in India, the realisation is there of linkage between Transit and Land Use in practical terms, there is little Transit oriented development. As a result, in Ahmedabad also the urban sprawl continues to spread in various directions. An effort was also made to promote Non Motorised Transport along the BRT by constructing cycle paths and footpaths as a significant volume (80% of EWS and Low Income Groups) use these means. However, results have been mixed.

In addition to the BRT, Ahmedabad is building a Metro system consisting of two corridors i.e. a North - South Corridor and an East - West Corridor in Phase 1. The total length planned in Phase 1 is 37.77 km with a total of 33 stations. It is eventually planned to build 82.33 km in later phases. The North South Corridor will be totally elevated and extends from APMC in the South to Motera Stadium in the North via Paldi, Usmanpura, Vadaj, Sabarmati Railway Station and is 17.23 km long. The East – West Corridor will be from Thaltej in the West to Vastal Gaam in the East via Commerce six Road, Kalupur Railway Station and Kankaria and is 20.53 km long. The North-South Corridor by 2021 is projected to have a daily ridership of 2.99 lakh and a PHPDT of 12,097 while on the East-West Corridor ridership is expected to be 3.62 lakh in 2021 with a PHPDT of 15,659 passengers. The project is estimated to cost Rs 9327 crore at 2014 prices and the investment gives a negative Financial Return although the Economic Rate of Return is 17.09%. Ahmedabad, therefore has a fairly comprehensive Mass Transit Capacity building plan.

3.9.6 **CHENNAI**: Chennai is India's fourth largest city with a population of 8.7 million in the last census. Despite having a significant Heavy Rail Commuter Rail system the City's Mass Transit system is facing severe bottlenecks and with the rapidly increasing vehicle population, the road network is severely congested. The Suburban Railway system consists of 3 corridors viz. Chennai Central to Gummidipundi (48 km, 16 stations), Chennai Central to Arrakonam (69 km, 29 Stations) and Chennai Beach to Tambaram (30 km, 29 stations). In addition a Mass Rapid Transit System line was built from Chennai Beach to Velachery (20 km) which is being extended to St Thomas Mount. A 2004 Chennai Metropolitan Development Authority Study revealed that Mass Transit trips in 2004 were 3.5 million by Bus and 0.5 million by Rail which were expected to grow to a total of 14.5 million in 2026 of which 8.7 million would be by Bus and 5.8 million by Rail. Bus transport is clearly the main Mass Transit mode in Chennai with the Metropolitan Transport Corporation (Chennai) transporting 5.15 million passengers a day with a fleet of 3,800 buses at present.

The future anticipated growth has resulted in the planning for new Metro lines in Chennai. At present two Metro corridors are being planned viz. the first from Washermenpet in the North to the Chennai Airport (23.1 km) and the second from Chennai Central to St Thomas Mount (22.0 km). In case of the first corridor 14.3 km and in the second 9.7 km shall be underground and the balance shall be elevated. The total project cost is estimated at Rs 14,600 crore of which 41% shall be funded by the Central and State Governments and the balance shall be through a bilateral soft Loan from the Japanese Govt. (JICA). The Financial Rate of Return is 1.40% and the Economic Rate of Return is 16.22%. The Project also envisages some income from property development apart from advertising, leasing of parking rights, co-branding and organizing special events. The first section of Chennai Metro was opened in June 2015.

3.10 Financing Mass Transit

3.10.1 Financing Mass Transit Projects is a major challenge for the Central, the State and the City Governments. In India, the resources available with State Governments and Urban Local Bodies are very limited although Urban Transport is primarily their responsibility. The need for investment in Public Transport has only gained importance in the last two decades. Independent India inherited high capacity Rail Suburban Systems in Mumbai and Chennai and created one in Kolkata soon after Independence. The subject was neglected at all levels, as no Central Ministry was responsible for it. The impetus to Urban Transport came after the subject was allocated in 1986 to the Ministry of Urban Development. Once the Ministry of Urban Development was able to familiarise itself with the subject it did begin to take the initiative. The Jawaharlal Nehru National Urban Renewal Mission (JNNURM) provided funding for Urban Transport in a number of cities. This was mainly for Roads, ROBs & Fly-Overs, acquisition of new Buses, creation of Bus Rapid Transit Corridors and Area Traffic Improvement schemes. During the Eleventh Five Year Plan, for example, under 'Urban Infrastructure & Governance (UIG)' component of JNNURM, 15,260 low floor and semi-low floor buses were sanctioned for 65 cities with Central assistance of Rs 2,089 crore. A total of 21 Urban Transport Projects including BRTs were sanctioned at a cost of Rs 5,211 crore. A number of major Metro rail projects were also taken up in major cities. In the Twelfth Five Year Plan (2012-2017) the total Capex requirement for Mass Transit has been estimated at Rs. 55,497 crore. More recently the Government has launched an 'Atal Mission for Rejuvenation & Urban Transformation' which also gives emphasis to Public Transport.

3.10.2 The Financing needs for Bus Rapid Transit system are relatively modest compared to Metro Rail and therefore it is important that in India we maximise the benefit that can be derived from it as we have seen in several other developing countries like Colombia, China and Brazil. Concentrating the population, commercial and other activities along the BRTS corridors could give rich dividends. The cities that have opted for BRTS in India, with total route operational or planned, and projected costs are given in the Table 7.10.2. Funding such projects is well within the capacity of the Central and State Governments.

CITY	LENGTH IN km.	COST (Rs. crore)
Ahmedabad	58.00	493.32
Bhopal	21.71	237.76
Delhi	14.50	190.00
Indore	11.45	98.45
Jaipur	26.00	239.19
Pimpri-Chinchwad	23.00	312.14
Pune	101.70	807.12
Rajkot	29.00	110.00
Vijayawada	15.50	152.64
Vishakhapatnam	42.80	452.93

Table 3.10.2: BRTS Projects in Indian Cities (Planned/Operational)
Source: 'Metro Rail Projects in India'

3.10.3 On the other hand, Metro Rail Projects require significant resource mobilisation and need to be planned carefully. Garnering funds for the various Metro Projects in India has been difficult. In most countries Metro Projects are Public Projects undertaken by the Government. As investment amounts are extremely large, returns at best modest and gestation periods long it is not easy to attract Private Investment and wherever there has been Public Private Partnership the Government has had to play a significant role through Viability Gap Funding, granting liberal Real Estate developmental rights above Stations etc. Many privately funded projects have run into problems for example in Pusan, S. Korea the line had to be taken back by the Government, in Kuala Lumpur the project had to be restructured and another one in Manila, the traffic risk had to be taken over by the Government.

3.10.4 The options available for raising financial resources are (i) Full funding by Central Government (ii) Full funding by Central and State Governments combined, (iii) Borrowing from a Multilateral Agency, (iv) Foreign Aid in the form of soft bilateral loans, (v) Dedicated local levies for the project, (vi) Private Investment and (vii) Raising funds through property development. Often a combination of one or more of these sources of funds is used. The pattern emerging in India for Publically Funded Projects is that Equity is contributed by both the Central and State Governments, further an element of Subordinate debt is raised by the Centre and the State for cost of land and a small component comes from Real Estate development. However, the Main debt component so far has come through a soft loan from Japan (JBIC/JICA) under a bilateral agreement. In the PPP framework the Centre and State continue to be equity holders in the project and also provide viability gap funds for the project whereas the private entity apart from equity contribution also must raise the debt. Some examples of the Funding Pattern in publicly funded projects in India are given in Table 7.10.4. Japanese soft loans at extremely low interest rates have played a significant role in the development of Metro Rail Transit Systems in India. In view of the fact that Financial Internal Rates of Return of these Projects are in the range of 4% to 7% the Credit Ratings of these Projects are low and it is difficult to raise funds from conventional sources like Banks and Financial Institutions.

(Figures in Rs. Crores)

	DELHI MRTS PH.I	DELHI MRTS PH.II	BANGALORE METRO	KOLKATA METRO	CHENNAI METRO
GOI EQUITY	1,464.00	1,194.19	1,223.70	731.18	2,190.00
STATE GOVT. EQUITY	1,464.00	1,194.19	1,223.70	731.18	2,190.00
SUBORDINATE DEBT (GOI)	252.00	175.00	815.80	487.45	730.00
SUBORDINATE DEBT (STATE GOVT.)	252.00	175.00	1,223.70	731.18	844.00
JBIC/JICA LOAN	6,839.00	5,056.97	2,877.75	2,193.56	8,646.00
PROPERTY DEVELOPMENT	300.00	405.00	0.00	0.00	0.00
LOCAL GOVT. SOURCES/OTHER	0.00	405.00	793.35	0.00	0.00
TOTAL	10,571.00	8,605.35	8,158.00	4,874.55	14,600.00

Table 3.10.4: Source of Funds for Some Metro projects in India in publically funded projects

Source: Based on Data from 'Metro Rail Projects in India' by M. Ramachandran

In the case of PPP projects, for example the Delhi Airport Express Line out of the total cost of Rs 3,869 crore, the Central and State Govt equity was Rs. 757.00 crore, Concessionaire Equity Rs. 538 crore, Debt of Rs 1,247 crore, and Grant by the Airport of Rs 350 crore and by Delhi Development Authority of Rs 217 crore. Unfortunately traffic volumes on the Line are abysmally low. The Hyderabad Metro is also a PPP project which was bid out on the criteria of least VGF. The total project cost of Rs. 16,375 Crore consists of Equity Rs 3,439 crore, Debt 11,478 crore and VGF from Govt. of Rs 1,458 crore. If Hyderabad succeeds it could be precursor for more Private investment in this area.

3.10.5 The Financing experience in India has so far been good. It is hoped that in future Indian cities will be able to attract low interest loans from Japan or elsewhere to fund publically promoted and funded lines. The Government could also consider creating a ring fenced Metro Development Fund by creating an SPV for this purpose to which Multilateral & Bilateral Agencies, Infrastructure Funds, and Government could contribute. The Fund should be controlled by Professional Fund Managers. Raising finance through private funding in smaller cities may be difficult given the low returns. However, Real Estate development needs to be explored and evolved so that larger amounts can be leveraged from this source for Metro Rail development in future. Here we need to learn from Japanese experience where Japanese Private Sector Metro and Railway Companies in many cases earn much more of their revenue from non transportation sources. For example the Tokyu Railway earns 17% from Transportation, 17% from Real Estate, 44% from Retail and 12% from Tourism.

3.11 Integration of Urban Transport Modes

3.11.1 A major weakness in our Urban Transport Systems is the lack of integration or coordination between different modes of Transport. For example, Mumbai has an excellent High Capacity Suburban Rail System, an extremely well managed Bus network, and now a Metro Rail Line as well as a Monorail line. However, no integration exists in terms of scheduling, ticketing, or transfer facilities to ensure seamless movement across modes. The same situation exists in other cities. In Kolkata, Suburban Rail, Trams and a variety of Bus operators function in total isolation, In Chennai whereas Suburban Rail and Chennai MRTS is managed by the Railways, the mammoth Bus network and the future Metro will operate independently. Even if common ticketing is introduced it would improve mobility and quality of urban commuting considerably. With the advances in Information Technology it should not be difficult to develop appropriate systems which can apportion revenue to various modes and tickets that facilitate travel on all modes.

3.11.2 The transfer facilities between Modes are also not as meticulously planned as they should be. In Delhi for instance at the Central Metro Hub of Rajiv Chowk (Connaught Place) if a passenger from the regular Metro lines wants to transfer to Airport Express line he has to walk 800 metres to Shivaji Stadium. Even at New Delhi Railway Station the transfer from the Metro to the Long Distance Train Station involves travelling a distance of half a kilometre. It is not that efforts are not being made to improve integration, for example, at Thane in Mumbai considerable investment has been made to improve transfer facilities between Suburban Rail and the local Bus System with excellent results. Much more needs to be done. Metro, Railway and Bus executives need to put their heads together to improve integrated planning.

3.11.3 A major cause for concern is that individual transport modes function in their own vertical silos without any attempt at coordination. While Rail is a Central Government subject Bus, BRT and Metro are under State Governments. It is important to draw lessons from the London example of how the City administration exercises control over so many diverse modes. Singapore is another case where a single corporate entity controls all modes which makes planning and development so much easier. We need to move in that direction, and over the course of the next decade or so ensure unitary control and integration between Transit modes. This will require that on the Railway front long distance rail operations are segregated from the suburban network and separate organisations are created. It will also require much greater levels of professional and managerial skills across City administrations, in planning and managing transport services. Once this organisational change takes place other issues related to combined ticketing, schedule integration and transfer facilities will automatically fall in place.

3.12 Institutional Development

3.12.1 With a range of new transport technologies coming into our cities in the form of Metro Rail Transit, Monorail, Bus Rapid Transit and new developments in ICT impacting Urban Transport, it is not only that physical infrastructure needs to be built and new transport technologies brought in but we also need to build new Institutions and upgrade the existing ones. The City governance structures at present are weak and will need to be strengthened. In the sphere of Transportation also competence levels tend to be low whether it is related to transport planning, traffic management, transport technology or the operational management of transport organisations. In order to strengthen these, appropriate organisational structures need to be built, and training at all levels is essential through the entire spectrum of knowledge, skills and attitude, in order to create a cadre of competent and dedicated Urban Transport Professionals.

3.12.2 The Ministry of Urban Development has established in 1997 an Institute of Urban Transport (IUT) as a professional body with the objective to promote, encourage and coordinate the state of the art Urban Transport including planning, development, education, research and management. It has been organising an Annual Urban Mobility India Conference where professionals from related fields exchange ideas. The Institution needs to be strengthened and must play a greater role. In addition, the Central Institute of Road Transport at Pune is an extremely fine establishment primarily catering to training, research and consultancy needs of State Road Transport Undertakings. The States also need to develop similar institutions in order to develop skills and expertise in Urban Transport. More of our leading Engineering and Management Institutes also need to organise special programmes and research in Urban Mobility and Mass Transit issues. Although some work is being done this needs to be expanded.

3.12.3 The Twelfth Five Year Plan (2012-2017) also recommends the creation of a new Department of Urban Transport in all States. If this can be implemented, it will be a very important step in Institution building, as it will be in a position to provide professional advice to the political leadership of the State and large Cities. With Metro systems being introduced a suitable institutional framework for planning, training professionals and ensuring safety in Metro systems and the range of Mass Transit options also needs to be built. Today DMRC is the major body that has helped plan many of India's new Metro systems;

they have also developed good systems and have a well established training establishment. This role will progressively need to be taken over by a separate and independent entity which has the necessary technical and professional know how. The nation needs a cadre of Urban Transport and Mass Transit professionals at the State Government and Municipal Corporation levels, if we are to transform Urban Transport in our cities.

3.12.4 As a corollary to the planning of Urban Infrastructure and Urban Public Transport in our Cities is the thought of 'Provision of Urban Amenities in Rural Areas (PURA) a concept promoted by our Late Rashtrapati A.P.J. Kalam in his Book, Target 3 Billion: PURA: Innovative Solutions towards Sustainable Development (written with Srijan Pal Singh) where he suggests building rural infrastructure providing facilities similar to those being planned in urban conglomerations by harnessing the potential of rural masses in order to achieve societal transformation. He states “PURA is an amalgamation of technology, people, traditions, skills and entrepreneurial spirit aimed at achieving sustainable development that is financially viable, socially equitable and eco-friendly”. In the Book he narrates an interesting exchange of views with Naga Tribal Leaders in a Tribal Council meeting at Tuensang bordering Myanmar. One of the issues discussed was how to develop a viable model for prosperity. There were serious infrastructure constraints of non availability of roads for transportation of exportable surplus to urban areas and bringing in tourists to this naturally beautiful and culturally rich region of the North East. Various options for developing the road infrastructure and building helipads were discussed. The case only highlights the issue that apart from Mass Transit in cities simultaneously sustainable rural transport infrastructure also requires attention.

3.13. Conclusions / Recommendations

3.13.1 The next few decades are going to witness urbanization in India on a scale never seen before in our history. As large populations move from rural areas to urban centres, their mobility within our large sprawling cities is going to be a cause for concern. With very limited road space, a fragmented and weak public transport system our urban planners face a very serious challenge in tackling this problem. Selecting appropriate Mass Transit modes to meet this massive mobility needs is the only option if we have to improve the quality of life of our urban dwellers. In addition, we need to arrest the growth of the rapidly growing mechanised vehicle population, both two and four wheelers, before they choke our road infrastructure and cause incalculable harm to the health and well being of our citizens owing to mounting pollution levels.

3.13.2 Our Urban planners also need to take urgent action in terms of dovetailing their land use plans with mass transit corridors. This is to ensure that commuting distance, are minimised and self contained neighbourhoods are developed with residential housing, commercial activity, leisure activity and open public spaces. By relaxing FSI norms, through various Town Planning Schemes and redevelopment, we need to ensure densification of population along transit corridors. **Transit Oriented Development**, in fact, should be a key element in urban planning in the years ahead. This is an area where sufficient emphasis has not been given in the past.

3.13.3 Mass Transit Options available include Heavy Suburban Rail and Metro capable of moving over 60,000 persons in the peak hour in one direction, to Light Rail Transit, Bus Rapid Transit, Monorail, and a regular Bus network to meet lesser transit needs. It is important that we have a suitable mix of transit modes in each city and a network that fits in to the land use pattern of the city. The LRT & BRT for example could feed the Metro system and Buses could act as feeders to the BRT. India has so far not tried out LRT and we need to try it out in a few of our cities. BRT though operational or under planning in several cities needs to be promoted in view of the fact that it is a relatively low cost option. BRT has transformed transport in several cities such as Bogota, Curitiba and Guangzhou.

3.13.4 There are a number of lessons India should learn from developments in various cities around the world, for example, unified management in London where the Mayor controls all modes of transport even though they may be separate entities or in Singapore where a single Corporation controls all modes and its regulation. Singapore has also imposed restrictions on private vehicle use in the CBD through a real time pricing mechanism. Hong Kong demonstrates how the Metro network has progressively grown in a well planned manner and massive benefits have been derived through real estate development. Bogota and Guangzhou have displayed the potential of BRT. Moreover in virtually all cities in Europe and several developing countries the integration between different modes is remarkable with common ticketing and convenient transfer facilities. We must draw on this rich global experience.

3.13.5 India over the last two decades has also made commendable progress in introducing Mass Transit in our cities where it was urgently needed. With the subject of Urban Transport being assigned to the Ministry of Urban Development in 1986 the subject has began to receive greater Government attention. The National Urban Transport Policy in 2006 provided the right policy framework. Under the JNNURM funds were provided to cities for acquisition of buses, improving road infrastructure and Traffic facilities. It is hoped under the rebranded 'AMRUT' scheme the effort will continue. Simultaneously Metro projects were initiated in several metropolitan cities. The timely completion of the Phase I and II of Delhi Metro was a feather in the cap which displayed that where there is a will and good leadership it is possible to deliver results. This is being replicated elsewhere in Bangalore, Jaipur, Kochi, Chennai, Mumbai and Hyderabad. This clearly establishes the capability of our engineers and transport professionals. The impetus must continue.

3.13.6 Financing Urban Transport projects is difficult as returns are low, gestation periods long and there are constraints on fares that the operator can levy. However, as recent experience has shown, if the Central and State Governments take the initiative and support projects with Equity and Viability Gap funding foreign Governments have been willing to support projects through soft loans. Moreover with suitable incentives such as rights related to commercial advertising, use of airspace for Real Estate development it is possible to attract Private Investment within a Public Private Partnership arrangement. However, every Urban transport development will require very strong Government Support.

3.13.7 The building of Institutions for planning and managing Public Transport is another crucial requirement. Building appropriate organisational structures in State and City administrations is critical. Building a trained cadre of Urban Transport specialists, engineers, and professionals is also essential for which the necessary Educational and Training infrastructure must be developed. Moreover, placing all modes of transport under unified management is imperative if our cities are to develop integrated transport systems with common ticketing and seamless transfer facilities. A small beginning has been made but much more needs to be done in order to transform Urban Transport. What is crucial is that Mass Transit Systems in our cities are made attractive in order to shift people from private cars to public transport.

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Abbreviations

AMRUT	Atal Mission for Rejuvenation and Urban Transformation
APTA	American Public Transportation Association
BRT	Bus Rapid Transit
BRTS	Bus Rapid Transit System
CBD	Central Business District
DBFOT	Design Build Finance Operate and Transfer
DMRC	Delhi Metro Rail Corporation
ETB	Electric Trolley Bus
FAR	Floor Area Ratio
HPEC	High Powered Expert Committee
ICT	Information and Communication Technology
IPT	Intermediate Para Transit
ITM	Intermediate Transit Mode
IUT	Institute of Urban Transport
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
LRT	Light Rail Transit
LRTS	Light Rail Transit System
MMTS	Multi Modal Transport System
MRT	Mass Rapid Transit / Metro Rail Transit
MRTS	Mass Rapid Transit System / Metro Rail Transit System
MRVC	Mumbai Rail Vikas Corporation
MUTP	Mumbai Urban Transport Project
NMT	Non Motorised Transport
NUTP	National Urban Transport Policy
PHPDT	Peak Hour Peak Direction Trips
PURA	Providing Urban amenities in Rural Areas
SPV	Special Purpose Vehicle
TDM	Transportation Demand Management
TfL	Transportation for London
UITP	International Association of Public Transport
ULB	Urban Local Bodies
VGF	Viability Gap Funding

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