First Report

INAE Forum on Technology Foresight and Management for Addressing National Challenges

Indian National Academy of Engineering

March 2014

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Foreword

The challenges being faced world-over by societies in the 21st Century include access to affordable health care; need for energy security and adequate transportation; mitigate climate change; providing more equitable access to information; access to clean drinking water; natural and man-made disaster mitigation, environmental protection and conservation and management of dwindling natural resources. It is acknowledged that the challenges being faced by humanity in achieving sustainable development while simultaneously mitigating the effects of climate change and bringing about alleviation of poverty are engineering issues which need to be addressed by engineers through deployment of relevant practices and technologies. UNESCO in its Report titled "Engineering: Issues, Challenges and Opportunities for Development (2010)" has also recognized the paramount importance of the role of engineering in development. It is the engineers and technologists who bring about positive and tangible changes in the advancement of nations overcoming the constraints of growing population; depletion of the natural resources and the effects of global warming and climate change.

It is a well known fact that "Technology Foresight" is regarded as the most upstream element of the technology development process. It provides inputs to the formulation of technology policies and strategies that guide the development of the technological infrastructure. In addition, technology foresight provides support to innovation, leading to enhanced competitiveness and inclusive growth. Technology foresight helps the engineers, scientists, industrialists, government officials and other strategists in the society; to identify the areas of strategic research and the emerging technologies likely to yield the greatest economic and social benefits.

In this direction, Indian National Academy of Engineering (INAE) constituted a "**Technology Foresight and Management Forum"** in Aug 2012, with Sh VK Agarwal as Chairman, besides INAE Fellows and experts, with the mandate of preparing a roadmap for addressing National Challenges. The domain of national challenges being very wide and transient, this Forum addresses some of the major issues such as Food Production and Utilization and Conservation of Water; Energy Generation and Utilities; Manufacturing Technologies; Mass Transit Systems and Building and Construction Technologies. This Forum endeavours to evolve solutions keeping in view the issues of sustainable development, poverty reduction, and climate change in focus and suggests appropriate technologies accordingly. Further, suitable Engineering Management techniques are employed to find cost effective and optimal solutions.

The Forum, Chaired by Sh VK Agarwal has finalized the suggestions/recommendations for three challenges/areas and the the first Report has been compiled on the pertinent issues related to "Waste Management"; "Water – Meeting the Future Challenges" and "Transport – Making it Greener". The report provides a perspective and an action plan for implementation

I am confident that the suggestions/ recommendations of the Forum highlighted in the report shall be of value to the Nation and all policy-makers, engineers, technocrats and administrators in addressing the national challenges. It is expected that the report shall pave the way for next steps forward in the vital areas of technology foresight for expeditious and inclusive growth of emerging India.

Baldev Raj
President INAE

Preface

1. A proposal to constitute a **INAE Forum on Technology Foresight and Management 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 the following five National Challenges for detailed study / examination with a view to foresee the needed futuristic technologies and to evolve suitable engineering management solutions. This was to be done keeping in focus the aspects of sustainable development, climate change, and poverty-reduction / inclusive growth.

(i) Energy – Major thrust on Solar

(ii) Waste Management

(iii) Agriculture – Waste reduction and its Use

(iv) Water – Meeting the Future Challenges

(v) Transport – Making it Greener

5.1 Each Challenge / Area was to be covered in a separate Chapter giving broad details of the overall situation and then giving specific details of the line of action suggested by the Forum. Once the Chapter details were finalized, a brief synopsis was to be made for each Challenge / Area also highlighting the suggested Plan for Action / Recommendations.

5.2 The Forum Members felt that there was need for more inputs / study for the following two Challenges / Areas :

(i) Energy – Major Thrust on Solar

(ii) Agriculture – Waste Reduction and its Use

5.3 It was, therefore, decided by the Group (Forum Members) to publish the suggestions / recommendations of the Forum for the balance three Challenges / Areas **and the current Report (First Report) has four Chapters including one on "Introductory / Explanatory Notes" as detailed below :**

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

6. Formulation of Action Plans / Recommendations by the Group (Forum Members) was not an easy task as several factors, many a times with conflicting requirements, had to be kept in view. These, inter-alia, included the following :

- Engineering using "Theories from Science" and "Tools provided by Technology" provides "Products and Benefits" to "Society and Nature" keeping in view the "Resources and Needs". Needs are increasing (population increase, improved lifestyles, etc.) at a very fast pace while the availability of critical Resources is becoming a major concern. Further, environmental concerns deny us the freedom to power our way into the future by burning fossil fuels. Interconnectedness of issues/problems needs that the development of appropriate Technology must take into account economical, social, and environmental factors.

- Sustainability requires the reconciliation of environmental, social equity, and economic demands. Economic growth alone cannot provide a sustainable development model unless environmental (climate change : mitigation and adaptation) and social equity (poverty reduction / inclusive growth) issues are also suitably addressed.

- There is universal recognition of the fact that challenges of sustainable development, climate change, and poverty reduction faced by humanity, are basically Engineering issues. UNESCO in its Report titled "Engineering : Issues, Challenges and Opportunities for Development (2010)", which is the first Report of its kind to be produced by any International Organisation, has also recognized the paramount importance of the role of Engineering in Development.

- Growing needs and declining availability of resources confronts Engineering and Society not only with unprecedented technical challenges, but also with a host of new ethical problems that demand the development of Global Engineering Ethics. How far should Engineering pursue the modifications of Nature? What are Engineering's roles and responsibilities in Society? How should Engineering address problems of equity in terms of the availability of resources and services of and between current and future generations? Should concerns about global warming take precedence over the urgent problem of poverty, or can they be addressed together?

7. 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. (i) Waste Management, (ii) Water – Meeting the Future Challenges and (iii) Transport – Making it Greener.

March 2014

V. K. Agarwal
Chairman of the Forum

Chapter 1

Introductory / Explanatory Notes

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Chapter 1

Introductory / Explanatory Notes

1.1 Introduction

The Indian National Academy of Engineering (INAE) constituted a INAE Forum on Technology Foresight and Management on Addressing National Challenges (**Forum** in short) in August 2012 having nine Members. 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.

To achieve commonality of approach and to have a common understanding of the various technical terms/issues the available literature was broadly sifted. This Note summarises these discussions. Some of the areas covered 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.

1.2 About the Indian National Academy of Engineering (INAE)

1.2.1 The Indian National Academy of Engineering (INAE) was established in the year 1987-1988 in response to the desire of the **fraternity of engineers, engineer-scientists and technologists** to be a “Peer” organization composed of the best talent from the entire spectrum of engineering in the country and to promote all round excellence.

1.2.2 The Academy provides a Forum for futuristic planning for the Country’s development requiring engineering and technological inputs and brings together specialists as necessary for comprehensive thinking of the needs of the 21st century. It is also concerned with the issues of academic excellence and growth of educational systems. Some of the notable contributions by the Academy are mentioned below:

- Scheme to encourage young talents through the annual “INAE Young Engineer Award”.

- Setting up of **Expert Study Groups on Railways, Metallurgy, and Civil Engineering to create Archives of Indian Engineering Heritage**.

- Institution of “Life Time Contribution” award to honour eminent Indians who have made outstanding contributions in ‘Engineering’.

- The Academy has been recognized as a Scientific and Industrial Research Organization (SIRO) and is an autonomous Institution supported by the Government of India, Department of Science and Technology since 1995.

- Academy has been elected as a Member of the International Council of Academies of Engineering and Technological Sciences (CAETS).

- Mentoring of Engineering Teachers and also of Engineering Students by the Fellows of INAE

- Formation of Tasks Forces to undertake studies on important/topical national issues.

- In order to assist the Government in formulating policies concerning important national issues, the Academy has instituted a **Forum on Engineering Education, a Forum on Microelectronics, and a Forum on Energy**.

- Recently (Aug. 2012) a **INAE Forum on Technology Foresight and Management on Addressing National Challenges has also been constituted**.

1.2.3 Fellowship of the Academy is by invitation and process of election is very rigorous. Every year about two or so Fellows are elected to the Academy in each of the ten Engineering Sections. Brief details about the Fellowship are given below :

1. Total Fellows of INAE are 720 (As on 1st Jan. 2013)

2. **List of Past Presidents of the Academy**

   Prof. Jai Krishna

   Dr. V. S. Arunachalam

Dr. S. Varadarajan

Dr. A.P.J. Abdul Kalam

Prof. P.V. Indiresan

Dr. Anil Kakodkar

Prof. P. Rama Rao

Dr. A. Ramakrishna

Dr. K. Kasturirangan

Dr. P. S. Goel

3. **Some other Notable Fellows**

   Fellows include Dr. R. Chidambaram, Dr. N. R. Narayana Murthy, Mr. Ratan N. Tata, Dr. Sam Pitroda, Dr. E. Sreedharan, Dr. Homi N. Sethna and Mr. R. A. Mashelkar.

4. **Scroll of Honours by GOI – INAE Fellows**

   Fellows include one Bharat Ratna, 14 Padam Vibhushan, 39 Padma Bhushan and 53 Padam Shri awardees.

1.3 INAE's Forum on Technology Foresight and Management for Addressing National Challenges

1.3.1 A INAE Forum on Technology Foresight and Management on Addressing National Challenges has been constituted by the Indian National Academy of Engineering (INAE) in August 2012. 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.

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

1.3.3 The Members of the Forum are as under :

1. **Mr. Vijai Kumar Agarwal**
   Formerly Chairman Railway Board & Ex-officio Principal Secretary, Govt. of India
   Formerly Director Indian Oil Corporation
   Formerly Director Steel Authority of India.

2. **Dr. Yogendra Pal Anand**
   Formerly Chairman Railway Board & Ex-Officio Principal Secretary, Govt. of India
   Formerly Director, National Gandhi Museum, New Delhi.

3. **Prof. Prem Vrat**
   Formerly Director-in-Charge IIT Delhi
   Formerly Founder Director IIT Roorkee
   Formerly Vice-Chancellor UP Technical University, Lucknow
   Currently Vice-Chancellor and Professor of Eminence, ITM University, Gurgaon.

4. **Dr. Chunchu Raghuveera Prasad**
   Formerly CMD, GAIL, New Delhi
   Formerly Chairman, British Gas India Pvt. Ltd., Gurgaon
   Currently CMD, Everest Power Pvt. Ltd., New Delhi.

5. **Mr. Anil Kumar Anand**
   Formerly Director (Reactor projects Group), BARC, Mumbai
   Formerly Scientific Consultant, Academia – Industry Interaction
   Office of PSA to the G.O.I.
   Currently Director Technical – Microtrol Sterilisation Services, Mumbai.

6. **Mr. Kishore Pal Singh**
   Formerly Managing Director RITES, New Delhi
   Formerly Managing Director Tata Projects, Hyderabad.

7. **Mr. Suresh Chandra Gupta**
   Formerly Member Electrical Railway Board & Ex-officio Secretary to GOI.

8. **Mr. Vinoo Narain Mathur**
   Formerly Member Traffic Railway Board & Ex-Officio Secretary to GOI
   Currently M.D. – Bharuch-Dahej Railway Company Ltd.

9. **Mr. Arun Kumar Gupta**
   Formerly Chief Administrative Officer, Diesel Maintenance Works, Patiala
   Formerly Director Oil India Ltd.

1.4 Some Definitions / Explanatory Notes / Points to Ponder

1.4.1 *Think Tank / Forum*

Think Tank

A think tank (or policy institute) is an organization that performs research and advocacy concerning topics such as social policy, political strategy, economics, military, technology, and culture. Most policy institutes are non-profit organizations, which some countries such as the United States and Canada confer tax exempt status. Other think tanks are funded by governments, advocacy groups, or businesses, or derive revenue from consulting or research work related to their projects.

(Source : https://en.wikipedia.org/wiki/Think_tank)

Forum

- The public square or marketplace of an ancient Roman city that was the assembly place for judicial activity and public business.

- A public meeting place for open discussion.

- A medium for open discussion or voicing of ideas, such as a newspaper, a radio or television program, or a website.
- A public meeting or presentation involving a discussion usually among experts and often including audience participation.
- A court of law; a tribunal.

(Source : http://www.thefreedictionary.com/forum)

1.4.2 *Technology Forecasts / Technology Foresight*

Technology Forecasts

Primarily, a technological forecast deals with the characteristics of technology, such as levels of technical performance, like speed of a military aircraft, the power in watts of a particular future engine, the accuracy or precision of a measuring instrument, the number of transistors in a chip in the year 2015, etc. The forecast does not have to state how these characteristics will be achieved.

Secondly, technological forecasting usually deals with only useful machines, procedures or techniques. This is to exclude from the domain of technological forecasting those commodities, services or techniques intended for luxury or amusement.

(Source : http://en.wikipedia.org/wiki/Technology_forecasting)

Technology Foresight

Technology foresight is regarded as the most upstream element of the technology development process. It provides inputs for the formulation of technology policies and strategies that guide the development of the technological infrastructure. In addition, technology foresight provides support to innovation, leading to enhanced competitiveness and growth.

(Source : http://www.waitro.org/)

1.4.3 *Engineering Management / Reengineering / Concurrent Engineering*

Engineering Management

Engineering Management or Management Engineering is a specialized form of management and engineering that is concerned with the application of engineering principles to business practice. Engineering management is a career that brings together the technological problem-solving savvy of engineering and the organizational, administrative, and planning abilities of management in order to oversee complex enterprises from conception to completion.

Reengineering

Reengineering is a management tool that became popular in the late 1980s and early 1990s. Like many such tools, it aims to cut costs while at the same time increasing productivity and providing higher levels of service. And while all this is true, reengineering still offers companies much more. The concept that is at the heart of all reengineering projects is the need to stay competitive in today's business world, and this broad concept involves costs, quality, productivity, and a host of other business elements. All of this is achieved by taking drastic steps to radically change an organization in areas like staffing, technology, and office culture.

Concurrent Engineering

Concurrent engineering is a work methodology based on the parallelization of tasks (i.e. performing tasks concurrently). It refers to an approach used in product development in which functions of design engineering, manufacturing engineering and other functions are integrated to reduce the elapsed time required to bring a new product to the market.

1.4.4 *Growth / Progress / Development*

- Most countries use **Gross Domestic Product (GDP)** to measure the standard of living. Economists, policymakers, international development agencies and even the media use it as an indicator of the economic health of a nation. The advantages offered by GDP are that it is widely and frequently used and its data requirements are readily available. Since the definition is common among countries, consistent comparisons can be made between and among them.

- The countries at the top of the GDP list take the lead in terms of total economic activity taking place within their boundaries. However, it does not necessarily mean that their citizens are better off than the rest of the world in terms of overall well being. For example, a high level of manufacturing and industry related activities (with consequent high toxic emissions) may contribute to a higher GDP but the people will suffer living and working in a polluted environment. Further, certain activities that have a negative impact on the people's well being could end up being recorded as positive contributions to GDP. Take for instance, Crime. Rising criminal activities can increase the country's GDP through greater expenditures towards maintaining law and order (e.g. hiring of additional police force, purchase of guns, prisons, etc.). The GDP is also criticized because it does not take into consideration other aspects that define human well being like life expectancy and educational attainment.

- It is for these reasons that alternative ways of measuring standard of living have emerged. One of these is the **Human Development Index (HDI)** developed by the United Nations. The HDI takes into account the GDP and adds more factors to measure other aspects of human development : knowledge, longevity, and decent standard of living. HDI values range from 0 to 1. The HDI, however, has its own share of critics. Some point out that it is difficult to chart a country's growth using HDI. There are also others who say that HDI does not capture the moral and spiritual aspects of human development. World rankings in GDP and HDI of some selected countries can be seen in Table 1.

Table 1 : GDP & HDI – World Ranking

Country	GDP Rank	HDI Rank
USA	1	4
China	2	101
Japan	3	12
Germany	4	9
France	5	20
Brazil	6	85
UK	7	28
Russia	9	66
India	10	134
Norway	24	1
South Africa	29	123
Bhutan	165	141

Source : IMF (2011) for GDP & UNDP Site for HDI.

- Bhutan has begun to use **Gross National Happiness (GNH)** as a broader and more nuanced measure of national progress than GDP. Bhutan's audacious solution is to build its society from the ground up using what it calls the **"four pillars" of GNH : sustainable economic development, conservation of environment, preservation of culture, and good governance.** Bhutan's happiness experiment has captured the fancy of economist and politicians from Brazil to Britain, Tokyo to Taiwan, who are looking for a new path to free-market prosperity – one that doesn't do so much damage to the environment, social equity and family life. Joseph Stiglitz, a Nobel Prize-winning economist has become world's leading advocate for developing better measures of national well being and he leads an influential Commission funded by the French Government for the purpose. Canadian researchers have created a composite of 64 existing statistics, including work hours and incidence of violent crime, that are considered proxies for various components of well being. (Ref.: Time Magazine – 22nd Oct. 2012)

- The above discussion clearly highlights that even though adequate tools to measure growth/progress/development may not be available but economic growth alone is not enough. **Indian planners are emphasizing 'inclusive growth' which broadly takes into account the aspects of poverty reduction and also of reducing disparities.** Our growth/progress/development model has to necessarily take into account the following three issues/areas besides the economic growth :

  - Sustainable Development

  - Climate Change : Mitigation and adaptation

  - Poverty reduction / Inclusive Growth

  These three issues are fundamentally Engineering issues and the Engineering/Engineers have a paramount responsibility and role to play in these areas.

1.4.5 *Sustainable Economics*

In recent decades an alternative to classical market based economics has emerged and we can call it "sustainable economics". It offers a different way to think economics in the light of our current environmental challenges and apparent failure of classical market economics to meet these challenges. Sustainable economics appeals to the same philosophical values for its justification – utility, freedom, equality – as does classical market economics. It claims, however, to better promote these values, given the current and future environmental reality. The following summarize the current and future challenges in this regard :

(a) A large percentage of the world population today lives in abject poverty. One quarter of the world's population lives in industrialized countries and consumes 80% of the world's goods. The world would, therefore, require significant economic growth during the next few decades just to meet the basic needs of the other 75% of the planet's population.

(b) The world's population during the next 50 years is likely to be doubled and so the economic activity to meet the basic needs of the population will need to increase significantly.

(c) Since the resources for all the economic activity are the natural resources of the earth itself and since the world's environment is already under stress from the current economic activity, the future looks bleak.

Thus, given these realities, we must create an economic system that can provide for the worlds' population without destroying the environment in the process. A typical statement of the goal of sustainable economics, in the words the World Commission on Environment and Development (an agency of U.N.) is to meet the **"needs of the present without compromising the ability of the future generations to meet their own needs".**

The classical economics is governed by the law of supply and demand and this model of economic activity is linear : resources enter one end, allocation decisions are made to produce various goods, and these are then distributed at the other end, in a competitive market place. Sustainable economics is particularly concerned with the rate at which resources flow through the economy. It recognizes that all the factors that go into production – natural resources, capital, and labour – ultimately originate in the productive capacity of the earth. The sustainable economic system will be that which uses resources only at a rate that can be sustained over the long term, and recycles or uses both the by-product of the production process and products themselves.

The "Sustainable Economics" as defined above can also be termed "Ecological Economics" as it has the following features (Ref.:Hay -2009) :

(i) It is a form of economic thought with which the environment movement, in its mainstream, is most comfortable.

(ii) Ecological Economics **not only shifts the focus from micro to macro but also from very short time period to 'deep' time**.

(iii) It complements the relational and synergistic realities of ecology.

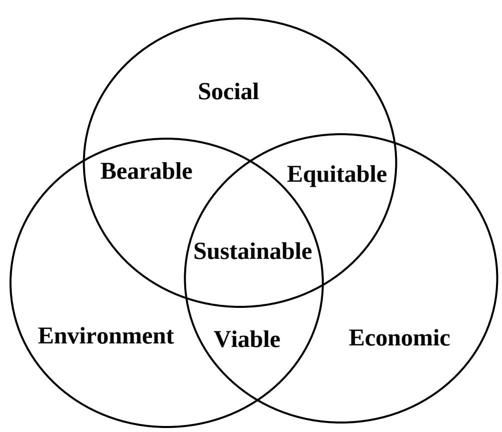
(iv) Such an economics **also incorporates an ethical and visionary dimension**.

1.4.6 *Sustainable Development*

The Brundtland Commission (UN) in their Report (1987) defined sustainable development as "development that meets the needs of the present, without compromising the ability of future generations to meet their own needs". This broad definition however needs further elaboration as detailed below (Ahluwalia – 2012) :

- A triple bottom line perspective, that considers **environmental, economic and social aspects**.
- A time dimension, which incorporates short term to long term, and considers impacts along the lifecycle, including impact on future generations.
- A resource context with respect to scarcity, over-abundance, or potential to disrupt resource availability in the future.

Sustainable development will be possible only when it is recognized that economic growth, social welfare and environmental issues are linked and have to be addressed together, rather than in a fragmented way as practiced currently. The figure below indicates the relationship **among the three pillars of sustainability viz., economic, environmental, and social aspects**.



Three Pillars of Sustainability

1.4.7 *Five E's of Sustainable Development (Agarwal – Jan. 2013)*

If one is asked to choose parameters which can help an individual to perform all his actions/activities, on a sustainable basis, in the best possible manner, the following **Five E's** could be listed :

(i) Efficiency

(ii) Effectiveness

(iii) Ethics : Essential for sustainable performance.

(iv) Environment : Be in tune; Don't damage; Improve, if possible.

(v) Evolution : Create positive impact on the value structure.

Efficiency covers all activities, which make actions efficient and will, interalia, include efficient time management, good physical and mental health, possession of adequate knowledge and skills, will to do the job, positive attitude, doing things right the first time, low stress levels, etc.

Effectiveness will mean that the actions result in achieving useful goals for which it will be essential to have necessary vision, broad idea of goals to be achieved, systems to be followed to reach the goals, necessary co-ordination/co-operation with other individuals/organizations, conscious realization of one's capacity/capability levels etc.

Ethics is essential for sustainable development and performance. It also helps in arriving at solutions, **which are more equitable (concern for Equity).** It reduces stress levels, as ethical paths can be very clearly charted as against the paths which are followed for achieving the goals through unethical means.

Environment has to be seen in a broader context and may include physical environment, working environment, political environment, financial environment and the like. Activities have to be performed keeping these in mind, lest they trigger reactions which may be difficult to control. Further, actions should not damage the Environment rather, improve it to the extent possible.

Actions must support the process of Evolution and Development in the positive direction for all those connected with the activities. Decline in human values can be detrimental to society.

For better performance on a sustainable basis these parameters, i.e., the Five 'Es' are equally relevant to a Group of Individuals (Teams), Activities, Systems, Organizations and even the Nations. Efforts should be directed to continuously improve upon them.

1.4.8 *Environmental Ethics (Ref.: Jardins – 1997)*

Environmental ethics is a systematic account of the moral relations between human beings and their natural environment**. It assumes that moral norms can and do govern human behaviour towards natural world.** A theory of environmental ethics, then, must go on to explain what these norms are, and to whom or to what humans have responsibilities, and to show how these responsibilities are justified. Different theories of environmental ethics offer different answers to these questions.

- Some philosophers argue that our responsibilities to the natural environment are only indirect, that the responsibility to preserve resources, for example, is best understood in terms of the responsibilities that we owe to other humans. **Anthropocentric ("human centered") ethics** holds that only human beings have moral value. Thus, although we may be said to have responsibilities regarding the natural world, we do not have direct responsibilities to the natural world.
- An extension of anthropocentric ethics occurs by considering future generations of human beings as objects of our moral responsibilities. Such an approach basically remains anthropocentric but it extends our responsibilities to include some of the humans who do not yet exist.
- Other philosophers argue that we also have direct responsibilities to natural objects other than human beings. This **Non-anthropocentric ethics** grants moral standing to such natural

objects as animals and plants, and consequently requires further extensions and revisions of standard ethical principles.

- Further development of environmental ethics occurs by shifting from a focus on individual living things to focus on collections or "wholes" such as species, populations, or ecosystems. **Holistic ethics** holds that we have moral responsibilities to collection of individual living things rather than (or in addition to) those individual living things who constitute the whole.
- The **ethics of Deep Ecology** propagated by Arne Naess focuses on two ultimate norms. These norms are ultimate in the sense that they are not derived from any further or more basic principles or values. They are the point at which ethical justification ends. These two ultimate norms of deep ecology are self-realization and bio-centric equality. Self-realization is a process through which people come to understand themselves as existing in a thorough interconnectedness with the rest of nature. Bio-centric equality is the recognition that all organisms and beings are equally members of an interrelated whole and therefore have equal intrinsic worth.

1.4.9 *Climate Change*

- To give a thrust to this vital area **National Action Plan on Climate Change (NAPCC)** has been prepared and was released in June 2008 by the Prime Minister. The **eight core missions** and the Broad Goals of NAPCC can be seen in Box 1.

Box 1 : National Action Plan on Climate Change : Eight Core Missions

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.

- It will be seen that the 'Missions' cover a wide range of aspects including solar technologies, enhanced energy efficiency, technology development and research, fuel economy and efficient transport vehicles, and incentives to use public transport, etc. **However, the benefits which could accrue by modal shift to more environment friendly modes of transport have not been explicitly covered.** This is an area which has a lot of potential as Transport is a major polluter while remaining an essential need of the Economy.

- Since the launch of NAPCC there have been serious efforts to dovetail national programmes of action to regional and local levels consistent with varying socio-economic and ecological considerations. At the Conference of State Environment Ministers on 18th August 2009, the Prime Minister requested all state governments to prepare State Action Plans for Climate Change (SAPCCs). The SAPCCs took their lead from National Mission documents while formulating mitigation / adaptation strategies.

1.4.10 *Science*

- **Science** covers the broad field of knowledge that deals with observed facts and the relationships among those facts.

- Science also differs from other types of knowledge in that scientific progress depends on new ideas expanding or replacing old ones.

- Science has enormous influence on our lives. It provides the basis of much of modern *technology* – the tools, materials, techniques and sources of power that make our lives and work easier. The term *applied science* is sometimes used to refer to scientific research that concentrates on the development of *technology*.

- Scientific study can be divided into four major groups :

  (i) **Mathematics and logic** are not based on experimental testing but they can be considered part of science because they are essential tools in almost all scientific study.

  (ii) **Physical sciences** examine the nature of the universe and include physics, chemistry, geology, astronomy and meteorology.

  (iii) **Life sciences** also called the *biological sciences* or *biology*, involve the study of livings organisms. The two main fields of life sciences are *botany* which deals with plants, and *zoology* which deals with animals.

  (iv) **Social sciences** deal with individuals, groups, and institutions that make up human society. The main branches of social sciences include anthropology, economics, political science, psychology and sociology.

- As scientific knowledge has grown and become increasingly complicated, many new fields of study have emerged, boundaries between scientific fields have become less and less clear cut, and today numerous areas of science overlap. For instance, both chemistry and physics deal with atomic structure, and both paleontology and geology study the age of rocks in the earth.

- In some cases, sciences have come to overlap so much that *interdisciplinary* fields have been established. For example, *biochemistry* combines areas of biology and chemistry in studying chemical processes that occur in living plants and animals.

1.4.11 *Technology*

- **Technology** refers to all the ways people use their inventions and discoveries to satisfy their needs and desires.

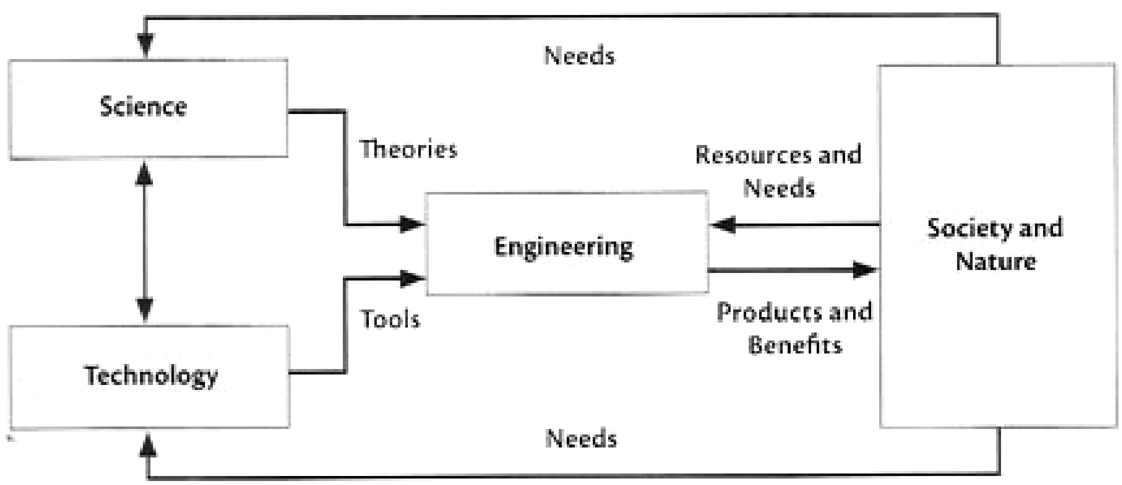
- Technology involves the use of tools, machines, materials, techniques and sources of power to make work easier and more productive.

- **Science has contributed much to modern technology. But not all technology is based on science, nor is science necessary to all technology.**

- The word technology is sometimes used to describe a particular application of industrial technology, such as medical technology or military technology. **The engineering profession is responsible for much of today's industrial technology.**
- It has been mentioned by Dr. A. P. J. Abdul Kalam (2001) that technology includes techniques as well as the machines that may or may not be necessary to apply them. It includes ways to make chemical reactions occur, ways to breed fish, eradicate weeds, light theaters, treat patients, teach history, fight wars or even prevent them.

1.4.12 ***Engineering***

- **Engineering** is the profession that puts scientific knowledge to practical use. The word *engineering* comes from the Latin word *ingeniare*, which means to *design* or to *create*.
- **Engineers** use principles of science to design structures, machines, and products of all kinds. They look for better ways to use existing resources and often develop new materials. **Engineers have had a direct role in the creation of most of modern *technology* – the tools, materials, techniques, and power sources that make our lives easier.**
- The field of engineering includes a wide variety of activities. For example, engineering projects range from the construction of huge dams to the design of tiny electronic circuits. Engineers may help produce guided missiles, industrial robots, or artificial limbs for the physically handicapped. They develop complex scientific equipments to explore the reaches of outer space and the depths of the oceans. Engineers also plan our electric power and water supply systems, and do research to improve automobiles, television sets, and other consumer products. They work to reduce environmental pollution, increase the world's food supply, and make transportation faster and safer.
- Tony Marjoram and Yixin Zhong (UNESCO Report – 2010) diagrammatically depict the role Engineering plays (using 'Theories' from 'Science' and 'Tools' provided by 'Technology') to provide 'Products and Benefits' to 'Society and Nature' keeping in view the 'Resources and Needs'.



- Tony Marjoram and Yixin Zhong (UNESCO Report – 2010) further elaborate **that almost every area of human interest, activity and endeavour has a branch of engineering associated with it.** They also provide an illustrative list of engineering branches mentioning various disciplines / subdisciplines. (See Box 2)

- Unlike earlier periods when resources were in abundance and societal needs low, the current situation is altogether different. The current needs are of a much greater order of magnitude; environmental constraints are dangerously close to being breached; worldwide competition for scarce resources could create international tensions; and the freedom to power our way into the future by burning fossil fuels is denied.

Resolving these issues requires tremendous innovation and ingenuity by Engineers, working alongside other technical and non-technical disciplines. **It requires the engineer's ability to synthesize solutions and not simply their ability to analyze problems.** Further, engineers need the **ability to take a systems view at a range of scales,** from devices and products through to the large-scale delivery of infrastructure services.

- Society today is making ever-greater demands on Engineering, ranging from those caused by exploding urbanization and by the endemic poverty of a quarter of world's population in the face of overall global affluence, to the mounting concerns about availability of critical resources, the consequences of climate change and increasing natural and man-made disasters. This confronts Engineering and Society not only with unprecedented technical challenges, but also with a host of new ethical problems that demand the development of Global Engineering Ethics. How far should Engineering pursue the modifications of Nature? What are Engineerings' roles and responsibilities in Society? How should Engineering address problems of equity in terms of the availability of resources and services of and between current and future generations? Should concerns about global warming take precedence over the urgent problem of poverty, or how can they be addressed together?

- **It is unfortunate that, under these circumstances of growing need for multi-talented Engineers, the interest in Engineering among young people is waning in so many countries. Awareness of the importance and the changing nature of Engineering needs to be raised in circles of Government as well as amongst the general public.**

Box 2 : Illustrative List of Engineering Branches

Agricultural engineering

- Engineering theory and applications in agriculture in such fields as farm machinery, power, bio-energy, farm structures and natural resource materials processing.

Chemical engineering

- Analysis, synthesis and conversion of raw materials into usable commodities.
- Biochemical engineering – biotechnological processes on an industrial scale.

Civil engineering

- Design and construction of physical structures and infrastructure.
- Coastal engineering – design and construction of coastline structures
- Construction engineering – design, creation and management of constructed structures.
- Geo-engineering – proposed Earth climate control to address global warming.
- Geotechnical engineering – behaviour of earth materials and geology.
- Municipal and public works engineering – for water supply, sanitation, waste management, transportation and communication systems, hydrology.
- Ocean engineering – design and construction of offshore structures.
- Structural engineering – design of structures to support or resist loads.
- Earthquake engineering – behaviour of structures subject to seismic loading.
- Transportation engineering – efficient and safe transportation of people and goods.
- Traffic engineering – transportation and planning.
- Wind engineering – analysis of wind and its effects on the built environment.

Computer and systems engineering

- Research, design and development of computer, computer systems and devices.

Electrical engineering and electronic engineering
- Research, design and development of electrical systems and electronic devices.
- Power systems engineering – bringing electricity to people and industry.
- Signal processing – statistical analysis and production of signals, e.g. for mobile phones.

Environment engineering
- Engineering for environmental protection and enhancement.
- Water engineering – planning and development of water resources and hydrology.

Fire protection engineering
- Protecting people and environments from fire and smoke.

Genetic engineering
- Engineering at the biomolecular level for genetic manipulation.

Industrial engineering
- Analysis, design, development and maintenance of industrial systems and processes.

Instrumentation engineering
- Design and development of instruments used to measure and control systems and processes.

Integrated engineering
- Generalist engineering field including civil, mechanical, electrical and chemical engineering.

Maintenance engineering and asset management
- Maintenance of equipment, physical assets and infrastructure.

Manufacturing engineering
- Research, design and planning of manufacturing systems and processes.
- Component engineering – assuring availability of parts in manufacturing processes.

Materials engineering
- Research, design, development and use of materials such as ceramics and nanoparticles.
- Ceramic engineering – theory and processing of oxide and non-oxide ceramics.
- Textile engineering – the manufacturing and processing of fabrics.

Mechanical engineering
- Research, design and development of physical or mechanical systems such as engines.
- Automotive engineering – design and construction of terrestrial vehicles.
- Aerospace engineering – design of aircraft, spacecraft and air vehicles.
- Biomechanical engineering – design of systems and devices such as artificial limbs.

Mechatronics
- Combination of mechanical, electrical and software engineering for automation systems.

Medical and biomedical engineering
- Increasing use of engineering and technology in medicine and the biological sciences in such areas as monitoring, artificial limbs, medical robotics.

Military engineering
- Design and development of weapons and defence systems.

Mining engineering
- Exploration, extraction and processing of raw materials from the earth.

Naval engineering and architecture
- o Research, design, construction and repair of marine vessels.

Nanotechnology and nanoengineering
- o New branch of engineering on the nanoscale.

Nuclear engineering
- o Research, design and development of nuclear processes and technology.

Production engineeing
- o Research and design of production systems and processes related to manufacturing engineering,

Software engineering
- o Research, design and development of computer software systems and programming.

Sustainable engineering
- o Developing branch of engineering focusing on sustainability and climate change mitigation.

Test Engineering
- o Engineering validation and verification of design, production and use of objects under test.

Transport Engineering
- o Engineering relating to roads, railways, waterways, ports, harbours, airports, gas transmission and distribution, pipelines and so on, and associated works.

Tribology
- o Study of interacting surfaces in relative motion including friction, lubrication and wear.

1.4.13 *Innovation*

Innovation is increasingly going beyond the confines of formal R&D. Today innovation can mean new and unique applications of new technologies, using designs to develop new products and services, new processes and structures to improve performance in diverse areas, organisational creativity, and public sector initiatives to enhance delivery of services. **Innovation is being seen as a means of creating sustainable and cost effective solutions for people at the bottom of the pyramid, and is being viewed as an important strategy for inclusive growth in developing countries.**

The National Innovation Council (NIC) under the Chairmanship of Mr. Sam Pitroda, Advisor to the PM on Public Information Infrastructure and Innovation (PIII) is preparing a road map for Innovation 2010-2020. The NIC will act as a platform to facilitate the engagement and collaboration of domain experts, stakeholders and key participants to create an innovation movement in India. The aim is to herald a mindset change and create a push at the grassroot level so that more and more people in education, business, government, NGOs, urban and rural development engaged in innovative activities are co-opted and become part of shaping the national level innovation policy.

Since greater role and involvement of people at the bottom of the pyramid is contemplated, the role of Engineers becomes even more relevant in the Innovation process.

1.4.14 *Gandhian Engineering : More from Less for More (MLM)*

- Dr. R. A. Mashelkar in his Lifetime Contribution Award Lecture 2012 (INAE – April 2013) mentions two tenets propounded by Mahatma Gandhi :

  (i) ‘I would prize every invention of science made for the benefit of all’.

  (ii) ‘Earth provides enough to satisfy every man’s need but not every man’s greed’.

He further elaborates that the first tenet refers to affordability and the second tenet to sustainability.

- He explains that industrial enterprises strive for getting more (performance) from less (resource) for more (profit) but the Gandhian Engineering has a different message. It means getting more (performance) from less (resource) for more (people), not just for more (profit).

- Getting More from Less for More (MLM) strategy forces us to measure an opportunity by the ends of innovation – what people actually get to enjoy – as opposed to just an increase in their means. In important ways, this rationale invokes a return to the traditional case for innovation – its ability to produce breakthrough improvements in the quality of life – alongside the usual objective of competitiveness.

- The objectives of MLM type of innovations would not be just to produce low performance, cheap, knock-off versions of rich country technologies so that they can be marketed to poor people. Rather, the objective is to harness sophisticated science and technology know-how to invent, design, produce and distribute high performance technologies at prices that can be afforded by majority of people.

- Gandhian Engineering is all about getting more from less for more people – this MLM way of innovations is anchored on the solid foundation of affordability and sustainability. It will create a more equitable society and will also help us in designing a sustainable future.

1.4.15 *The Great Age of Engineering ? (Ref.: UNESCO Report – 2010)*

It's easy to think, from the Western perspective, that the great days of engineering were in the past during the era of massive mechanization and urbanization that has its heyday in the nineteenth century and which took the early Industrial Revolution from the eighteenth century right through into the twentieth century which, incidentally, simultaneously improved the health and well-being of the common person with improvements in water supply and sanitation. That era of great engineering enjoyed two advantages: seemingly unlimited sources of power, coal, oil and gas, and a world environment of apparently boundless capacity in terms of water supply, materials and other resources relative to human need.

Now we know differently. We face two issues of truly global proportions – climate change and poverty reduction. The tasks confronting engineers of the twenty-first century are :

- Engineering the world to avert an environmental crisis caused in part by earlier generations in terms of energy use, greenhouse gas emissions and their contribution to climate change, and

- Engineering the large proportion of the world's increasing population out of poverty, and the associated problems encapsulated by the UN Millennium Development Goals.

This will require a combination of re-engineering existing infrastructure together with the provision of first-time infrastructure at a global scale.

And the difference between now and the nineteenth century? This time the scale of the problem is at a greater order of magnitude; environmental constraints are dangerously close to being breached; worldwide competition for scarce resources could create international tensions; and the freedom to power our way into the future by burning fossil fuels is denied.

Resolving these issues will require tremendous innovation and ingenuity by engineers, working alongside other technical and non-technical disciplines. **It requires the engineer's ability to synthesize solutions and not simply their ability to analyze problems. It needs the engineers' ability to take a systems view at a range of scales, from devices and products through to the large-scale delivery of infrastructure services.**

This means that the great age of engineering is NOW.

1.4.16 *Role of Technology*

- Many thinkers believe that environmental problems center on technological problems and solutions. This view claims that we are victims of our success. We suffer from environmental problems because we have become rich and mobile so quickly that we have overwhelmed the technological systems that enabled these successes to occur. When few people had automobiles it did not matter very much that they were highly polluting. When everyone has an automobile it creates an environmental problem. This kind of story can be told for many environmental problems.

  The solution appears to be to do a new round of technological development. Previous generation of technologies were developed to solve problems and reduce labour in a world in which environmental costs were not significant. Now that they are important, **a new generation of technology is needed that performs these labour saving functions but with much greater sensitivity to the environment.**

  Technological approaches are popular both with the politicians and with the public because they promise solutions to environmental problems without forcing to change values, way of life, or economic systems. However, the situation is rather vague about what these new technologies should be or what they might actually accomplish.

- It has been mentioned by Collier (2010) that Technology can turn Nature into an asset by giving these natural assets the potential to become valuable to the society. However, for natural assets to be valuable instead of being dissipated in competitive struggle, their ownership and use must be regulated. **Regulation requires good governance**. Unregulated use of Technology can turn Nature nasty; the Technology that has given us cheap energy has also given us carbon-dioxide that will over-heat the Planet. The challenge of harnessing Nature has been summarised by him as under :

  (a) NATURE + TECHNOLOGY + REGULATION = PROSPERITY

  (b) NATURE + TECHNOLOGY - REGULATION = PLUNDER

  (c) NATURE - TECHNOLOGY + REGULATION = POVERTY

- In his Book “Ten Technologies to Save the Planet”, Goodall (2008) shows considerable optimism and mentions that each of the ten Chapters of the Book looks at a technology or technique that could reduce carbondioxide emissions by atleast 10 per cent of the annual world total. All these technologies are comfortably within our scientific and technological reach and so the Author argues that we should be able to ‘decarbonise the economy’ at an affordable price. The Ten Technologies mentioned are :

  - **Capturing the Wind**
  - **Solar Energy** : The sunlight hitting the earth’s surface every day contains around 7,000 times more energy than the fossil fuels that humanity consumes.
  - **Electricity from the Oceans** : Tapping tides, waves and currents.
  - **Combined Heat and Power (CHP)** : (i) Use of fuel cells powered by hydrogen created from renewable sources for individual buildings, and (ii) Use of small power stations close to homes or offices fired by wood or other biomass and piping the ‘waste’ heat to where it is needed.
  - **Super-efficient Homes**

- **Electric Cars**
- **Motor Fuels from Cellulose** : Second-generation biofuels.
- **Capturing Carbon** : Clean coal, algae and scrubbing the air.
- **Biochar** : Sequestering carbon as charcoal.
- **Soil and Forests** : Improving the planet's carbon sinks.

The importance of Soil Carbon has been especially highlighted as warming of planet can trigger speeding up the pace of climate change (See Box 3).

Box 3 : Importance of Soil Carbon

Goodall (2008) mentions that we generally focus too much attention on the carbon dioxide in the atmosphere. The world's soils hold more carbon than the atmosphere, trees and plants put together. The thin layer of soil which covers much of the earth's surface, but is rarely more than a metre thick, produces a very large fraction of our food and sustains life.

Where is the world's carbon?

Plants and trees	***600 billion tonnes***
Atmosphere	***800 billion tonnes***
Organic carbon in the soil	***1,600 billion tonnes***
Fossil fuels in the ground	***4,000 billion tonnes***
Oceans	***40,000 billion tonnes***

And for comparison:

Carbon added annually to the atmosphere from fossil fuels	***8 billion tonnes***

The location of world's carbon is not static. Carbon in its various forms moves from soil to air to plant and also in the reverse direction all the time. The amount of carbon – usually in the form of carbon dioxide – flowing in and out of soils in the natural cycle is perhaps ten or twenty times the volume put in the atmosphere by the burning of fossil fuels. In other words, we don't have to disrupt this cycle by a large percentage in order to achieve real reductions to the amount of carbon dioxide ending up in the atmosphere.

One further comparison should strike us forcefully. The weight of carbon in the soils is about 1,600 billion tonnes. Mankind's actions produce about 8 billion tonnes of carbon in greenhouse gases every year, of which about half is added to the atmosphere (causing climate change), with the rest absorbed by oceans, plants and soil. **As the planet warms, one side-effect could be a small annual reduction in the soil's ability to retain carbon. As temperatures rise, many chemical reactions in the soil will speed up, meaning that carbon dioxide, an important end-product of many of these reactions, will tend to escape more rapidly back into the atmosphere. This is one of the many 'tipping points' that may threaten to produce a speeding up in the pace of climate change.**

- While discussing "smart energy" Piccioni (2010) cites Einstein's most famous equation $E=mc^2$ 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 2 will indicate the current huge resource use (and consequent pollution) vis-à-vis the position if we are able to use hydrogen fusion.

Table 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

Sun uses hydrogen fusion to generate energy. Our research activities must be directed with a much greater vigour to use the energy from the Sun and also towards generating energy from 'hydrogen fusion'.

1.4.17 ***Promising approaches that are good for Farmers and good for the Environment (Ref.: World Development Report 2010)***

- **Promising Practices**

  Cultivation practices such as zero-tillage (which involves injecting seeds directly into the soil instead of sowing on ploughed fields) combined with residue management and proper fertilizer use can help to preserve soil moisture, maximize water infiltration, increase carbon storage, maximize nutrient run-off, and raise yields. Now being used on about 2 percent of global arable land, this practice is likely to expand.

- **Promising Technologies**

  Precision agriculture techniques for targeted, optimally timed application of the minimum necessary fertilizer and water could help the intensive, high-input farms to reduce emissions and nutrient runoff, and increase water use efficiency.

  New technologies that limit emissions of gaseous nitrogen include controlled-release nitrogen through the deep placement of supergranules of fertilizer or addition of biological inhibitors to fertilizers.

  Remote sensing technologies for communicating precise information about soil moisture and irrigation needs can eliminate unnecessary application of water.

- **Learning from the Past**

  A technology used by indigenous peoples in the Amazon rain forest **could sequester carbon on a huge scale while improving soil productivity**. Burning wet crop residues or manure (biomass) at low temperatures in the almost complete absence of oxygen produces biochar, a charcoal-type solid with a very high carbon content. Biochar is highly stable in soil, locking in the carbon that would otherwise be released by simply burning the biomass or allowing it to decompose.

1.4.18 ***Project Management***

- While we can boast of our 'Planning' abilities but our 'Execution' record on most fronts has been below par and Project execution is no exception. Project Management today is no longer an issue concerned only with Planning, Scheduling, Estimating and Cost Control but several other issues and processes have got integrated with it like Total Quality Management, Concurrent Engineering, Risk Managemnt, etc.(See Box 4)

Box 4 : Project Management

(A) In his Book titled "Project Management", Dr. Harold Kerzner addresses the various issues / problems concerning the Project Management in detail. Dr. Harold Kerzner is an eminent engineer / manager and has very wide experience. He is / was President of the International Project Management Association (IPMA) and the Book under reference is in its Eight Edition and thus clearly testifies the experiential learning on which it is based. Some of the observations of Dr. Kerzner are mentioned below which indicate the changing trends and the increasing need of integration with other related disciplines in this vital area of Project Management :

1. In the 1980s, we believed that the failure of the project was largely a quantitative failure due to :

    - Ineffective planning
    - Ineffective scheduling
    - Ineffective estimating
    - Ineffective cost control
    - Project objectives being 'Moving Targets'

2. During the 1990s, we changed our views of failure from being quantitatively oriented to qualitatively oriented. A failure in the 1990s was largely attributed to :

    - Poor morale
    - Poor motivation
    - Poor human relations
    - Poor productivity
    - No employee commitment
    - No functional commitment
    - Delays in problem solving
    - Too many unresolved policy issues
    - Conflicting priorities between executives, line managers and project managers

3. During the 1990s, the following processes were integrated into a single methodology:

    - Project Management
    - Total Quality Management
    - Concurrent Engineering : The process of performing work in parallel rather than in series in order to compress the schedule without incurring serious risks
    - Scope Change Control
    - Risk Management

4. In coming years, companies can be expected to integrate more of their business processes in the Project Management methodology like :

    - Supply Chain Management
    - Business Processes
    - Feasibility Studies
    - Cost Benefit Analysis (ROI)
    - Capital Budgeting

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(B) In any Project organisation there are 'class or prestige' gaps between various levels of management. There are also functional gaps between working units (Departments) of the organisation. If we superimpose the management gaps on top of the functional gaps we will find that the Project organisations are made up of small operational islands. For effective and purposeful communication between these operational island systems are necessary (see figure – Why systems are necessary?)

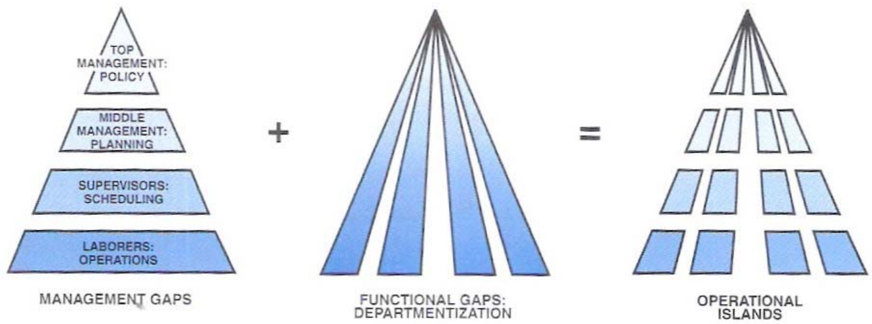

Fig.: Why are Systems necessary?

Ref.: Kerzner, Harold : "Project Management – A Systems Approach" – John Wiley (2003).

- Design and implementation of engineering projects takes care of the **objectives** but not of the **consequences**. To give examples :

  - Water-logging following irrigation as well as depletion of ground water.
  - Insanitation following water supply.
  - Traffic jams following boost to automobile industry.
  - Dry patches in rivers following a hydropower project.

  This is an area which is mostly neglected resulting in below par performance of the executed projects, needing additional inputs to correct the matters.

- Further, so long as there will be persons who have authority but little responsibility and persons who have responsibility with little authority, development will be either distorted or stunted. We must envision a governance in which authority and responsibility are commensurate with each other. **This highlights the need for having competent Engineer-Managers for successful execution of Projects from conception to completion.**

1.4.19 ***Technology Foresight needs People with T-Shaped Skill Profiles (Ref.: UNESCO Report – 2010)***

- **Futures studies have been with us for a long time, but the term 'foresight' has only come into wide use in recent years.** A striking development in the last decade of the twentieth century was the growing prominence of large scale foresight exercises conducted at national and international levels. This trend was amplified in the new millennium. **These exercises**, usually funded by governments and intended to provide insights for innovation policy, priorities for research and development funding, and the like, **frequently went by the name 'Technology Foresight'.**

- Several factors converged to foreground foresight. **First** was the need to prioritize research budgets – choices needed to be made as to where to invest, as governments were not able to continue funding across the whole spectrum. **Second, there were growing concerns about the implications of science and technology and how to shape development so that new technologies could prove more socially and environmentally beneficial.** A **third set of**

factors concern innovation. Innovation has come to be recognized as a key element in competitiveness, national performance and achieving socio-economic objectives.

- One lesson learned early on during Foresight exercises was that it was important to bring together expertise in social affairs, business management, financial issues and policy together with expertise possessed by scientists and engineers.

- What was proved to be at a premium is the capability to possess (and share) highly specialized knowledge but also to be able to relate this understanding to the issues raised in a wide range of other fields : people with T-shaped profiles (people with in depth knowledge of their own domain as well as competence in a much broader spectrum of managerial, interpersonal and other skills). Additionally, foresight required open minded people.

1.4.20 *Improving the 'Image' and 'Role' of Engineering (Ref.: Agarwal – 2013)*

The Government/Society must recognize the Role which Engineering/Engineers are playing in Development and should take adequate steps to suitably empower them. In this direction, following are suggested :

1. Boundaries between Science, Technology and Engineering have to be made more explicit. **Engineering should no longer be the 'Unsung Partner of Science'.**

2. The scope of the present 'Science and Technology Policy' of the Government of India (currently there is no Engineering Policy) has to expand to include 'Engineering' also or else a separate 'Engineering Policy' needs to be developed.

   A more holistic view of science and technology needs to be taken, better integrating engineering into the rather narrow linear model focusing on basic sciences, research and development. To do this, we need to emphasise the way engineering, science, and technology contribute to social and economic development, promote sustainable livelihoods, and help mitigate and adapt to climate change. We also need a better integration of engineering issues into science and technology policy and planning, and of engineering, science, and technology considerations into development policy and planning, in order to reflect a more useful, beneficial and accurate position of reality. This apparently difficult task might best be achieved by taking a more cross-cutting and holistic approach, with greater reference to the important role of engineering, science, technology, and innovation in economic and social development, poverty reduction and climate change mitigation and adaptation.

3. There is a need to have an 'Engineering Advisor' to the Govt. of India on the lines of the present 'Scientific Advisor'.

4. To have Engineers in Government who have direct contact with the ground realities in the States and who come to the Centre for short stints to get an overall National View and also share their Field experience from their respective States, **there is need to have an 'Indian Engineering Service' which should be an All-India Service on the patterns of IAS, IPS & IFS.** Formation of such a Service will not only send a signal about the importance of the role of Engineering/Engineers which the Government acknowledges but will also enhance Inter-State cooperation in this vital field of Engineering. More talented Engineers from diverse States joining the proposed "Indian Engineering Service" will also help in National/Technological integration.

5. Various Institutions and others should project the important role which Engineering/Engineers are playing/have to play in Development to educate the Public. **This will enhance the Public image of Engineering and will also result in better public support for related Projects in addition to attracting better talent to the Profession.**

1.5 Challenges & Risks

1.5.1 *Major Challenges of the 21st Century*

According to Sachs (2008), the defining challenge of the twenty-first century will be to face the reality that humanity shares a common fate on a crowded planet. This common fate will require new forms of global cooperation. While the challenge of the twentieth century was to handle a divided world, the challenge of the twenty-first century will be to handle an inter-dependent world.

In the last seventy-five years, most successful countries have gradually come to understand that their own citizens share a common fate, requiring the active role of government to ensure that every citizen has the chance and means to participate productively within the society, and to curb society's dangerous encroachments on the physical environment. Sachs (2008) observes that the challenges of sustainable development – protecting the environment, stabilizing the world population, narrowing the gaps between the rich and the poor, and ending extreme poverty – will need global cooperation. To find the way peacefully through these difficulties, we will have to learn, on a global scale, the same core lessons that successful societies have gradually and grudgingly learnt within their own national borders.

Four goals have been suggested by Sachs (2008) to overcome these challenges of sustainable development :

- Sustainable systems of energy, land, and resource use that avert the most dangerous trends of climate change, species extinction, and destruction of ecosystems.
- Stabilization of the world population at eight billion or below by 2050 through a voluntary reduction of fertility rates.
- The end of extreme poverty by 2025 and improved economic security within the rich countries as well.
- A new approach to global problem solving based on cooperation among nations and the dynamism and creativity of the non-governmental sector.

Attaining these goals on a global scale may seem impossible. Yet there is nothing inherent in global politics, technology, or the sheer availability of resources on the planet to prevent us from doing so. We need agreements at the global level and attitudes throughout the world that are compatible with meeting the global challenges.

1.5.2 *Climate Change as a Security Risk*

The core message of WBGU's (German Advisory Council on Global Change – 2008/2009) risk analysis is that without resolute counteraction, climate change will overstretch many societies adaptive capacities within the coming decades. This could result in destabilisation and violence, jeopardising natural and international security. However, climate change could also unite the international community, provided that it recognises climate change as a threat to humankind and soon sets the course for avoidance of dangerous anthropogenic climate change by adopting a dynamic and globally coordinated climate policy. If it fails to do so, climate change will draw ever-deeper lines of divisions and conflict in international relations, triggering numerous conflicts between and within countries over the distribution of resources, especially water and land, over the management of migration, or over compensation payments between the countries mainly responsible for climate change and those countries most affected by its destructive effects.

The WBGU identifies four conflict constellations in which critical developments can be anticipated as a result of climate change. "Conflict Constellations" are defined as typical causal linkages at the interface of environment and society, whose dynamics can lead to social destabilisation and, in the end, to violence. These Conflict Constellations are :

(i) Climate induced degradation of fresh water resources.

(ii) Climate induced decline in food production.

(iii) Climate induced increase in storm and flood disasters.

(iv) Environmentally induced migration.

1.5.3 ***Global Risks 2013***

- The World Economic Forums' Global Risks Report 2013 has been developed from an annual survey of over 1,000 experts from industry, government, academia and civil society who were asked to rate landscape of 50 global risks. These fifty global risks comprise of Economic, Environmental, Geo-Political, Societal and Technological risks. By their very nature global risks do not respect national borders. To give examples :

  (i) Extreme weather events exacerbated by climate change will not limit their effects to countries that are major greenhouse gas emitters.

  (ii) False information posted on social networks can spread like wildfire to the other side of the globe in a matter of milliseconds.

  (iii) Genes that make bacteria resistant to our strongest antibiotics can hitch a ride with patients on an international flight.

  The above amply demonstrate the international and interdependent nature of such global risks and a compelling need for a stronger cross-border collaboration among stakeholders from governments, business and civil society. **Further, while we can map and describe global risks we cannot predict when and how they will manifest, and so building national resilience to global risks is of paramount importance.**

- The World Economic Forums' Global Risks Report 2013 mentions the following **Top Five Risks by Likelihood** :

  (i) Severe income disparity

  (ii) Chronic fiscal imbalances

  (iii) Rising greenhouse gas emissions

  (iv) Water supply crisis

  (v) Mismanagement of population aging

- The World Economic Forums' Global Risks Report 2013 mentions the following **Top Five Risks in terms of Impact** :

  (a) Major systemic financial failure.

  (b) Water supply crisis.

(c) Chronic fiscal imbalance.

(d) Food shortage crisis.

(e) Diffusion of weapons of mass destruction.

1.5.4 ***US National Academy of Engineering : Grand Challenges (Ref.: UNESCO Report 2010)***

- **Make solar energy economical**
- **Provide energy from fusion**
- **Develop carbon sequestration methods**
- Manage the nitrogen cycle
- **Provide access to clean water**
- **Restore and improve urban infrastructure**
- **Advance health informatics**
- **Engineer better medicines**
- Reverse-engineer the brain
- Prevent nuclear terror
- Secure cyberspace
- Enhance virtual reality
- Advance personalized learning
- Engineer the tools of scientific discovery

1.5.5 ***INAE Vision 2037***

A Committee consisting of Prof. Prem Krishna, Dr. K. V. Raghavan, Prof. C. V. R. Murthy, Dr. Aloknath De, Prof. Arun Kumar De and Prof. S. C. Dutta Roy is working on a project to prepare a document titled 'INAE Vision 2037'. While the Nation is poised to achieve a higher growth profile in the coming years, there are numerous concerns for the Indian engineering community, particularly with respect to environmental sustainability, long term security issues, education, energy, housing, water resources, food, industrial production and public utility infrastructure. The INAE would naturally be expected to play a major role in achieving the various Engineering goals of the Country. The 'INAE Vision 2037' document tries to envision the state of Indian Engineering during the coming years to enable INAE to chalk out priorities for its activities.

1.5.6 ***United Nation's Millennium Development Goals***

The **UN Millennium Development Goals (MDGs)** and their progress can be seen in Box 5. The global community is now working on a set of **Sustainable Development Goals (SDGs)** with an effort to integrate them with the MDGs.

Box 5 : United Nation's Millennium Development Goals

S. No.	Details of MDGs	Position as on April 2010
MDG 1	**Eradicate Extreme Poverty & Hunger** Halve, between 1990 and 2015, the proportion of people whose income is less than $1 a day. Achieve full and productive employment and decent work for all, including women and young people. Halve, between 1990 and 2015, the proportion of people who suffer from hunger.	In 2005, 1.4 billion people, or one quarter of the population of the developing world, lived below the international poverty line, on less than $1.25 a day in 2005 prices. In 1990, there were 1.8 billion poor. Globally, the number of hungry people rose from 842 million in 1990-92 to 1.02 billion people in 2009.
MDG 2	**Achieve Universal Primary Education** Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling	In the developing regions, net enrolment in primary education reached 88% in 2007, up from 83% in 2000.
MDG 3	**Promote Gender Equality And Empower Women** Eliminate gender disparity in primary and secondary education, preferably by 2005, and in all levels of education no later than 2015	The gender gap in primary school enrolment has narrowed to over 95 girls for every 100 boys in developing countries, a 4 percentage point improvement since 1999. Women's share of national parliamentary seats increased to 19% in 2009, a 6 percentage point improvement since 1999.
MDG 4	**Reduce Child Mortality** Reduce by two thirds, between 1990 and 2015, the under-five mortality rate	In the developing regions as a whole, the under-five mortality rate decreased from 99 deaths per thousand live births in 1990 to 72 in 2008. This corresponds to a 28% decline, well short of the target of a two-thirds reduction.
MDG 5	**Improve Maternal Health** Reduce by three quarters the maternal mortality ratio Achieve universal access to reproductive health	In developing regions, maternal mortality has declined only marginally, from 480 deaths per 100,000 live births in 1990 to 450 per 100,000 live births in 2005. The proportion of births attended by skilled health workers in developing regions increased from 53% in 1990 to 61% in 2007.

MDG 6	**Combat HIV/Aids, Malaria And Other Diseases**	
	Have halted by 2015 and begun to reverse the spread of HIV/AIDS Achieve, by 2010, universal access to treatment for HIV/AIDS for all those who need it Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases	Globally, the new HIV infection rate decreased from an estimated peak of 3.5 million in 1996 to 2.7 million in 2008, a decline of 30%. The estimated number of AIDS-related deaths appears to have peaked in 2005 at 2.2 million. It has since decreased to 2 million in 2008. 31% of African households owned an anti-malaria insecticide-treated net in 2008, a 14 percentage point increase since 2006.
MDG 7	**Environmental Sustainability**	
	Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation By 2020, to have achieved a significant improvement in the lives of at least 100 million slum dwellers	The world is on track to achieve the safe water target. Yet, 884 million people worldwide still use unimproved water sources. In 2006, 2.5 billion people — more than 37% of the world's population — did not have access to toilets, latrines or other forms of improved sanitation. 1.2 billion people in the world practice open defecation, posing enormous health hazards to entire communities – 87% of these people are in rural areas.
MDG 8	**Global Partnership**	
	Develop further an open, rule-based, predictable, non-discriminatory trading and financial system Address the special needs of least developed countries, landlocked countries and small island developing states Deal comprehensively with developing countries' debt In cooperation with pharmaceutical companies, provide access to affordable essential drugs in developing countries In cooperation with the private sector, make available benefits of new technologies, especially ICTs	

Source : UN Department of Public Information – Updated April 2010.

1.6 Action Plan of the Group – Challenges taken up for Study

1.6.1 After discussions, the Forum Members selected the following five National Challenges for detailed study / examination with a view to foresee the needed futuristic technologies and to evolve suitable engineering management solutions. This was to be done keeping in focus the aspects of sustainable development, climate change, and poverty-reduction / inclusive growth.

1.6.1.1 Energy – Major thrust on Solar

Energy is fundamental to growth and economic progress. Dr. Michio Kaku in his book 'Physics of the Future (2011)' highlights the role of Energy by quoting novelist Jerry Pournelle as under :

> "Food and pollution are not primary problems : they are energy problems. Given sufficient energy we can produce as much food as we like, if need be, by high-intensity means such as hydroponics and greenhouses. Pollution is similar : given enough energy, pollutants can be transformed into manageable products; if need be, disassembled into their constituent products."

While the energy sector is vital for development, its emissions are large and growing. The two major sectors of 'electricity' and 'transport' together account for over 78% (65% from electricity +13% from transport) of energy related emissions in India. Growing energy needs for growth / development (about 3-4 times the current levels in next 25 years) and growing concerns about the rising Green House Gas (GHG) emissions point toward renewable options like solar energy, hydropower, wind power, etc.

The Integrated Energy Policy (2006) of the GOI indicates a potential of 1200 Mtoe each for the Solar – Photovoltaic and Solar – Thermal in our country, i.e., a total of 2400 Mtoe. When seen in the backdrop of current Total Primary Energy requirement of 600-650 Mtoe the Solar Power has the potential to meet even the future Energy needs.

The Forum Members felt that with the increasing costs of the fossil fuel based power supply (besides the pollution aspect) and reducing costs of the Solar Power (especially the Solar –Photovoltaic) and in view of its huge potential in our Country the Solar Power option needed much greater thrust even beyond the targets as fixed in Jawaharlal Nehru National Solar Mission (JNNSM). But here one major problem is (besides the need for making Solar Power commercially viable) the need for 'Storage' of energy during day hours for use in other periods. This becomes particularly relevant if the Solar Power has to find a dominant place in the energy mix. Various options and technologies were accordingly to be examined for giving a major thrust to Solar Power.

1.6.1.2 Waste Management

A 'waste' is 'a resource remaining unutilised' or 'a resource out of place'. Waste has critical socio-economic-health-environmental implications and the efficient / effective management of waste is the hallmark of a sustainable society / system. Growing resource and environmental constraints are making the need for waste management even more important / relevant. Minimization of waste generation (prevention / reduction), optimal waste recovery (reuse/recycling) and the effective waste treatment and disposal are the need of the hour. Suitable waste-to-energy (WTE) approaches also need to be explored. The Forum was to examine the matter holistically to suggest suitable technological / managerial / legal / regulatory measures.

1.6.1.3 Agriculture – Waste reduction and its Use

Our country does not fare well in terms of agricultural yields or productivity. Further, there are wide yield gaps among various crops across the country. Improvements in yields and reduced wastage of foodgrains hold the key for India to remain self-sufficient on food front. Further, sustainable agricultural strategy needs that concerns about land and water degradation due to soil erosion, soil salinity, water-logging, excessive application of nutrients, and over exploitation of water resources are adequately addressed. The Technology Foresight and Management exercise in addition to suitably addressing the issues concerning the Energy-Water-Food nexus was to concentrate on reducing the agriculture related wastes and also on their effective utilisation.

1.6.1.4 Water – Meeting the Future Challenges

Access to water and sanitation at an affordable price has to be recognized as the basic right of all human beings. The World Economic Forum in their latest Report (2013) have identified Water Supply crisis as one of the top five global societal risks both in terms of 'likelihood' and 'impact'. Water scarcity already affects more than 40% of the world population. Even though water is seemingly abundant (70% of Earth's surface is covered with water) but the real issue is the availability of fresh water suitable for human use which is less than 1% of the Earth's available water. The Forum was to examine the matter in depth to suggest suitable Technological / Engineering Management solutions for improved availability / accessibility of water suitable for drinking (both for urban and rural areas) as also for irrigation purposes.

1.6.1.5 Transport – Making it Greener

The vision for transport is to be guided by a modal mix that will lead to an efficient, sustainable, economical, safe, reliable, environment-friendly, and regionally balanced transport system. More than 90% of the traffic in our country is carried by Road/Rail. The Rail is 4-6 times fuel efficient vis-à-vis Road and uses lesser land. However, since 1950-51 the market share for Rail in Freight traffic has fallen from 89% to 30% and for the Passenger traffic from 69% to 15%. Efforts to improve the share of environmental-friendly transport mode viz., the Rail have not made the necessary dent. In addition, Water transport even though currently carrying about 5% traffic has also not received the required thrust even though it is more or less similar to Rail from environmental considerations. The Forum was to study and address these and other related issues including the aspects of fuel efficiency / reduced pollution of various transport modes to suggest suitable technologies to make the transport system Greener using appropriate engineering management techniques.

1.6.2 Each Challenge / Area was to be covered in a separate Chapter giving broad details of the overall situation and then giving specific details of the line of action suggested by the Forum. Once the Chapter details were finalized, a brief synopsis was to be made for each Challenge / Area also highlighting the suggested plan for action.

1.6.3 For each Challenge / Area Sub-groups were formed for speedy and directed action as detailed below :

1.	***Energy – Major Thrust on Solar***	Mr. S. C. Gupta / Dr. Y. P. Anand / Prof. Prem Vrat
2.	***Waste Management***	Dr. Y. P. Anand / Prof. Prem Vrat
3.	***Agriculture – Waste Reduction and its Use***	Mr. Anil Kumar Anand / Dr. C. R. Prasad
4.	***Water – Meeting the Future Challenges***	Mr. K. P. Singh / Mr. A. K. Gupta
5.	***Transport – Making it Greener***	Mr. V. K. Agarwal / Mr. V. N. Mathur

1.6.4 The Forum Members felt that there was need for more inputs / study for the following two Challenges / Areas :

(i) Energy – Major Thrust on Solar

(ii) Agriculture – Waste Reduction and its Use

It was, therefore, decided to publish the suggestions / recommendations of the Forum for the balance three Challenges / Areas and **the current Report has four Chapters including one "Introductory / Explanatory Notes" as detailed below** :

Chapter	Title	Coordination by
1.	Introductory / Explanatory Notes	Mr. V. K. Agarwal
2.	Waste Management	Dr. Y. P. Anand / Prof. Prem Vrat
3.	Water – Meeting the Future Challenges	Mr. K. P. Singh / Mr. A. K. Gupta
4.	Transport – Making it Greener	Mr. V. K. Agarwal / Mr. V. N. Mathur

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Some Quotations

- Scientists investigate that which already is; Engineers create that which has never been. - Albert Einstein
- Make everything as simple as possible, but not simpler. - Albert Einstein
- Learn from yesterday, live for today, hope for tomorrow. The important thing is not to stop questioning. - Albert Einstein
- Everything that can be counted does not necessarily count; everything that counts cannot necessarily be counted. - Albert Einstein

Chapter 1(S)

Introductory / Explanatory Notes

Brief Synopsis and Suggested Plan for Action

CONTENTS

Chapter 1(S)

Introductory / Explanatory Notes

Brief Synopsis and Suggested Plan for Action

S.1.1 **Brief Synopsis**

S.1.1.1 The Indian National Academy of Engineering (INAE) constituted a INAE Forum on Technology Foresight and Management for Addressing National Challenges in August 2012 having nine Members. The Members of the Forum are :

1. **Mr. Vijai Kumar Agarwal**
   Formerly Chairman Railway Board & Ex-officio Principal Secretary, Govt. of India
   Formerly Director Indian Oil Corporation
   Formerly Director Steel Authority of India.

2. **Dr. Yogendra Pal Anand**
   Formerly Chairman Railway Board & Ex-Officio Principal Secretary, Govt. of India
   Formerly Director, National Gandhi Museum, New Delhi.

3. **Prof. Prem Vrat**
   Formerly Director-in-Charge IIT Delhi
   Formerly Founder Director IIT Roorkee
   Formerly Vice-Chancellor UP Technical University, Lucknow
   Currently Vice-Chancellor and Professor of Eminence, ITM University, Gurgaon.

4. **Dr. Chunchu Raghuveera Prasad**
   Formerly CMD, GAIL, New Delhi
   Formerly Chairman, British Gas India Pvt. Ltd., Gurgaon
   Currently CMD, Everest Power Pvt. Ltd., New Delhi.

5. **Mr. Anil Kumar Anand**
   Formerly Director (Reactor projects Group), BARC, Mumbai
   Formerly Scientific Consultant, Academia – Industry Interaction
   Office of PSA to the G.O.I.
   Currently Director Technical – Microtrol Sterilisation Services, Mumbai.

6. **Mr. Kishore Pal Singh**
   Formerly Managing Director RITES, New Delhi
   Formerly Managing Director Tata Projects, Hyderabad.

7. **Mr. Suresh Chandra Gupta**
   Formerly Member Electrical Railway Board & Ex-officio Secretary to GOI.

8. **Mr. Vinoo Narain Mathur**
   Formerly Member Traffic Railway Board & Ex-Officio Secretary to GOI
   Currently M.D. – Bharuch-Dahej Railway Company Ltd.

9. **Mr. Arun Kumar Gupta**
   Formerly Chief Administrative Officer, Diesel Maintenance Works, Patiala
   Formerly Director Oil India Ltd.

S.1.1.2 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.

S.1.1.3 Technology Foresight exercise for finding solutions to the identified challenges was to keep the following in View / Focus :

- 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 **D**ata / **S**ource was not a practical reality as the challenge was many a times to venture into new areas not only **S**cientific / **T**echnological / **E**ngineering but also areas concerning **S**ocial affairs / **B**usiness management / **F**inance / **P**olicy 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 testifies 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.

S.1.2 **Suggested Plan for Action – Challenges taken up for Study**

S.1.2.1 After discussions, the Forum Members selected the following five National Challenges for detailed study / examination with a view to foresee the needed futuristic technologies and to evolve suitable engineering management solutions. This was to be done keeping in focus the aspects of sustainable development, climate change, and poverty-reduction / inclusive growth.

.1 Energy – Major thrust on Solar

Energy is fundamental to growth and economic progress. Dr. Michio Kaku in his book 'Physics of the Future (2011)' highlights the role of Energy by quoting novelist Jerry Pournelle as under :

> "Food and pollution are not primary problems : they are energy problems. Given sufficient energy we can produce as much food as we like, if need be, by high-intensity means such as hydroponics and greenhouses. Pollution is similar : given enough energy, pollutants can be transformed into manageable products; if need be, disassembled into their constituent products."

While the energy sector is vital for development, its emissions are large and growing. The two major sectors of 'electricity' and 'transport' together account for over 78% (65% from electricity +13% from transport) of energy related emissions in India. Growing energy needs for growth / development (about 3-4 times the current levels in next 25 years) and growing concerns about the rising Green House Gas (GHG) emissions point toward renewable options like solar energy, hydropower, wind power, etc.

The Integrated Energy Policy (2006) of the GOI indicates a potential of 1200 Mtoe each for the Solar – Photovoltaic and Solar – Thermal in our country, i.e., a total of 2400 Mtoe. When seen in the backdrop of current Total Primary Energy requirement of 600-650 Mtoe the Solar Power has the potential to meet even the future Energy needs.

The Forum Members felt that with the increasing costs of the fossil fuel based power supply (besides the pollution aspect) and reducing costs of the Solar Power (especially the Solar – Photovoltaic) and in view of its huge potential in our Country the Solar Power option needed much greater thrust even beyond the targets as fixed in Jawaharlal Nehru National Solar Mission (JNNSM). But here one major problem is (besides the need for making Solar Power commercially viable) the need for 'Storage' of energy during day hours for use in other periods. This becomes particularly relevant if the Solar Power has to find a dominant place in the energy mix. Various options and technologies are accordingly being examined for giving a major thrust to Solar Power.

.2 Waste Management

A 'waste' is 'a resource remaining unutilised' or 'a resource out of place'. Waste has critical socio-economic-health-environmental implications and the efficient / effective management of waste is the hallmark of a sustainable society / system. Growing resource and environmental constraints are making the need for waste management even more important / relevant. Minimization of waste generation (prevention / reduction), optimal waste recovery (reuse/recycling) and the effective waste treatment and disposal are the need of the hour. Suitable waste-to-energy (WTE) approaches also need to be explored. The Forum intends to examine the matter holistically to suggest suitable technological / managerial / legal / regulatory measures.

.3 Agriculture – Waste reduction and its Use

Our country does not fare well in terms of agricultural yields or productivity. Further, there are wide yield gaps among various crops across the country. Improvements in yields and reduced wastage of foodgrains hold the key for India to remain self-sufficient on food front. Further, sustainable agricultural strategy needs that concerns about land and water degradation due to soil erosion, soil salinity, water-logging, excessive application of nutrients, and over exploitation of water resources are adequately addressed. The Technology Foresight and Management exercise in addition to suitably addressing the issues concerning the Energy-Water-Food nexus intends to concentrate on reducing the agriculture related wastes and also on their effective utilisation.

.4 **Water – Meeting the Future Challenges**

Access to water and sanitation at an affordable price has to be recognized as the basic right of all human beings. The World Economic Forum in their latest Report (2013) have identified Water Supply crisis as one of the top five global societal risks both in terms of 'likelihood' and 'impact'. Water scarcity already affects more than 40% of the world population. Even though water is seemingly abundant (70% of Earth's surface is covered with water) but the real issue is the availability of fresh water suitable for human use which is less than 1% of the Earth's available water. The Forum intends to examine the matter in depth to suggest suitable Technological / Engineering Management solutions for improved availability / accessibility of water suitable for drinking (both for urban and rural areas) as also for irrigation purposes.

.5 **Transport – Making it Greener**

The vision for transport is to be guided by a modal mix that will lead to an efficient, sustainable, economical, safe, reliable, environment-friendly, and regionally balanced transport system. More than 90% of the traffic in our country is carried by Road/Rail. The Rail is 4-6 times fuel efficient vis-à-vis Road and uses lesser land. However, since 1950-51 the market share for Rail in Freight traffic has fallen from 89% to 30% and for the Passenger traffic from 69% to 15%. Efforts to improve the share of environmental-friendly transport mode viz., the Rail have not made the necessary dent. In addition, Water transport even though currently carrying about 5% traffic has also not received the required thrust even though it is more or less similar to Rail from environmental considerations. The Forum will study and address these and other related issues including the aspects of fuel efficiency / reduced pollution of various transport modes to suggest suitable technologies to make the transport system Greener using appropriate engineering management techniques.

S.1.2.2 Each Challenge / Area was to be covered in a separate Chapter giving broad details of the overall situation and then giving specific details of the line of action suggested by the Forum. Once the Chapter details were finalized, a brief synopsis was to be made for each Challenge / Area also highlighting the suggested plan for action.

S.1.2.3 The Forum Members felt that there was need for more inputs / study for the following two Challenges / Areas :

(i) Energy – Major Thrust on Solar

(ii) Agriculture – Waste Reduction and its Use

It was, therefore, decided to publish the suggestions / recommendations of the Forum for the balance three Challenges / Areas **and the current Report has four Chapters including one "Introductory / Explanatory Notes" as detailed below :**

Chapter	Title	Coordination by
1.	Introductory / Explanatory Notes	Mr. V. K. Agarwal
2.	Waste Management	Dr. Y. P. Anand / Prof. Prem Vrat
3.	Water – Meeting the Future Challenges	Mr. K. P. Singh / Mr. A. K. Gupta
4.	Transport – Making it Greener	Mr. V. K. Agarwal / Mr. V. N. Mathur

Chapter 2

Waste Management

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Chapter 2

Waste Management

2.1 Introduction

2.1.1 *A 'Waste' is also a 'Resource'*

A 'waste' is 'a resource *remaining unutilized*' or 'a resource *out of place*'.

For example, out of the food that we consume, only a part is 'utilized' by the body system and the balance is thrown out as 'waste'. The part 'utilized' is converted into useful components such as blood, bones, flesh, nerves, and so on, or looked at in another way, into cells and microorganisms constituting the body, and these too, in turn are thrown out as 'waste'. Finally, the body itself, on death, becomes a 'waste'. Here, whatever is being released as 'waste' could be recycled as 'resource' as it contains same components as present in the food that was consumed.

Another example: to run a 1 million tonne (m. t.) steel mill, nearly 5 m. t. of raw materials---mostly iron ore, limestone and coal---are needed, the extraction of which leaves behind huge mineral and allied wastes. Most of these raw materials themselves are released as wastes from the mill. Steel ingots are sent to rolling mills, which release their own wastes. The rolled sections are utilized in manufacturing and construction industries which release the concomitant wastes. After the manufactured equipment and structures have lived their life, these too are junked mostly as wastes. Here, most of what is released as raw 'waste' could be utilized for other uses, and what is released as 'waste' from steel processing or junked steel, could be recycled as it mostly contains the same components as steel.

2.1.2 *How a Society manages its 'Wastes' also determines its Sustainability*

How a society manages its 'wastes', has critical socio-economic-health-environmental implications, because:

- A 'waste', like any other product, represents inputs of valuable, finite and scarce material and energy resources, and, hence, unless gainfully recovered, appears as a loss of these resources.

- A 'waste', to the extent it is not recovered, generally causes environmental pollution and damage---of land, water, air and living environment---being beyond the capacity of the environment to absorb and recycle it through natural processes, and, in many cases, is also a serious health hazard. For example, polluted drinking water alone is likely to kill around 1 to 2 million people in the world per year.

- A 'waste' requires to be collected, transported, and disposed off, often after being suitably sorted and treated, and the collection-cum-disposal systems are themselves becoming increasingly costly and cumbersome, and may require significant inputs of energy, material, land and labour resources, and may also cause widespread environmental distress.

2.1.3 *Waste Management is especially relevant for Modern Societies*

Modern civilization has come to mean a consumerist society. Gross Domestic Product (GDP) as the primary indicator of its economic progress urges people to continually buy to add and replace, even throw away, and towards pursuit of needless packaging. Globalization has come to mean denial of the *swadeshi* (or, 'neighbourhood') approach and, hence, in most cases, growing but avoidable consumption of resources and costs for transportation, packaging, storage, and distribution. All this leads to enormous generation of avoidable wastes, parts of which will persist, despite growing emphasis on waste management, for hundreds of years.

Wasteful attitudes and shortsightedness peculiar to the 'modern' society are leading to the appearance of mounds of trash/ garbage and Landfills all over, apart from the squandering of finite natural resources and turning these into poisons for soil, water and air and all life.

Until about a century ago, the wastes mostly consisted of products made of naturally degradable/ recyclable materials, such as ash and inedible foods. Now, the wastes are growing enormously in volume and consist more and more of materials not easily degradable/ recyclable in nature. Rise in living standards mostly goes with more waste generation. Global waste generation now amounts to over 2 billion t./year of municipal solid waste (MSW) alone, apart from which there are enormous agricultural, mining, forestry, construction, industry, commercial and other solid and liquid wastes. A sustainable future for humankind means minimizing generation of wastes, recycling of wastes as resources, and developing a personalized responsibility for management of the wastes generated.

Modern societies are becoming increasingly identified with the generation of wastes having hazardous/ toxic contents, such as automotive, electronic, plastic and bio-medical (hospital) wastes. The ubiquitous presence of plastics is a typical example. These had originated from waste byproducts of oil and gas refining. Celluloid was one of the very first plastics in commercial use for making items such as combs, brushes and buttons. In World War II, plastic industry sprang up in order to replace strategic metals and materials, and this capacity later brought about use of plastics in durables such as cars, furniture, appliances, textiles and toys. In 1950s and 1960s, the industry entered disposables such as cups, forks and straws. Plastic bags and bottles were introduced in 1970s. The polyethylene industry replaced paper products and ultimately, the shopping bag became universal, 0.5-1.0 trillion plastic bags being consumed globally per year!

Thus, there are hundreds of plastics in wide use now. A real shift came with the throwaway mindset: now about half of the plastics go into single use items and $1/3^{rd}$ into packaging. Now plastic pollution is seen all over, even on the remote beaches

2.1.4 *'Waste Management' includes All Its Aspects*

The term '*Waste Management'* includes all issues and processes associated with the generation, processing, and disposal of all categories of wastes produced by human activities and existence; it includes, therefore, all aspects of waste production and minimization, collection, handling and transportation, reuse and recycling, and treatment and disposal. Waste management is undertaken basically to minimize the effect of wastes on resource loss and non-conservation, health, environment, costs, and aesthetics. It incurs financial and social and other costs including 'external' costs. The term also includes the issues of technology and of 'regulation' of the various aspects of management of wastes.

2.1.5 *Importance of Laws, Rules & Regulations, Studies, Documentation, R&D, and Training*

With rising populations, urbanization, mobility and economic growth and the concomitant resource and environmental constraints, a growing need for appropriate laws, rules and regulations, studies and documentation, R&D and training infrastructures in areas relating to the generation and management of wastes is evident. There is already a large corpus of rules and regulations, in India and other countries, related to handling, treatment, processing and disposal of various wastes, particularly municipal and industrial wastes. These are also being formulated now for the upcoming ever more varied and specialized kinds of wastes. For example, Biomedical Waste (Management and Handling) Rules came into force in Delhi in 1998 for processing and disposal of hospital-generated wastes. Such efforts need to be suitably upgraded from time to time to meet the evolving needs in each sector.

2.1.6 *Responsibility for Wastes & Waste Management*

The responsibility for ensuring appropriate management of different categories of wastes may lie with governments and local bodies but as well as with the 'producers' of goods or waste generators. For example, the *Extended Producer Responsibility* (EPR) concept promotes the integration of all costs and responsibility associated with a product throughout its life-cycle (including the packaging and the end of life waste disposal costs) into its market price; while the *Polluter to Pay* (PtP) principle is another concept to make the polluter bear the costs of waste management and/or the incident costs of environmental pollution.

2.1.7 *Scheme of Presentation*

The multi-faceted subject of 'wastes and waste management' is being presented here in the form of a holistic review of its important aspects. It begins with the listing of 'Main Categories of Wastes' (para 2.2), followed by a brief description of the four-step 'Hierarchy of Options and Stages in Waste Management' (para 2.3). Then follow illustrative write-ups relating to each of the four steps of the hierarchy, viz. 'Minimization of Waste Generation' (para 2.4), 'Efficient Waste Collection and Classification' (para 2.5), 'Optimum Waste Recovery, i.e., Reuse & Recycling' (para 2.6), and 'Effective Waste Treatment and Disposal' (para 2.7). Then follows a section dealing with 'Treatment and Disposal of Common Categories of wastes' (para 2.8). The Paper ends with a brief review of 'Important Implications' (para 2.9) and 'Policy Issues' (para 2.10) concerning 'Waste Management'. The presentation has been interspersed with a few striking examples of advanced and innovative approaches adopted in waste management.

2.2 Main Categories of Wastes

2.2.1 *Categories of Wastes*

Waste categories may be as numerous and varied as their sources of generation.

As citizens, we are most conscious of the household garbage (or, trash). In developed urban areas, it may amount to, say, 1 t. per household/year. But the whole urban garbage, or 'Municipal Solid Waste' (MSW), may be just 1-2% of total national waste stream, as far more waste is generated upstream in extracting raw materials, from various industries, and from transportation, storage, and distribution systems of the innumerable products and services we use. Similarly, wastewater is generated not only from urban areas but also from numerous industrial units and other such sources as well as from some of the areas following modern agricultural practices.

While detailed and precise categorization of the wastes in India will require nationwide surveys and documentation, based on common considerations, the following main categories may be easily distinguished:

I. Municipal or 'Sanitation' Wastes

- I.1. Human Wastes
- I.2. Municipal Solid Wastes (MSW)
- I.3. Municipal Liquid & Drainage Wastes ('Wastewaters')
- I.4. Wastes from large Hotels, Restaurants, and Canteens, &, other Food Wastes
- I.5. Other Municipal Wastes

II. Hazardous/ Toxic (Solid) Wastes

- II.1. Motor Vehicular ('Automotive') Wastes
- II.2. Electric and Electronic Equipment (EEE) and allied Wastes (e-Wastes or WEEE: becoming increasingly important due to the fast growing use of computers, cell-phones and other electric and electronic equipment)
- II.3. Plastic Wastes
- II.4. Hospital (Bio-medical) Wastes
- II.5. Other Hazardous/ Toxic Wastes (e.g., Nuclear Wastes)

III. Animal related Wastes

III.1. Animal and Dairy Wastes

III.2. Slaughterhouse Wastes

IV. Industrial Wastes (Differentiated Industry-wise, e.g., wastes related to Iron & Steel, Cement, Textile, Jute, Sugar, Pulp & Paper, Motor Vehicle Manufacturing, and Food & Beverages industries)

IV.1. Large-scale Industrial Wastes

IV.2. Medium-scale Factory Wastes

IV.3. Small-scale (scattered) Industrial Wastes

IV.4. Cottage Industry wastes

IV.5. Industrial Effluents

V. Equipment and Machinery Wastes

VI. Building Construction and Demolition (C&D) Wastes

VII. Mining Wastes (Differentiated mineral-wise, e.g., wastes related to coal and lignite, iron ores, bauxite, and uranium mines)

VIII. Wastes related to Energy Production Complexes

VIII.1. Thermal Power Station Wastes

VIII.2. Petroleum Refining and Processing Wastes

VIII.3. Wastes from Nuclear Power Plants and Other Nuclear Establishments

VIII.4. Hydro-power Plant Wastes

VIII.5. Other Energy Production Wastes

IX. Plant Wastes

IX.1. Agricultural (Farm) Wastes

IX.2. Forest and Garden Wastes

IX.3. Agricultural and Forest Processing Industry Wastes

X. Other Wastes

The 'wastes' may be solid, liquid, gaseous, or radioactive; hazardous or non-hazardous, and, toxic or non-toxic.

2.2.2 *State of Waste Generation in India*

According to a 1998 report, in India municipal solid wastes were estimated as 27.4 million t./year and liquid wastes (for 121 Class I and II cities) as 12,145 million litres/day; food and fruit processing wastes as 4.5 million t./year, distillery (243 in number) wastes as 8,057 kilolitres/day, sugarcane press-mud as 9 million t./year, dairy industry waste as 50-60 million litres/day, pulp and paper industry (300 mills) wastes as 1,600 cum/day, tannery (2,000 units) wastes as 52,500 cum wastewater/day, willow dust as 30,000 t./year. In addition, there would be enormous wastes from agriculture, mining, other large and small industries, construction activities, animal wastes, and so on. Further, with fast economic, urban and population growth since 1998, the amounts of wastes would have doubled or grown even more by now. For example, a recent report gives the present (solid) wastes generation in India as 70-100 m. t./year, expected to grow further by 500% by 2030! [*Rail Business*, vol.4, issue 8, March 2013, Kolkata, p.33]

Presently most of the wastes are dumped or let into the streams, ponds, seas and on ground without treatment, leading to wide-spread water, ground and air pollution and degradation, health hazards, and emission of greenhouse gases.

2.3 Hierarchy of Options and Stages in Waste Management

2.3.1 *Follow Nature*

Management of different categories of wastes requires varied and different approaches and solutions suited to the specific origin, nature, extent and composition of respective waste categories as well as the attendant situations under which these have to be dealt with.

In nature, there is near total upward recycling of end products into numerous processes and practically no waste accumulates. Nature builds up every leaf and then recycles it after it falls, without any waste. But human manufacturing processes use, say, only about 4% of the bulk materials entering into the processes as the end product and 96% is released as 'waste' at various stages of production itself. Our waste management solutions should try to mimic nature's "no waste" and "full recycle" principles, operating within accessible opportunities and limits.

Nature takes earth, water, atmosphere and solar energy to manufacture most products, and its materials get up-cycled from one product to another. Even its 'waste', such as faeces and dead bodies of organisms, are up-cycled as raw inputs into new bodies. But then nature uses mainly only six elements of the periodic table (carbon, hydrogen, nitrogen, oxygen, phosphorus and sulfur) for most of its bio-molecules, which get easily up-cycled.

As against this, we have, say, 350 types of commercial plastics (polymers) alone, and the materials and chemicals so synthesized can be used by no living matter in its body---the root problem of non-biodegradable wastes.

Bio-mimetic thinking means using local materials for manufacture of products, at the end of whose life these can be recaptured to make new products. Bio-mimetics is a field of science and engineering that seeks to understand and use nature as a model for copying, adapting and evolving concepts and designs, i.e., mimicking biology or nature. Some of the capabilities of nature's materials include self-healing, reconfigurability, replication, and balancing pH, temperature, pressure, etc. As a mindset, it means 'abstracting processes from nature, identifying the business opportunity for these processes and applying them'. For example, species of Bacillus group can be used to locally increase pH and promote deposition of CO_2 as $CaCO_3$ in a calcium rich environment [refs. 7 and 13].

Everything 'green' is made out of CO_2, e.g., a leaf combines CO_2 with H^+ from H_2O and sunlight to make sugars and starches, i.e. its polymers. A start has been made commercially now similarly to make bio-degradable plastics out of CO_2, as well as to make concrete which sequesters ½ t. or more CO_2 instead of emitting 1 t. CO_2 for every t. of concrete made. 'Bio-mimicry', i.e. learning from nature, will lead to endless ways, such as developing and using cement which sequesters CO_2, like a forest does, and plowing back rotten vegetables and fruits from large markets into the soil to build it up instead of dumping these as 'waste'.

2.3.2 *Important Options and Stages in 'Waste Management'*

These are listed below in a broadly hierarchical order:

1. *Prevention and Reduction:* The first option should be to prevent the generation itself of a waste, and since that may not be mostly possibly, to reduce its generation to the minimum level possible.

2. *Collection and Classification*: Once a waste is produced, the best option for the next stage would be to ensure its efficient collection and suitable classification ('sorting' & 'segregation').

3. *Recovery through Reuse & Recycling:* After collection and till final disposal, at each stage, the first option should be to ensure maximum possible recovery of usable products and useful resources (materials and energy) from the wastes through 'reuse' ('salvage' or 'repair') and through 'recycling', not only before but also during and even after the treatment processes.

4. *Treatment and Disposal:* Whatever residual waste remains after recovery through 'reuse' and 'recycling' during pre-treatment stages, should be treated for being disposed off in a suitable and, to the extent possible, socially useful manner, including again recovery through 'reuse' and 'recycling'. Many wastes, such as human waste, garbage, and e-waste, due to their highly polluting, health-hazardous or toxic nature, require extensive physical, and/ or chemical---biological, and other types of specialized 'treatment' before being safely disposed of into land, water or air.

Thus, a **Waste Management System (WMS)** includes both an hierarchy of 3 R's---Reduction, Reuse, and Recycle---as well as treatment and final disposal of wastes. Hence, it essentially involves four basic stages or processes, which may be partly overlapping: Minimization of Waste Generation ('Prevention' & 'Reduction'), Efficient Waste Collection and Classification ('Sorting' & 'Segregation'), Optimal Waste Recovery, i.e., Reuse & Recycling, and Effective Waste Treatment and Disposal. These are discussed in paras 2.4 to 2.7 below.

2.4 Minimization of Waste Generation ('Prevention' & 'Reduction')

2.4.1 *Why Minimization of Waste Generation?*

Both material and energy resources go into the formation of all products which in stages end up as 'wastes'. Even the processes of reuse, recycling, treatment and disposal of wastes, along with the processes of waste collection, handling, transportation, and storage, involve significant material, energy, environmental, and financial inputs. All un-recovered energy inputs finally end up degraded as low grade heat and are lost. Conventional energy resources, being mostly non-renewable, are getting scarce, particularly in India, where over 75% of its hydrocarbon energy needs are at present imported at increasing costs, and other fossil fuel resources, such as coal, too are not adequate. Material resources, particularly mineral resources, too are becoming increasingly scarce in the scenario of growing population and fast economic growth. Therefore, the growing use of energy and material resources is becoming more and more unsustainable, and the greatest challenge in Waste Management is how to minimize the loss of these resources, firstly through 'prevention' and 'reduction' itself of waste generation.

2.4.2 *'Prevention' & 'Reduction'--- Issues and Approaches*

There is a large-scale scope for 'prevention' of waste generation by avoidance of production and consumption of obviously superfluous, non-essential, non-utilitarian products and services. According to a recent news report [23.02.2013], women in UK spent 3.5 billion pounds on footwears last year. An average woman owns 19 pairs but only wears seven. Easily preventable waste generation occurs when goods and services are patronized in such a way. Lifestyles and social attitudes that encourage tendencies such as consumerism, shop-alcoholism, and display of enticing advertisements, encourage generation of easily avoidable wastes in a society. It particularly happens in societies where consumption of socially and ecologically unaffordable goods and services becomes increasingly respectable, and economic growth itself is partly measured in terms of such a consumption pattern. All this happens because of the growing dichotomy between individual and social and short-term *v*. long-term perspectives. This also costs heavily in terms of scarce energy and material resources while a large part of society still awaits satisfaction of its basic needs.

Promotion of waste 'prevention' in a society will require extensive and on-going studies and research, documentation, and propagation and advocacy against ill-effects of avoidable production and consumption of goods and services.

Obviously, there are limits to such a ‘preventive’ approach for minimization of waste generation and an equal, if not greater, emphasis is needed on ‘reduction’ of waste generation without materially affecting the necessary consumption and life styles. It may be done, say, (a) by increasing the efficiency of processes of production and minimizing the net consumption of vital resources such as water and energy, (b) by enhancing the durability of products, improving their maintainability, and instituting performance standards, (c) by minimizing packaging, storage and transportation requirements, and (d) by improving ‘repair’ and upgradation services, and discouraging the ‘throwaway’ tendencies. Adoption of the principle of *Swadeshi*, as was done during the freedom struggle of India, to encourage use of local resources and products and self-reliance as an important factor of economic growth and its measurement, can also help in minimizing transport, packaging, storage and energy costs and curbing socially undesirable consumerist tendencies, apart from providing an ideological support towards resource conservation and social concern. (see also para 2.1.3)

2.4.3 *Specific Approaches are Necessary for each major Sector, such as various Industries, Civil Construction, Transportation, & Food Sector*

Ongoing studies and experimentation are necessary in order to devise specifically viable approaches for each major sector in order to minimize waste generation. For example, major improvements are possible in order to minimize the use of water in various Indian industries and other sectors (leading to less generation of wastewater as well as less water scarcity). Current annual industrial water discharge has been estimated at over 30,000 million cum, about 88% of it being from thermal power plants, 5% from engineering industries, 2.3% from pulp and paper units, 2.1% from textile units, 1.3% from steel mills and the rest from other industries. The scope for the saving of water becomes obvious from comparing levels of water consumption in Indian industries with the best global practices: in case of thermal power plants it is 80 (average) *v*. 10 cum/MWh, in case of pulp and paper units it is 75-200 *v*. 10-75 cum/t., and in case of iron and steel mills it is 10-80 *v*. 5-10 cum/t. Recycling and reuse of water through suitable treatment processes can minimize both consumption of water and generation of wastewater effluents from various industries. TATA and SAIL steel plants and IOC refineries have already achieved much success in this direction. The scope for similar waste ‘reduction’ in each major industry is nearly unlimited.

In case of building construction, use of ‘passive’ architectural practices and designing structures in conformity with the climate can reduce the energy and material needs considerably. Similarly, preference for public over personal transport and non-motorized over motorized means of transport, wherever feasible, and use of more fuel-efficient designs and of smaller or lighter use-oriented vehicles can result in considerable all round waste reduction.

[*Pioneer*, 6.6.2013, &, *Hindustan Times*, 20.6.2013]: Globally, food wastage-cum-loss has deep social-ecological-economic impacts, involving avoidable use of scarce resources such as land, energy and water. In the US, organic food waste is the second highest component in Landfills, and the largest source of methane (a Greenhouse Gas) emissions. According to the United Nations Environment Programme, 1.3 billion t. or 1/3rd of global food production is wasted or lost while one in seven people go to bed hungry and over 20,000 children die daily of starvation. In the US, 30% of all food is thrown away, and in the UK nearly 6.7 m. t. of food out of total 21.7 m. t. purchased by households is wasted. While in developed countries, food waste/ loss is centred in later stages of food supply chain, unnecessarily strict sell-by dates, attractive discounts, and consumer demand for cosmetically perfect food (in the UK, 30% of the vegetable crop remains unharvested for not meeting the exacting standards of physical appearance), in developing countries, it is centred in the financial, managerial and technical limitations in the early stages of food-chain related to harvesting and storage. Most of the food waste/ loss are avoidable. In India, authorities need to prevent situations such as rotting of foodgrains in open storage, and to strengthen the supply chain by empowering the farmers and investing in infrastructure, transportation, and packaging industry. Overall, there is an enormous potential for ‘prevention’ and ‘reduction’ of food and foodgrain waste-cum-loss, and thus minimizing our *food-print*.

2.4.4 *Role of Taxes and Other Levies*

In general, generation of wastes can be discouraged also by levying the real 'marginal' costs or 'luxury' taxes as well as by including the 'external' (social and environmental) costs, such as the costs of pollution of air and health effects on fuel exhausts, and on the use of material and energy resources in production of non-essential goods and services. Also, graded charges may be levied on consumption of scarce commodities and on generation and disposal of avoidable wastes.

2.5 Efficient Waste Collection and Classification ('Sorting' & 'Segregation')

2.5.1 *Issues in Waste Collection & Classification*

Since most of the wastes are generated in residential, commercial, industrial, mining, or agricultural establishments which are scattered, to a greater or lesser extent, in areas all over the country, various waste 'collection' functions, including the processes of handling, transfer, storage, and transportation of collected wastes, assume a critical importance. Different categories of wastes, e.g., organic *v*. inorganic wastes, biodegradable *v*. non-biodegradable wastes, solid *v*. liquid *v*. gaseous wastes, hazardous/ toxic *v.* non-hazardous/ non-toxic wastes, isolated *v*. concentrated wastes, urban *v*. rural wastes, and municipal *v*. industrial *v*. mining *v*. agricultural wastes, will require different strategies for their collection, treatment and disposal.

2.5.2 *Current Practices, and Hazards of Inefficient Waste Collection*

If waste collection systems are not efficient, many of the wastes may escape collection and/ or may be exposed, thus causing environmental and health hazards and ungainly sights. 'Municipal' and many other waste collection and associated processes are still being managed largely through 'scavenging', resulting in human degradation and drudgery (the primary basis of the practice of 'untouchability' in India was such practices of waste collection and disposal). Insanitary methods of waste collection and disposal can be injurious to the associated workers who handle these wastes. Therefore, extensive studies and research and action are needed to ensure that the waste collection systems do not pose any hazards to the health of the workers involved in it or to that of the surrounding population and environment.

2.5.3 *Collection of Concentrated v. Non-concentrated Wastes*

Collection of widely scattered wastes such as garbage, particularly in large cities, presents major problems in logistics and management and is an area requiring much greater research and regulation. For example, the USA alone daily generates 0.6 m. t. garbage. In India it is 0.2-0.3 m. t. daily. Even in Delhi, collection, separation, storage, transportation and disposal of the daily generated 9,000 t. garbage continues to defy a satisfactory solution. Similarly, the problem of collecting municipal wastewater through an intricate system of sewers and then its treatment and disposal present no easy solutions. The cases such as those of scattered animal wastes, the hazardous/ toxic wastes from the users, wastes from rural sector and from cottage and small-scale industries present their own unique problems.

2.5.4 *Classification cum Segregation*

Suitable classification and segregation, done before or after the collection of wastes, is the cornerstone of Municipal Solid Wastes (MSW) management, including adoption of optimum technology options for subsequent treatment and disposal after recovery of all possible components of the waste. In India, this task has been left to the ubiquitous 'rag-pickers' who are supposed to pick out saleable inorganic material from the collected wastes. In India, with its nearly 8,000 cities and towns, over half a million families are estimated to be working as waste pickers. They may be enabling even 10 to 25% of MSW being recycled, but they have to manually spread the wastes leading to health and other hazards, apart from a large portion of inorganic wastes remaining behind and thus contaminating the wastes being composted or digested for biogas. For example, in Delhi, at Ghazipur Landfill, where nearly 2,000 t. of waste is dumped daily, a large number of children work under dangerous conditions as rag-pickers, selling the salvaged plastic bottles, rags, cardboard, glass, metal pieces, etc. to scrap aggregators.

‘Waste Ventures’, an NGO in Delhi, has developed a model for large-scale employment of adult waste pickers, extracting a much greater worth of materials from the wastes, working with protective gear and under much healthier working conditions. It is estimated that up to 80% of household garbage can be thus recovered.

However, the only sensible and rational solution is to enforce appropriate segregation of such wastes at source, say into easily implemented and regulated 3 or 4 categories, which would obviate the very need for any waste ‘picking’ and can contribute substantially towards reuse and recycling of recoverable materials and adoption of suitable treatment and disposal strategies. For example, organized segregated collection of enormous quantities of waste paper alone, only a part of which is now collected and handled in the unorganized sector, can help in optimum recycling of this valuable resource.

2.6 Optimal Waste Recovery, i.e., Reuse & Recycling

2.6.1 *Traditional Practices in India*

India is a large semi-tropical country with an extensive agricultural economy and large human and animal (particularly cattle) populations. Therefore, all over the country enormous quantities of organic wastes (human, animal, and plant wastes) are produced. These have been traditionally handled through their reuse/ recycling to a large extent by their being utilized in multiple ways such as manure, fuel, feed, fermentable substrates and soil conditioner, directly or after some simple treatment procedures such as composting. In a way, these ‘wastes’ have been utilized as valuable resources for the rural and even non-rural economy. These traditional methods have been also largely environment friendly. We need to study these traditional approaches and see how these can be improved upon and adapted to the management of increasing density and extent of such organic wastes under modern circumstances.

2.6.2 *Need for Technical &Financial Feasibility Studies*

The subject of reuse/ recycling of different categories of wastes, both organic and inorganic, to the extent it may be practically, technologically and financially feasible, needs much greater study and research and technical and management inputs than are being devoted at present. The process of reuse/ recycling of wastes starts right from the point of waste generation and goes on till its final disposal. As a waste is collected, transported, stored and treated, sorting out/ segregation and handling and extraction of useful components (such as paper, metals, plastics, plant components and energy) from it usually becomes increasingly more difficult and expensive at each successive step. Hence, reuse/ recycling of wastes requires meticulous planning and execution of different steps, and building into waste collection and treatment and disposal systems adequate financial incentives so that different agents are encouraged to take up the required tasks of sorting out and segregation. For example, waste paper is best sorted out at the point of waste generation and collection itself. Writing paper which has been used only on one side, can be simply retained for reuse on the unused side, while used up and printed paper waste, if sorted out, can be recycled into varieties of useful paper and packaging materials in a small factory. (1 t. of recycled paper amounts to a saving of about 15 trees, 2500 kWh of energy, 20,000 litres of water, and 25 kg of air pollutants!)

2.6.3 *Potential and Opportunities---Before and Under Treatment*

Water is becoming more and more a scarce resource in India. Hence, reuse/ recycling of any wastewater is a major field for study and research. Similarly, reuse/ recycling of municipal wastes, building wastes, clothing wastes, industrial wastes, electronic wastes (e-waste) and all other such categories of wastes presents immense and increasingly cost-effective possibilities and meets socially-essential requirement of resource conservation. For example, recent innovation of reusing plastic wastes in a plastic-tar mix for provision and repair of road surfaces offers immense possibilities.

In the West, ‘Remanufacturing’ plays a major part in recycling and is big business in numerous sectors such as automobiles, electronics, machinery, office furniture, and toner cartridges, and is globally larger than the steel industry. Ships, aircraft and automobiles lend themselves to substantial recovery of useful materials by ‘recycling’. In such cases the hierarchy of recovery may be listed as Reuse (parts which can be removes and reused), Remanufacture (items like electric motors, alternators, and starters, which can be remanufactured from recovered parts—a major industry in the US), Recycle (majority of components which can be recycled to give useful raw material and feedstock), and Residue (such as leftover ‘automotive shredder residue’ (ASR) that goes to Landfill).

The goal should be to eliminate all ‘black bin bag’ waste, i.e. to aim for a time when we are able to reuse or recycle every item we take.

2.6.4 *Biodegradable v. Non-biodegradable Wastes*

Many of the ‘modern’ wastes are not easily biodegradable and hence remain unprocessed by natural processes. Typically, wood may take 10 years to be fully biodegraded, but a tin can may take 100 years and a glass bottle 500 years! But most of such materials can be reused or recycled.

Most of the biodegradable wastes can be recycled through aerobic (such as ‘composting’ for solid wastes) or anaerobic (bio-methanation) digestion processes, or through a combination of physical, chemical and biochemical processes.

2.6.5 *Some Striking Examples of Reuse/ Recycling of Wastes*

Sugar Industry is a classic example where utmost recycling is being practised in many progressive sugar factories. Typically, sugarcane contains about 12% (by weight) of sugar and the rest was earlier being released mostly as factory wastes. Now water which constitutes 50-60% of the weight of sugar-cane, and which becomes vapour, may be condensed and recycled resulting in substantial savings in cost of sugar production. The molasses (say, 4%) may be used to manufacture spirit, alcohol, ethanol, animal feed, lactic acid and other chemicals while the distillery effluents may be processed to yield fertilizer and biogas. Bagasse (nearly 30%) may be used to make paper, briquettes, manure and fuel (for the cogeneration plant). Even the ‘pressmud’, the residue removed during purification of sugar juice, may be used as fertilizer. On similar lines, reuse/ recycling of wastes offers enormous opportunities in most industrial and agricultural sectors, which not only reduces the incidence of waste generation but also yields valuable material and energy resources.

New Life for Shoes [ref. 1: p.13]: Nike’s Reuse-A-Shoe-Program has been operating in the US, Canada, Australia, New Zealand, Netherlands, Spain, and Germany, since 1990, and 28 million pairs (any brand) have been collected and recycled into materials for different kinds of sports ground surfaces.

Gemah Ripah Fruit Market, Yogyakarta (Indonesia) [ref. 1, p.6]: In a demonstration plant for handling 4-10 t. rotten fruit/day, earlier dumped 40 km away, the waste is now crushed and filtered, the liquid goes to a biogas reactor and solids are composted to produce fertilizer. Biogas is used to produce 500 kWhe/4 t. of waste. The waste is thus handled as an important resource in an environmentally and economically sound manner.

In San Francisco, food scraps are collected for being composted, and waste paper and containers, mattresses, light bulbs, and hazardous household goods for being recycled. In USA, there are nationwide ‘drop off sites’ for collecting food scraps, as about 40% of edible food is being thrown away, which means loss of resources, avoidable pollution and clogging of Landfills. Modern societies similarly ‘throw away’ enormous amount of such valuable goods, which can be collected and recycled. Similarly, fabrics, footwear and other goods can be recycled on a large scale.

Three letters to *The New York Times* (3 May 2013) in response to the editorial, ‘Mayor Rethinks Recycling’ (30 April 2013): 1) The New York City mayor deserves praise for programmes for expanded plastic recycling and the new food waste recycling. By including rigid plastics, New York joins the growing number of such cities. Since 2005, the number of food waste collection programmes have grown eightfold, but New York’s recycling average of 20% is well below the US average of 34%. New York’s efforts to educate its citizens and expand its recycling efforts can lead to its long-term goal of becoming a ‘sustainable city’. 2) US’s private sector waste and recycling industry applauds New York’s efforts. The industry has put up gas controls at most of the Landfills receiving New York’s waste, to process methane into renewable energy. Nearly 600 Landfills in the US produce such ‘green’ energy, enough to power or heat nearly 1.8 million homes. 3) Instead of using the expensive ‘clear’ recycling bags for the expanded categories of waste, the existing opaque grocery store bags could be used as recycling bags if made of clear plastic. Recycling bags should be given at a nominal cost.

2.7 Effective Waste Treatment and Disposal

2.7.1 *The Scope*

‘Effective Waste Treatment and Disposal’ also includes simultaneously the processes of ‘Minimization of Waste Generation’ and ‘Optimum Waste Recovery’ as these remain as relevant and applicable during the stages of waste treatment and disposal as before these.

2.7.2 *Type of ‘Treatment’ of a Waste is also Related to Its Circumstances*

In most cases, a waste is required to be suitably ‘treated’ before it may be disposed off into land, water or air, lest it may pollute and damage the environment, may accumulate without being processed by natural processes, may become a serious health hazard, or may result in avoidable depletion of scarce resources. For example, human waste collected through sewerage system in cities has to go through a multi-stage treatment in sewage treatment plants before it may be disposed off, while the same waste collected in a less diluted form in rural areas or isolated habitations may be dealt with through numerous decentralized ways, including being treated by anaerobic digestion or by composting for conversion into organic manure.

2.7.3 *Relevance of Environmental Factors*

The capacity of particular land, water or air bodies and the density of generation of particular wastes in the area also determine the limits to what the wastes may contain specific pollutants before being finally disposed off. For example, motor vehicular exhausts which may be allowed in areas far away from cities may not be permissible within the cities, or thermal power houses may require installing fly-ash precipitators before the chimney exhausts may be allowed near cities, or certain industrial effluents just may not be permitted to be discharged into flowing rivers near towns and cities. Delhi presents a typical example in regard to the use of the Yamuna river for discharge of its liquid wastes. Delhi constitutes only 2% of the Yamuna basin catchment area, yet has been known to contribute about 80% of its pollution load over its 48 km stretch within its territory. According to an earlier report, while the Yamuna water at its entry into Delhi area was fit for drinking after treatment, and had 7.5 mg/l DO (Dissolved Oxygen), 2.3 mg/l BOD, and coliform count 8,506/100 ml, at the exit its DO was 1.3 mg/l, BOD 16 mg/l, and coliform count 3,29,312/100ml! Since 1993, Delhi, UP and Haryana governments have spent enormous sums to tackle the Yamuna pollution but with little success as the pollution load remains too high.

2.7.4 *Main Stages, Methods and Options concerning Treatment of Municipal and Industrial Wastes*

The various stages in treatment of different wastes are usually categorized as preliminary, primary, secondary, and tertiary. The treatment processes for different categories of wastes may be physical (mechanical processes such as separation, sedimentation, and filtration, or compression or drying), or chemical (such as oxidation or reduction processes, or other chemical reactions), or biological (such as aerobic or anaerobic), or a combination of these. Specific tertiary treatments may be necessary in case of certain wastes, usually for recovery of certain useful components or removal of certain unwanted components. Radioactive wastes require a very special treatment. Some wastes may need to be treated to remove hazardous/ toxic components such as mercury or arsenic. Each category of waste has to undergo treatment appropriate to its composition before it may be safely discharged into the environment, especially near inhabited areas or into water bodies. Treatment processes are also so designed as to help in recycling of wastes to the utmost extent.

The most common methods of treatment and disposal adopted for municipal and industrial wastes are indicated below.

2.7.4.1 Landfills

Landfills are the most commonly employed option of treatment-cum-disposal of solid wastes. A Landfill is basically a large hole in earth, lined with clay, sand or gravel and a plastic liner. A day's waste is dumped, crushed and compressed with heavy machines, and then covered with material such as soil or dirt or crushed glass. When a Landfill reaches its regulated height, it should be capped with soil and plastic and seeded with grass. Landfills are generally large and may cover tens or even hundreds of acres of land, and need a high level of management. The main issues or problems with regard to these are:

(a) Organic material generates methane (CH_4), a Greenhouse Gas (GHG). In the US, Landfills are the third largest anthropogenic source of methane. Some Landfills arrange to collect a part of the methane so produced as an energy source.

(b) Leachate trickles through the dumped garbage, picking up solvents, acids, heavy metals, pesticides, etc. Even with the leachate collection systems, which are rarely perfect, it contaminates underground water, waterways and soil. With time, any Landfill liner will leak.

(c) Different components of the garbage take very variable time periods to disappear, e.g., a plastic bottle may even take 1,000 years.

In India, Central Pollution Control Board's (CPCB's) directions for management of MSW suggest use of only 'Secured/ Engineered' sanitary Landfill practices, separate disposal of hospital and other hazardous wastes, the wastes being inert and with low leachability, and Landfill sites being an adequate distance away from the localities, and having necessary fencing, approach road, fire protection, etc. Operational requirements for prevention of pollution, compliance with air quality norms, provision of greenery at the Landfill site, and post-closure care such as retention of final cover and monitoring of leachate collection system, should be laid down. However, in actual practice, most of the solid wastes are just being dumped and even if Landfills are provided, these are largely unregulated and used mainly as dumping sites. A 'Scientific' Landfill would have provision for segregation and waste recycling/ processing through production of compost and fuel, and for prevention of seepage of any pollutants.

2.7.4.2 Incineration

Incinerators take less space than Landfills and significantly reduce the volume of waste, but these are expensive to build and operate and their residual product still needs Landfills. Further, only such non-biodegradable wastes, which can be burnt, are taken to the incinerators. Modern incinerators do release large amounts of CO_2, smell and even dangerous levels of lead and dioxins. Incineration may also destroy resources which could have been recovered from the waste, and the process needs a steady input to operate.

2.7.4.3 Bio-methanation (Anaerobic Digestion)

Anaerobic digestion (bio-methanation, or biogas generation) of organic wastes is an ideal option for treatment-cum-recycling of these. The resultant biogas has about 60% methane (CH_4), and the digested (i.e., stabilized) sludge can be recycled as manure. Anaerobic digestion is a common component of most sewage treatment plants. Technological advances, particularly for treatment of special wastes, have been common in this field. Advances in understanding anaerobic microbiology and engineering have replaced the drawbacks of conventional digesters, leading to evolution of high rate anaerobic systems, e.g., Upflow Anaerobic Sludge Blanket (UASB) Reactor, Anaerobic Fixed Film Reactor (Upflow and Downflow), Expanded/ Fluidized Bed Reactor, and Hybrid Reactor. For example, Tata Energy Research Institute (TERI) had developed a high rate digester based on its Enhanced Acidification and Methanation (TEAM) process, especially suited for food and agro-based industries.

A project, 'Development of High Rate Bio-methanation Processes to Reduce GHG Emission' [ref. 2, 1998 report], has been implemented (1994 onwards) by National Bio-energy Board (NBB, under Ministry of Non-conventional Energy Sources, MNES), and its associated eminent national institutions

[National Environmental Engineering Research Institute, Nagpur, (NEERI), for sewage and leather industry effluents; Central Leather Research Institute, Madras, (CLRI), for leather industry and abattoir wastes; Central Pulp and Paper Research Institute, Saharnpur, (CPPRI), for pulp and paper industry effluents; Indian Institute of Science, Banglore, (IISc), for power generation from biogas; and University of Roorkee, for animal wastes.] The projects completed by 1998 included:

(a) A 4 million litres/day capacity Sewage Treatment plant at Bhubneswar, based on Fixed Film Reactor technology developed at NEERI; biogas is used for cooking.

(b) A Treatment Plant at Medak (Andhra Pradesh), for wastes from a slaughter house dealing with 500-600 buffaloes and 1,500-2,000 sheep/day, based on Upflow Anaerobic Sludge Blanket (UASB) technology, and treating about 2,000 cum of abattoir effluent/day. The treatment gives 75-80% Chemical Oxygen Demand (COD) reduction, 85-90% BOD reduction, and 3,500 – 4,500 cum biogas/day.

(c) A Paper Mill black liquor treatment plant at Muktsar (Punjab): The Mill uses agro-residues such as rice husk, wheat straw, reed and bagasse. Two reactors based on UASB technology treat about 4,000 cum black liquor/day, giving 75% reduction in COD and 50% reduction in BOD, and about 10,000 cum biogas, which is used as boiler fuel, replacing the use of about 20 t./day of rice husk.

Bio-methanation of Dairy Waste at Haibowal, Ludhiana [ref. 2, 2005 report]: 160-170 t. cattle dung is fed to digesters to finally produce 12-13 MWe/day. It is planned to use 235 t. dung/day to recover 20-22 MWe plus organic fertilizer (7 t. having 70% solids and 40 t. having 50% solids), and also reduce GHG emission [vide Agenda 21, Rio, 1992].

A striking example of an advanced technology focused on use of high temperature biological processes integrated with membrane technology to close the water circuits in pulp and paper mills is that of Thermophilic Anaerobic Digestion of MSW, Jukka A Rintala (Finland) [ref. 2, June 2000 report]. The first digester was started at Mustasaat (Finland) in 1990 for MSW and sewage sludge as a mesophilic (at ambient temperature) process, the main emphasis being to stabilize the waste, reduce the waste going to Landfill and reduce GHG emission. In 1996, laboratory scale studies showed that thermophilic digesters can be started with mesophilic process digested waste. In 1997, full scale thermophilic process (at 55^0C) was started. Presently (2000 report), 12,000 t. MSW and some industrial wastes yield up to 0.9 million cum CH_4 /year. The process destroys pathogens better. It is seen that wastewaters can be treated anaerobically even up to $70\text{-}80^0$. This Waasa Thermophilic technology is being now used in other countries also.

2.7.4.4 Aerobic Treatment including Activated Sludge method, &, ‘Composting’

After preliminary treatment, organic matter may be subjected to anaerobic (‘bio-methanation’) or aerobic biological decomposition to make it innocuous and amenable to being dewatered (if in liquid form) before final disposal. Common examples of aerobic treatment are ‘activated sludge’ method (commonly used in wastewater – including sewage -- treatment), and ‘composting’ (appropriate for most of such solid wastes). Composting allows recovery of a more basic fertilizer value in the waste and has lower capital cost and operational problems but no utilizable byproduct such as biogas that is obtained in anaerobic digestion.

2.7.4.5 Miscellaneous

Treatment and disposal of specific wastes usually involves a composite application of two or more of the above processes and/ or specialized processes designed for dealing with certain particular components in the wastes.

Waste handling approaches in Denmark and Switzerland [ref. 2, 1998 report] offer a good example of a composite solution to waste management. In Denmark, it was planned to use Incineration for non-organic and Bio-methanation or Composting for organic wastes. The Government Action Plan aimed at recycling of 40-50% volume of household waste by 2000 and unrecycled waste being incinerated for energy recovery; 20-25% volume being composted or turned to biogas; and Landfills to be discarded. In Switzerland, bio-methanation for wastewater treatment has been an old method as it reduces pollution loads. Biogas plants are prioritized for recovery of energy and fertilizer. A Swiss ordinance requires organic fraction of MSW to collected separately, upgraded and recycled—by aerobic composting or anaerobic digestion.

2.8 Treatment and Disposal of Common Categories of Wastes

Treatment and disposal of wastes being the core of the processes covered under the subject of 'Waste Management', such issues related to the most common categories of wastes, viz. of human waste, of MSW, of municipal and industrial wastewaters, and of toxic/ hazardous wastes (typically automotive waste, e-waste, plastic waste, and bio-medical waste) as well as those related to 'Waste-to-Energy' (WTE) conversion during treatment are being specifically dealt with below (see, respectively, paras 2.8.1, 2.8.2, 2.8.3, 2.8.4 and 2.8.5).

2.8.1 *Treatment and Disposal of Human Waste*

Apart from the practice of 'open defecation' and use of 'dry' type toilets, human waste is being collected through a variety of water-borne systems, which include:

(a) the use of centralized sewerage system *cum* sewage treatment plants, or decentralized sewerage *cum* treatment in waste stabilization ponds/ lagoons, the waste being digested mainly through aerobic, anaerobic or facultative (aerobic *cum* anaerobic) processes;

(b) or the use of localized septic tanks, or various forms of 'bio-latrines', such as aqua privies, taking the waste to an attached tank allowing for an adequate retention period for digestion. The digested waste is discharged locally.

Human waste management system in use in an area may depend on the feasibility of having centralized or decentralized options as well as on the socio-economic status of the population. It may be sanitary or an insanitary system.

In India, despite 'The Employment of Manual Scavengers and Construction of Dry Latrines (Prohibition) Act, 1993' making manual scavenging and construction of 'dry' type toilets punishable with imprisonment and fine, these practices continue on a wide scale. According to the Census 2011, there are still 2.6 million insanitary latrines in India, from which human waste is deposited in open drains or is manually removed. The Government introduced a new Bill in 2012 (not yet passed), requiring, in addition, conversion of all insanitary latrines to sanitary ones and the Indian Railways to introduce environment friendly sanitary toilets on all trains by 2021-22. However, this Bill too leaves 'open defecation, still being practiced by 49.8% of Indian population according to the Census 2011, out of its purview. The Government hopes to eliminate this practice by 2022 through its Nirmal Bharat Abhiyan. Even in slums of Delhi, a substantial proportion of population, particularly children, still uses 'open defecation' for want of adequate public and mobile toilets.

In advanced societies, human waste management is commonly attained through water-borne sewerage system and sewage treatment plants (STP), with septic tanks or similar alternatives being used for isolated habitations. But in India and other developing countries, absence of adequate management of human wastes constitutes a serious social issue and a health hazard. According to a recent report, 2.6 billion people in the world still have no toilet facility. In India, till 2012 only 162 out of 7932 towns and cities had a water-borne sewerage system (first set up in London in 1850 and introduced in India in Kolkata in 1870). Further, not more than 30% of the sewage is treated before it is dumped leading to contamination of water bodies.

The issue of waste management of human waste calls for foremost attention and urgent action.

2.8.2 *Treatment and Disposal of Municipal Solid Waste (MSW)*

To a large extent, management of 'municipal solid waste', also termed as 'garbage' or 'trash', around the world amounts to leaving solid wastes in open dumps and in Landfills (and letting untreated liquid wastes flow into streams, ponds, or just spread over land). In big cities such as Mumbai and Delhi in India, about 0.5 or more kg/head/day of solid waste is generated and its safe disposal is normally the responsibility of respective municipalities. It is usually disposed off over widespread dumping grounds or in nominated Landfills. The waste so dumped decomposes very slowly leading to problems of pollution of air, land and water. Its appropriate segregation at source can be a great help through biodegradable component being converted into compost manure---even at the community level---and a major part of non-biodegradable component being recycled, thus considerably reducing the final volume to be disposed off. Many such experiments have been successful.

Solid waste management is in a poor state in most cities of India. For example, Bangalore which generates 4,000 t. SW/day, underwent a major crisis in September 2012 when the villagers blocked the way to the Landfill to protest against the dumping of untreated waste. As a result, segregation at source has been made mandatory; however, aggregated waste collection still continues. Now a processing unit for each assembly area is being planned. But in a few cities, Chandigarh and Surat being the best examples, the MSW is functioning quite well. In Chandigarh, those violating the regulations under the Punjab Municipal Corporation Act, 1976, are fined, while in Surat anyone littering or making the environment unclean is fined, with higher fines being imposed on hotels and industries, etc. In Surat, the outbreak of plague in 1994 was seen as being due to the failure of the management of MSW. This realization has led to a transformation of the whole system with the civic body and the residents cooperating by adopting the ‘reduce, reuse and recycle’ path and the management of waste being successfully decentralized.

A few European countries have apparently succeeded in finding better solutions for SW. In Sweden, Switzerland, Austria, and Netherlands less than 1% of MSW goes to Landfills, while it is 47% in UK and 99% in Romania and Bulgaria. In developing countries, much of the MSW is left all around and even hazardous waste is dumped along with other waste and harmful gases from Landfills escape into atmosphere.

The US as a whole produces about 2 kg garbage/head/day (it was 1.2 kg in 1960), and only about 30% of it is recycled and composted. New York City produces some 12,000 t./day of MSW, which is then mostly transported to scores of Landfills located up to 1000 km away; a part of it goes to Incinerators in Newark and Long Island; recyclable plastic goes to a plant on Long Island for making plastic lumber, metal waste goes to China, paper waste to Staten Island and thence to Indiana for making cardboard boxes, and glass waste is crushed for use as ‘cover’ for Landfills to keep down dust, rats, odour, and gulls. By 2004, China had become the top waste producer, replacing the US, and by 2020 would need 1400 new Landfills.

The present state of MSW in Delhi is described below in greater detail in para 2.8.2.1 as an important example, and some other striking examples regarding MSW are given below in para 2.8.2.2. Specific cases of MSW pertaining to ‘Construction and Demolition Wastes’ and to ‘Slaughterhouse Wastes’ are dealt with in paras 2.8.2.3 and 2.8.2.4 respectively.

2.8.2.1 Solid Waste Management in Delhi

Municipal Committee of Delhi (MCD), now divided into East Delhi Municipal Committee (EDMC), South Delhi Municipal Committee (SDMC), and North Delhi Municipal Committee (NDMC), covers an area of 1442 km^2. 96% of Delhi’s waste is managed by these three civic bodies, the rest being shared by Delhi Cantonment Board and New Delhi Municipal Committee. Delhi Pollution Control Committee (DPCC) is responsible for the monitoring and licensing functions and Delhi Development Authority (DDA) controls most of the government land. The three main civic bodies serve a population of about 1.7 crores (projected at 2.6 crores in 2020) divided into 12 zones/ 272 wards/ 2373 colonies. At present, they employ about 55,000 sanitary workers and a fleet of about 800 trucks for transporting the MSW and spend about Rs. 1,400 crores/year on waste management and sanitation, 85% of it on waste collection and transport alone.

At present, about 9,000 t./day MSW is generated in Delhi (projected at 15,000 t./day by 2020), while the three civic bodies collect only about 7,900 t./day. Apart from the usual MSW, Delhi also generates daily about 4,000 t. of Construction and Demolition (C&D) waste, 800 t. of plastic waste, 30 t. of e-waste, and 15 t. of biomedical waste. Vide MCD Act, 1957, residents have a duty to deposit household SW into the MCD's collection points (or, *dhalaos*), about 2,500 in number at present. In practice, these are mostly overflowing with the waste spilling over into the open.

About 30% of the MSW is recyclable and another 50% is biodegradable and fit for 'composting'. Hence, with effective 'segregation', only about 20% should be sent to the Landfills. But segregation at source works only if the civic bodies ensure use of separate bins for 'wet' and 'dry' wastes before collection, door to door collection with pick ups too having separate containers, and then supplementing with segregation during transit and at Landfills also, as necessary. In actual practice, only about 15% of Delhi is presently covered under door-to-door collection.

At present, the civic bodies collect and transport MSW to their three old Landfill sites at Ghazipur, Okhla, and Bhalswa and the new (fourth) Landfill site at Narela-Bawana. The Landfill sites at Ghazipur (70 acres; started in 1984; under EDMC), Okhla (56 acres; started in 1994, under SDMC) and Bhalswa (40 acres; started in 1993; under NDMC) have exhausted their life-spans in 2008-2009 but, despite DPCC's instructions to stop any further dumping of MSW in these, the dumping continues for want of alternative sites. The case has gone to Delhi High Court. The three civic agencies have been demanding new landfill sites but DDA has been unable to provide any site for want of suitable land and due to citizens' opposition to having a Landfill site in their neighbourhood. The civic bodies' plea to allow use of the large pits in the Bhatti mines area too is pending in the Court due to opposition by environmentalists. The new site at Narela-Bawana (150 acres; under NDMC) serves only Rohini and Civil Lines zones, and is the only 'scientific' Landfill in Delhi. It is being developed more as a treatment facility than as a dumping site.

Delhi's non-dumping options too are now limited. Burning of waste is no more viable due to environmental concerns and the poor state of 'segregation', and compost plants are not progressing mainly as the compost does not sell. Private sweepers or the residents take most of the waste to the *dhalaos* and ragpickers continue to slog through the waste there and in the Landfills.

In these circumstances efforts are being made to set up Waste-to-Energy (WTE) and compost plants at the Landfill sites and to 'reclaim' the three old sites. At Ghazipur, a WTE plant to handle 1,300 t./day garbage and produce 10 MWe energy is on trial, and dumping is proposed to be allowed only for the waste fit for composting or the WTE plant. The National Highway Authority of India (NHAI) is also considering to utilize the residual inert waste as sub-base material for road construction.

At Okhla Landfill site, a WTE plant to handle 1,300 t./day garbage and produce 16 MWe energy has been mired in controversy due to environmental concerns since it started in January 2012. Sukhdev Vihar residents have sought its closure as it is thought to be releasing harmful dioxins into air. Reports by National Green Tribunal and by the CPCB have concluded that it causes pollution. The matter is presently in Delhi High Court. While 'wet' waste should be segregated for composting, recyclables should be picked out and only non-hazardous 'dry' waste should be fed into the WTE plant but that does not happen primarily due to the poor state of waste segregation under the Municipal Committees in Delhi. Even a report, on stack and ambient air quality, submitted in May 2013 by a commissioner appointed by the National Green Tribunal has found pollutants beyond permissible limits. Earlier it was reported that bottom ash and fly ash inside the plant were not being regulated as per norms. Both for reclamation of the Landfill site and for running the WTE plant as well as the proposed 200 t./day composting plant, apart from funds and technology, land for dumping waste is needed.

Consultants have been hired to study the reclamation of the Bhalswa Landfill site. For the Narela-Bawana site also, a high-tech WTE plant to process 3,000 t./day wastes and to generate 24 MWe energy (likely to generate initially 13 MWe with 1,300 t./day and finally up to 35 MWe with 4,000 t./day garbage), and a compost plant to process 1,500 t./day waste are likely to come up from 2014.

According to the Delhi Master Plan (2021), Delhi needs 1500 acre area for Landfills. But availability of any additional land is becoming less and less likely as time passes. According to a May 2013 report, after the High Court's order regarding Landfill sites, a tentative list of 10 new sites has been prepared by the authorities: near Okhla SLF (60 acres), in Bhatti Mines (450 acres), in Tajpur Jaitpur Pahari (30 acres), in Ghitorni (150 acres), and in Mandi village (100 acres) for the SDMC plus EDMC, &, in Sultanpur Dabas (100 acres), Pooth Khurd (150 acres), near Hamidpur village (27.5 acres), and near Palla village (42.5 acres, and 62.5 acres) for the NDMC. These sites might become available but only after getting environmental clearances and necessary changes in the Delhi Master Plan. The only way out in the meantime is for the civic bodies to ensure scientific segregation of wastes at source and recovery of the recyclables, management of the Landfill sites on 'scientific' and non-polluting lines, and running of properly managed composting units and WTE plants at the Landfills so that only a small fraction of MSW is finally dumped into the Landfills. Otherwise the situation can only become worse.

2.8.2.2 Some Other Case Studies Worth Notice

Vijyawada [ref. 2, 1998 report]: A private company based plant was being set up to produce 20 t. fuel pellets (calorific value=3,400 to 4,000 kcal/kg) from 60 t. MSW/day, for being sold to industries as substitute for coal. The rejected MSW would be disposed off at the adjacent Landfill site.

Pune [ref. 2, 1998 report]: Earlier, out of 900 t. garbage generated/day, only 550 t. was being collected, and 150 t. was being taken by farms or for vermiculture. A Citizens Sanitation Committee was formed in 1997 and it recommended a decentralized administration, with each of the 124 wards as a unit, and a daily/ weekly monitoring system at each of the 12 zones, house-to-house collection through identified 'rag-pickers', adequate number of collection bins, carts for collecting waste in slums, having toilets in slums on pay-and-use basis, segregation of biodegradable wastes during collection, hospital wastes being dealt with in the hospitals, banning of dumping in public places, private sector participation in treatment and disposal of wastes, and having awareness and training campaigns. The corporation tried hard to achieve good results but the efforts soon petered out.

Some European countries [ref. 2, 1998 report]: In European Union, 5.86% of total renewable energy comes from MSW (49.3% in Netherlands, 37.2% in Denmark). Most developed countries opt for Landfills as the main system for disposal of MSW but Belgium, Denmark, Netherlands, Japan, Switzerland, and Sweden prefer incineration. For recovery of energy from wastes, the general trend is to ban disposal of combustible and organic wastes in Landfills. In UK, over 2/3rd of the 400 million t./year of SW now went for Landfills, and the policy target for 2005 was to recover 40% of MSW and recycle or compost 25% of household waste by 2000. In Netherlands, the SW management hierarchy has been: reduction – reuse – Incineration with energy recovery – sanitary Landfill. By 2000, CO_2 emission reduction by 3.5 to 4.5 million t./year is planned. Municipalities collect organic waste (i.e. 'bio-waste') separately, and take 'Garden – Fruit – Vegetable Wastes' for composting and anaerobic digestion for conversion into soil improvers. In Sweden, Landfill of burnable and other organic wastes was being banned, for increased recycling, biological treatment, and Incineration. In Spain, the emphasis has been on Incineration with energy recovery.

[ref. 5, 2013 report]: Existing SW management system in Madurai has been augmented in 2009, involving development of an integrated facility for 350 t./day of MSW. The biodegradable waste is subjected to aerobic composting and non-biodegradable waste is sent to a sanitary Landfill. Household coverage of waste collection has risen to 98% and door-to-door collection to 95%. The project has been implemented on a public-private partnership basis, with a concession period of 20 years.

2.8.2.3 Case of Construction & Demolition (C&D) Waste

With growing urbanization, economic growth, and infrastructure development, the volume of new civil construction and demolition is also bound to keep rising. Hence, the growing generation of the Construction & Demolition (C&D) waste (or *malba*), and the concomitant problems of its management, particularly in metropolitan cities, too becomes an important issue. The C&D waste is just dumped anywhere, on the roadside, in open public spaces, and along or in the water bodies, such as on the Yamuna banks in Delhi, and the immense potential for recycling such waste is largely ignored.

Delhi produces at present about 4,000 t./day of C&D waste. The sole C&D waste processing plant in Delhi at Jehangirpuri can handle only 500 t./day. Already about 90,000 cum, or 10,000 truckloads, of debris has been dumped on the Yamuna banks.

Delhi Government has offered financial incentives for recycling the debris for manufacture of roadside tiles and kerb-stones for footpaths, road dividers, walking tracks, etc. As an example of eco-friendly construction, nearly 3,000 t. of concrete waste is planned to be recycled into products such as pavement tiles at the PWD's recycling plant at Burari and flyash will be used for earth filling and in concrete making. A Supreme Court appointed panel has located 70 sites in north Delhi and 15 sites in east Delhi for dumping the debris, which must finally be taken to the processing and recycling plants. Much greater regulatory effort is needed in this area than is being made. [*Hindustan Times*, 2.5.2013; *Indian Building Congress*, vol.7, issue 3, March 2013]

[ref. 13, 2013]: In a recent Seminar held by Indian Building Congress, it was brought out how the use of pre-engineered construction and the concepts such as those of 'Green'/ 'eco-friendly'/ 'sustainable' construction lays stress on ways and means of minimizing the C&D waste generation during construction, maintenance, renovation and reconstruction, as well as on recycling/ salvaging of not less that 50-75% of the C&D wastes as feedstock for future construction. These also involve using more durable, renewable, efficient, locally available and biodegradable materials. We need to have a definite C&D waste reduction plan.

[*Pioneer* 20.6.2013]: Driven by economic-ecological forces, builders across the world are experimenting with recycling demolished building wastes as materials for new buildings. A new approach, called 'deconstruction' (instead of demolishing a building, it is so dismantled that its elements can be reused, thus reducing both the C&D waste and the Carbon foot-print of new structures) is also being pursued. Organizations, such as the Rebuilding Centre in the US, are thus able to divert nearly 85% of a building's major components for reuse. Authorities in India too should inculcate awareness about reuse of materials from demolished buildings, and how it is different from the currently practiced recycling of rubble such as that of concrete. They should also identify common hazards in 'deconstruction' involving items such as asbestos and lead.

2.8.2.4 Case of Solid Wastes from Slaughter Houses

Most slaughter houses in India function under primitive conditions. Many are small ones and in widely scattered locations, while large ones are mostly located in congested urban areas. Slaughter houses generate substantial amounts of solid wastes, which attract pathogens, flies, dogs, birds and vermin if dumped without treatment. Their disposal by burying or burning would result in loss of valuable byproducts.

Slaughter houses mostly deal with cattle and buffaloes, goats, sheep and pigs through processes of slaughter (done manually in majority of the cases as stunning facilities are not available), dressing (removal of horns, legs, hide, head trimming, demasking, and flaying of abdomen and chest), and evisceration (edible offal being sold, and non-edible becoming solid waste in mechanized slaughter houses). Solid waste generation amounts to about 83 kg/head (27.5% of animal weight) in case of bovines, 2.5 kg/head (17% of animal weight) in case of goats or sheep, and 2.3 kg/head (4% of animal weight) in case of pigs. It is mostly biodegradable and is classified as Type I (vegetable matter) and Type II (animal matter).

In most slaughter house, there is no organized disposal of waste and solid waste goes to Landfills. In a few, dung and rumen are digested or composted. Nearly every byproduct of slaughter houses can be utilized but it is not being done, and hence it comes out as 'waste'. For these wastes, following options are available for effective disposal:

(i) Composting: Both Types I and II can be composted.

(ii) Bio-methanation: An organic solids loading rate of 0.5-0.6 kg/cum/day with solids up to 8% in conventional cattle dung digesters and up to 2.5 kg/cum/day with solids up to 12% in high rate digesters is possible. The digested sludge can be processed as manure and the filtrate recycled for the feed slurry.

(iii) Rendering: In Type II wastes, fat, water and solids are separated by heating and rupturing of the tissue. Fat may be used for edible or industrial purposes and solids (called bone and meat meal) as stock-feed and fertilizers.

(iv) Incineration: In this case, no byproduct is recovered but heat recovery is possible. It has not yet been adopted in India. Non-combustible residue is taken to Landfills.

For large slaughter houses, Bio-methanation for Types I and II wastes, and Rendering for Type II waste are suggested, while for medium slaughter houses the same, along with the alternative of composting, are suggested. For small slaughter houses, the more natural process of composting is suggested.

On the whole, it is necessary to upgrade slaughter houses on modern lines for wholesome meat production and effective recovery of byproducts, recycling of wastes and treatment of residual wastes.

2.8.3 *Treatment and Disposal of Municipal and Industrial Wastewaters*

Seeing the widespread pollution, degradation and depletion and fast deteriorating state of rivers and other water bodies in India, CPCB has issued norms for classification of river stretches into five categories (A - fit for drinking after disinfection, B – fit for mass bathing, C – fit for drinking after conventional treatment, D – fit for fisheries and wildlife, E – fit for agriculture, industrial cooling, etc.) based on specified parameters including those of dissolved oxygen (DO) (min.), biochemical oxygen demand (BOD) (max.), total coliform organisms (MPN) (max.), and pH value. [ref. 4, 2012 report]

The utility, aesthetic and religious value of the natural ecology of the Ganges and other river systems in India is invaluable. Naturally flowing fresh and clean streams meet various water needs of people living close to these, recharge the ground water along their course, improve the farmland fertility through their silt and provide habitat for the diverse life forms. Taking the example of the Ganges-Yamuna river system, which is the life-line of nearly 40% Indians, at many places these are no more flowing as rivers but appear more like badly polluted drainages.

The National Ganga River Basin Authority (NGRBA) was set up (in 2008-09) to make the Ganges and its tributaries free from pollution and degradation. It must not be allowed to fail as did its earlier version of Ganga Action Plan (GAP) (Phases 1 & 2) created in 1985. The desired action would include discontinuing the allowing of even treated sewage being discharged into the rivers and instead using it only for purposes such as irrigation, industrial, non-potable domestic and commercial uses, groundwater recharge, etc., and of industrial effluents and other harmful wastes, such as hospital wastes, entering into the rivers or being mixed with sewage which is to be used for irrigation after treatment.

Wastewater treatment through “Pond System and Plant Based Management of Sewage and Waste Treatment” and using the nutrient rich treated wastewater for farming is the most effective and economical option. The East Kolkata Wetlands system is an ideal example of low-cost wastewater management and recycling for organic farming and sanitation technology (see the end of this para). Organic farming should be promoted for decreasing the non-point pollution of rivers, maintaining soil fertility, reducing water needs of crops and checking ground water degradation. We must develop a policy of minimum interference with the natural flow of our rivers in place of the present practices leading to increasing abstraction and pollution of their waters. In short, we must make our rivers and their tributaries free from entry of industrial effluents, urban sewage and hazardous chemicals from agricultural run-offs.

[ref. 4, 2012 report]: Domestic and industrial wastewaters are a growing concern in fast urbanizing and developing India. Treatment of such wastewaters usually involves costly, elaborate and energy-consuming (a typical figure being 0.634 GWh of energy to treat 1 million cum of sewage) physical, chemical and biological processes. Typically, it undergoes three stages of treatment: ‘primary’ stage in which solids are settled out, ‘secondary’ stage in which organic matter is converted to a carbon-rich sludge, and ‘tertiary’ stage for removal of more organic matter and/ or for disinfecting the effluent. In place of such centralized treatment, wherever land is available, localized 'distributed' sewage treatment in stabilization ponds can provide a much more sustainable and energy-efficient natural option.

There are mature, widely-practised technologies available for generation of energy as a byproduct of sewage treatment, such as incineration and biogas production by anaerobic digestion. Typically, biogas output for each million gallons/day wastewater processed can generate energy up to 35 kW. There are also several novel technologies (e.g. conversion of bio-sludge to fuels, use of sewage sludge as fertilizer, and use of anaerobic membrane bioreactor) that yield valuable fuel/ energy as a byproduct of sewage treatment, but further innovations are necessary to improve their performance, reliability and cost-effectiveness.

India's urban population in 2000 was 310 million leading to generation of 35.6 million cum/day sewage; it is estimated to become about 910 million by 2050 leading to generation of 127.67 million cum/day of sewage. This indicates the enormous scale of the problem as well as the enormous potential for reusing/ recycling treated wastewaters as water resource for agriculture, horticulture and other needs. Appropriate and more sustainable sewage treatment processes are necessary in the context of scarcity of both water and energy resources.

[Press reports, 6 and 11 March, and 3 April, 2013]: Presently, in dry season no water flows in the Yamuna downstream of Delhi and what reaches Mathura is mainly the treated-cum-untreated wastewater contributed by the various drains in and around Delhi. A recent survey by State Forest Department and World Wide Fund for Nature (WWF) India shows that the habitats of the UP river systems, the Ganges, the Yamuna and the Ghagra, are fast degrading; the wild-life is disappearing due the depletion of Dissolved Oxygen (DO). Huge spending to control pollution in the Ganges and the Yamuna in the plains is showing no tangible results, mainly due the large gap between the growing demand and the available capacity for sewage treatment and the lack of fresh water in these rivers. The Yamuna Action Plan III is in operation just as the Ganga Action Plan Phase I & 2 and the NGRBA. Despite Rs. 6,500 crore spent so far to clean up the Yamuna it remains dirtier than before.

The real problem in Delhi is the large scale presence of unauthorized colonies whose number has grown from 1432 in 2007 to 1639 (only 57 having sewers) in 2012. Only 55% of Delhi's population is served by sewer system. Delhi now has 17 sewage treatment plants (STPs) which work only at 63% of their installed capacity. Another report says that 44% of Delhi's sewage is discharged into the Yamuna untreated and that Delhi Jal Board collects and treats only 367 MGD out of 680 MGD sewage generated, and that too despite its having the sewage treatment capacity of 543.40 MGD.

[ref. 5, 2013 report]: There are also reports of effective sewage treatment plants (STP) coming up in some cities. For example, in Lucknow, the Bharwara STP project for 345 ml/d has been developed under Phase II of Gomti Action Plan. It became fully operational in 2011. It is installed with the upflow anaerobic sludge blanket and extended aeration treatment technologies, and is designed for an inlet BOD of 200 mg/l, COD of 500 mg/l and suspended solids of 400 mg/l, and biogas production of 402.5 cum/hour which is planned to be processed to produce CNG. The STP presently handles 292 ml/d of sewage. A project for development of a new sewerage system at Indore is coming up (by 2013) to prevent unrestricted discharge of sewage into the Khan river. It aims to use gravity-based movement and involves laying 14 km of main pipelines and construction of two STPs with a total capacity of 367 ml/d and a main pumping station.

East Kolkata Wetland—A Unique Wastewater Management System **[ref.10]:** When Calcutta came up as a city at first, its wastewater sewers were laid in 1803 so as to discharge into the Hoogly. As the city grew, the sewers, laid against the land slope, started overflowing during the rains and the Hoogly too was getting polluted. The British then built new sewer lines, which instead of going to the Hoogly in the west, led towards the Matla stream in the southeast along the land slope. The Vidyadhari stream took the wastewater through the 'Salt Lake' to the Matla stream which then went through the Sunderbans to the sea. By 1928, the Vidyadhari stream had dried up and in 1929, a fisherman realized that a limited stay of wastewater in the *Bheri* (pond) improved the fishing prospects. So, by 1945, a 28 km long canal had been constructed towards the east taking the wastewater up to the Kultigang stream. A barrage on the canal ensures that the wastewater flows along a small canal along the land slope. As a result, fish rearing

Bheris have replaced the salt water marshy area. The wastewater is now first retained in about 1 meter deep *Bheris* for preliminary stabilization and growth of microorganisms, and then it goes to the fish rearing *Bheris*, from which treated wastewater is released for the rice and vegetable fields, thus achieving recycling of the whole wastewater through production of fish, rice and vegetables. It was assessed in 2005 that in the absence of the *Bheris,* the sewage treatment plants would have to be set up at a cost of Rs. 600 crores. This area (*Ramsaar Anubandh*) was recognized in 2002 by the UNO as a unique set up in the world.

2.8.3.1 Specific Case of Treatment and Disposal of Industrial Wastewater

[ref. 8] : Chemical and process industries, such as petroleum refineries, pulp and paper plants, distilleries, tanneries, textile mills and dairies consume large amount of water and generate almost an equal amount of wastewater having high biochemical oxygen demand (BOD), chemical oxygen demand (COD), turbidity and colour. In addition, such industrial effluents contain variable amounts of organic and inorganic compounds such as lignin, sulfides, sulfates and chlorides that are toxic and non-biodegradable. The problem is more acute in small industrial units due to poor controls.

Industrial wastewaters are generally treated by physico-chemical and biological methods. Among the latter, treatment in ponds, activated sludge (aerobic) plants and anaerobic treatment are commonly employed. High energy requirement in aerobic treatment and longer start up time and need for alkalinity addition and further treatment of the effluent in anaerobic treatment are the drawbacks. Conventional treatment processes like chemical pre-treatment, lagooning and activated sludge treatment are not adequate to meet the prescribed effluent norms for being discharged into the sewers. Hence, in many cases a tertiary polishing stage becomes necessary where methods such as membrane separation, adsorption and coagulation and flocculation are employed. Adsorption has been found to be attractive for the removal of organic compounds.

In case of petroleum, after carbon and hydrogen, sulfur is the most abundant element. Issues of deep desulfurization are becoming more serious because of the increase in sulfur content in the crude oil and lowering of the allowed sulfur content in diesel and gasoline. Removal of thiophene (TH), benzothiophene (BT) and substituted BT has presented particularly major problems and processes such as catalytic oxidation, absorptive desulfurization (ADS) have been explored for the removal of dibenzothiophene from liquid fuels.

Studies have been ongoing for treatment of the various industrial wastewaters by physical, chemical and electrochemical methods which can effectively remove the pollutants, require less energy and costs and generate none or minimal secondary pollutants. Methods are also being developed for disposal of secondary pollutants such as sludge and spent adsorbents and catalysts during treatment processes.

Chemical precipitation (and/ or coagulation) using alum, ferric chloride, lime, ferrous sulfate and polyaluminium chloride (PAC) has been studied for treatment of pulp and paper mill effluent. PAC has been used in treatment of oil-water emulsions.

Treatment of dairy wastewater has been tried by inorganic coagulants such as PAC, ferrous sulfate and potash alum giving 60-70% COD removal which occurs mainly due to charge neutralization and adsorption.

Electrochemical treatment for various types of industrial wastewaters such as distillery, dairy, tannery, dyes and textile printing wastewaters, is an emerging area. The major contribution of these studies lies in finding parameters which maximize the percentage removal of COD and colour and minimize specific energy consumption.

Granular activated carbon is generally used as an adsorbent in treatment of industrial wastewaters. However, several low cost adsorbents such as coal flyash, rice husk ash, bagasse flyash (BFA), etc., are also being tried. BFA has also been used for removal of COD and colour in pulp and paper mill effluents. Two stage treatment using PAC as a coagulant and then BFA as an adsorbent has been particularly effective.

A suspended growth (activated sludge) process in which all major steps occur in the same tank in a ‘Sequencing Batch Reactor’ has been one of the best options for biological treatment of industrial wastewaters having very high concentration of COD, BOD, phenolic compounds and other hazardous pollutants.

Recently enacted environmental regulations require industries to limit gaseous and aqueous emissions containing volatile organic compounds (VOCs). A system has been developed for collection and treatment of VOCs from the effluent treatment plants of petroleum refineries.

The above is only a bird’s eye-view of the vast and complex field of industrial wastewater treatment and disposal requiring sustained research, studies and innovation.

2.8.4 *Treatment and Disposal of Toxic and Hazardous Wastes*

Treatment and recycling of toxic/ hazardous wastes before these may be disposed off presents special and at times serious waste management problems. For example, lead commonly used in manufacture of petrol (now unleaded petrol also being made), lead pencils, paints, batteries, water pipes, sealing cement, vermillion and many modern toys has serious health implications. Hence, necessary regulation by Governments of its removal before disposal of such wastes is essential. CFLs are being recommended these days in place of incandescent bulbs etc. in order to reduce electrical power consumption in lighting. But there are rising concerns over the resultant likely mercury pollution (exposure to elemental mercury as vapour occurs when products containing it break and expose mercury to air) which has serious health hazards. Hence, the Government has decided to set up 50 facilities across India where CFLs can be safely disposed of and mercury in these recovered.

In case of hazardous wastes coming out of hospitals and industries, the Supreme Court has recently even suggested to the Government to form a central monitoring committee. However, Ministry of Environment and Forests has not considered it necessary because of the steps already taken by the CPCB, the State Boards, and the Pollution Control Committee (PCC), and treatment, storage and disposal facilities (TSDF) for hazardous wastes having already been expanded considerably. But the issue still remains open.

[ref. 3: 2007 INAE Seminar on ‘Recycling of Electronics & Automotive Industry’ report]: In the context of ongoing exponential growth of industrial production and urbanization in India, the issue of disposal of engineering goods at the end of their useful life is becoming increasingly relevant. The end-of-life recycling of such goods not only minimizes waste generation and its associated problems of treatment and disposal but it also protects the environment, saves depleting natural resources of materials and energy, and creates a viable employment oriented industry. Automotive goods, electronic goods, and plastic goods, are the three such major sectors whose wastes can be toxic/ hazardous, and which at the end of their useful life can follow the progressive system of Reuse, Remanufacture, and Recycle. The element of recyclability will depend upon features such as ease of dismantling, use of recyclable materials, and elimination of toxic materials being built into the design and production systems. Workable legislation and regulations should be instituted corresponding to the Indian conditions after duly studying the international practices. National guidelines should be prepared on Reduction of Hazardous Waste (ROHS), including offering of tax benefits and incentives to ‘producers’ (both manufacturers and importers) who come forward to set up recycling units. Closed loop material flow should be aimed at in order to minimize consumption of virgin natural resources. The certifying laboratories and training centres should be set up. Demonstration pilot plants will need to be set up. The un-organized recycling industry should be got ‘organized’ by suitable training, by making available appropriate processing technologies, and by providing easy financing. All stake-holders like ‘producers’, consumers, recyclers, and regulators should be brought together for effective waste management through recycling.

In modern societies, following four categories of toxic/ hazardous wastes are regarded as particularly requiring specialized waste management systems:

- Automotive Waste
- ‘Electronic’ Waste (e-waste)
- Plastic Waste
- Biomedical (Hospital) Waste

These are dealt with below in paras 2.8.4.1, 2.8.4.2, 2.8.4.3, and 2.8.4.4 respectively.

There is another very major area of hazardous wastes, viz., **nuclear and other radioactive wastes**, which is not being dealt with here because of its vast non-transparent political and technical ramifications and the very long periods for which such wastes have to be maintained. The issue has been progressively becoming public with the expansion of nuclear power reactors, including in India, as is being witnessed in the case of the new power plant coming up in Kudankulam, which has just been cleared by the Supreme Court despite strong public opposition. The problems involved in the case of Japanese Fukushima, Russia’s Chernobyl and other such cases of nuclear reactors have been well known.

A recent illustrative example of the nature of nuclear ‘wastes’ may be seen in *The New York Times* (US) report (2 April 2013) regarding the treatment plant being set up to stabilize the nuclear wastes at US’s largest environmental clean-up project at Hanford Nuclear reservation in Washington State. The Defense Facilities Safety (DFS) Board has warned that design problems of the plant could lead to chemical explosions, inadvertent nuclear reactions and mechanical breakdown. The waste is also not safe there in leaking tanks as it may put dangerous pollutants into the soil and radioactive sludge and liquids in the tanks produce Hydrogen which could burn and disperse the waste. The Energy Department had signed an agreement in 1999 to start the plant construction but it started only in 2001. The current cost estimates have gone beyond the two year old estimate of $12.2 billion and its completion date is not known. This first-of-its-kind plant needs serious technical issues to be resolved. The need to mix the radioactive waste more thoroughly is being realized in order to break up the Plutonium concentration to avoid any chain reaction, but it raises other problems. The radioactive waste here is a byproduct of nine nuclear reactors being used to produce Plutonium including that used for the atom bomb dropped at Nagasaki in World War II. That the oldest tanks are leaking has been known for decades. The DFS Board says that many of the double shell tanks have enough Hydrogen waste to create a flammable atmosphere. The treatment plant would mix radioactive waste with molten glass to turn it into a solid that shall not break for millenniums.

2.8.4.1 Automotive Waste

Important recommendations made in the Report of the INAE Seminar (2007) on ‘Recycling of Electronics & Automotive Industry’ [ref. 3] include:

(a) Methods developed abroad can be adapted as applicable for recycling of cars and commercial vehicles but we should develop low cost methods for our large volume of two and three wheelers.

(b) The collection centres for end-of-life vehicles (ELVs) should be located close to areas of high vehicle concentration and to metal processor units.

(c) Vehicle manufacturers should provide detailed dismantling information after the launch of any model.

(d) The last owner should be given suitable incentives and made responsible for delivering the vehicle to the collection centre. Heavy penalties may be stipulated for abandonment of old vehicles.

(e) Vehicle ‘producers’, auto component units, S&T units, and Government’s regulatory bodies should work together to improve recyclability. In some countries, the conventional responsibility of producers has been extended to the end-of-life in the ELV policies, defined as the *Extended Producer Responsibility* (EPR).

(f) R&D units should carry out research and technology demonstration units should be set up to understand fully the techno-economic aspects of dismantling and recycling, and recovery of useful materials from shredded residues and their use as fuels, minimizing pressure on Landfills.

(g) Necessary training centres should be set up and the subject be covered under the automotive engineering curricula.

According to the above referred Report, at present, over 2 million cars and nearly 10 million other automotive vehicles are produced/year in India and current automotive population may be around 120 million. The automotive production is likely to grow 5-10% annually for many years to come. This gives an idea of the end-of-life vehicles (ELVs) which must be dealt with every year and the enormous amount of automotive waste generation and loss of scarce resources apart from environmental damage if its recovery is not suitably organized through reuse, remanufacture, and recycling. It is both a major challenge and an opportunity for India. From each 1 m. t. (million tonnes) of ELV scrap, about 0.6 m. t. of steel scrap, 72,000 t. of aluminum, and 30,000 t. each of rubber and plastics and other useful materials can be recovered with efficient dismantling, shredding and recycling. Recycled aluminum needs only 7% of electrical energy needed for its production from the ore.

Already about 35 million vehicles enter the recycling infrastructure each year globally: 13 million in North America, 11 million in western Europe, 5 million in Japan, and the balance in other countries. Typically, over 75% of the automotive materials are profitably recycled, and the rest---automotive shredded residue (ASR)---typically goes to Landfills. Under European Directive 2000/53/EC, (issued in 2003) vehicle life-time is nominally taken as 10-12 years and the last owner addresses the ELV issues. The aim is to achieve reuse and recovery up to 95% by 2015 (including 10% through WTE). Also, under the Directive, the last owner should not have to pay for disposal and recyclers will be licensed for compliance with the anti-pollution requirements. Japan Automobile Recycling Law had come up in 2002 and China’s ‘Statute 307-ELV Standard’ in 2001.

2.8.4.2 ‘Electronic’ Waste (e-Waste)

IT revolution and the fast changing technological developments across the globe have led to ever faster obsolescence and thus to generation of massive ‘wastes of electric and electronic equipment’ (WEEE). This ‘e-waste’ is the fastest growing segment of solid wastes in the world. Regulations have been coming up in many countries to minimize the presence of hazardous substances in electric and electronic equipment (EEE) but the problems with the rising volumes of e-waste management persist. Current global production of e-waste is estimated at 20.25 million t./year.

According to CPCB, ‘e-waste’ in India encompasses the waste of a wide range of used electric and electronic devices such as computers, cellular phones, stereos and household appliances such as refrigerators and air conditioners. e-Waste is growing rapidly in India due to growing consumption resulting from economic growth and falling prices of electrical/ electronic goods.

While major volume of e-Waste is constituted by its packaging, the small amounts of toxic elements like Cadmium, Lead, and Mercury, hexavalent Chromium, plastics, polychlorinated biphenyls, etched chemicals and brominated flame retardants in the products are of much greater concern. Therefore, e-waste must be handled in an eco-friendly manner (an example: the radiation leak case in Mayapuri scrap yard in Delhi in 2010 took a life due to exposure to Cobalt 60). The e-Waste recycling industry is not organized and mostly follows inefficient and unsafe practices for lack of awareness and competence, nor do they have the minimization of e-Waste for ultimate disposal as a perceived objective. Consumer awareness of the environmental impact of e-Waste is also lacking. The ‘producers’ do not have norms for designing goods for recyclability and 'taking back' as is practiced in the West nor are any collection centres mandated by government or provided by the industry.

Ministry of Environment and Forests (MOEF) had notified the 'Electronic Waste Management and Handling Rules (2011)' to come into force from 1 May 2012. These put the onus on manufacturers or the brands based on the principle of *Extended Producer Responsibility* (EPR). But there is lack of public awareness in this regard. Of course, the Government has drawn regulations for the e-waste buyers and the pollution control boards in states would authorize e-waste collecting agencies based on their competency, infrastructure, etc. for recycling the waste. Scrap dealers too can be registered as e-waste collectors under the Rules (2011) provided they have the requisite base and awareness. As the Government had mandated the segregation of e-waste, some areas, such as Ahmedabad Municipality, have taken a lead. On the whole, the Government needs to be much more proactive.

In a recent 'National Conference on E-Waste Sustainability: Needs and Solutions for its Management' (7-8 March 2013) held in Bhaskaracharya College of Applied Sciences, New Delhi, the bare list of the main issues involved shows the immense potential of e-waste management: Implementation of e-waste policy/ regulation, initiatives of Government in reducing e-waste, integrating e-waste and green design, technological development and recycling of e-waste, recovery and reuse of metals/ plastics/ glass from e-waste, role of *Extended Producer Responsibility* (EPR) and of informal recycling in e-waste management, e-waste as pollutant on the ecosystem and humans, shift in design methodologies (green design and de-manufacturing), ROHS compliance and green production, and economic and social aspects of possible reuse of EEE. A multi-disciplinary approach is necessary for collection, sorting, reuse, repair and remanufacture of EEE in order to reduce toxic emissions and save energy. We need to create a culture involving better accountability, traceability and transparency of e-waste information systems and pursuit of the 4R principles of recycle, refurbish, reuse and reduce. The Indo-German Environmental Partnership (IGEP), a co-sponsor of the Conference, is executing an European funded WEEE Recycle project aiming at a collection system for environmentally sound management of e-waste across Delhi, Bangalore, Pune and Kolkata.

According to a press report [*Hindustan Times,* 11.4.2013], as electronic goods manufacturers fear penal action under the Rules (2011) requiring setting up of collection centres based on the European model of the mandatory take back policy, now the International Finance Corporation has created a link between local scrap dealers, recycling companies and manufacturers as the basis for India's first door to door e-waste collection system. It has been just launched in Delhi NCR, Mumbai, Hyderabad and Ahmedabad for the present. Sellers would get reasonable offers to sell their used laptops, printers, TV or refrigerator, etc.

Central Pollution Control Board had estimated that India generated about 0.15 million t. e-waste in 2005; it was 0.33 million t. in 2007 and is likely to grow to nearly 1.85 million t. in 2025. Delhi alone now produces around 30 t./day of e-waste. It is a serious health and environmental hazard as it contains toxic substances. No wonder, already numerous informal and some formal enterprises have come up to handle and treat these wastes. However, as stated earlier, urgent action is needed to legislate an adequate regulatory mechanism assisted by institutional support in science and technology areas, and creation of awareness through producer-consumer sensitization, in order to ensure satisfactory recycling and management of the growing quantum and variety of e-waste. According to one estimate, of the total waste recycled in India, 95% is being done by informal recyclers. Much progress has been made in the European Union and elsewhere, as indicated below, and we may study such examples for our guidance.

[2007 INAE Seminar Report: 'Recycling of Electronics & Automotive Industry', ref. 3]:

Restriction on the Use of Hazardous Substances (ROHS) refers to legislation restricting use of 6 substances in electrical and electronic equipment (EEE) sold in or to European Union (EU) countries, and covers items like computers, cell phones, TVs, fluorescent lamps, household appliances, toys and sports equipment. Its ROHS Directive 2002/95/EC applies to most electronic products with electrical cord or battery. The EU Directive obligates producers of EEE to take back old equipment and to dispose of the final wastes in environmentally sound manner and meet the specified recycling quotas, leading to the maximum possible closed loop material flow. The recycling loop starts with ‘producers’, goes to consumers, then to haulers/collectors and closes with the ‘producers’.

The California ROHS Directive SB20 (2007) is similar to the EU Directive but narrower in scope. Concrete limits (% by weight) allowed under these Directives are: Pb 0.1 (i.e. 1000 ppm), Hg 0.1, Cd 0.01, Hexavalent Cr 0.1, Polybrominated biphenyls (PBB) 0.1, and PBB ethers 0.1. EU’s Directive 2002/96/EC is a complimentary WEEE (waste from EEE) Directive which makes ‘producers’ responsible for meeting the costs of waste collection, treatment and recycling, starting 2006.

Typically, WEEE contains about 30.2% each refractory oxides and plastics, 20.1% copper, 8.1% iron, 4% tin, 2% each nickel, lead and aluminium, and rest 1.4% other items, and is contributed, say, 20% by refrigerators, 15% by consumer electronics, 10% each by monitors and TVs, 30% by household appliances and 15% by information and communication equipment. While tin, copper, silicon, carbon and aluminium can be recovered in bulk and cadmium and mercury in small amounts, a large number of elements can be recovered in traces from the WEEE.

Handling of e-Waste in the unorganized sector constitutes high risk activities. E-Waste disposal may be effected by incineration, open burning or in Landfills.

According to the Basel Convention, imports of second-hand products is prohibited but illegal imports of WEEE do abound in India. A UNO report estimates that 20 to 50 million t. e-waste is being shipped abroad from developed countries as e-waste being full of toxic metals and chemicals, its recycling and disposal are expensive processes. Discarded computers are being sent to poorer countries disguised as ‘donation’ to circumvent the international laws against such dumping. One such case is that of Ghana Digital dumping Ground (Agbogblostrie slum) where 9-10 year old children are seen breaking apart heavy computer monitors. There is so much computer junk there that the soil in the area has got dangerously high levels of cadmium, chromium and lead. The Basel Action Network has established an e-Stewards program to certify recycling centres for e-waste, and San Jose (Silicon Valley) was the first major US city to adopt the program in 2011.

2.8.4.3 Plastic Waste

Historical background of the phenomenal growth in the use of plastics has been briefly indicated in para 2.1.3.

[Press reports: *Hindustan Times*, 4.4.2013 & 1.5.2013]: Plastic waste, being non-biodegradable is not composted nor is most of it being recycled. According to a CPCB report, out of more than 15,000 t. plastic waste being generated daily in India, only about 60% is being collected for being recycled and the rest remains uncollected as ‘plastic waste’. Delhi itself generates about 800 t./day of plastic waste of which 750 t. reaches Landfills; 80% of Delhi’s plastic waste is plastic bags and packaging. Further, 80% of whatever is recycled is being done by unregistered agents. Vide the ‘Plastic Waste Management Rules, 2011’ issued by Government of India, while CPCB should monitor the pollution aspect but it is not accountable for the plastic waste management.

In 2009, on High Court’s directive, Delhi Government had banned use of plastic bags. In 2012 it banned their manufacture also, against which the manufacturers have moved the High Court and the verdict is awaited. The government had banned the use of polythene twice in last three years. In fact, the government, civic bodies and plastic industry need to work together for ensuring plastic waste reduction and for setting up effective collection centres and facilities for its recycling. The citizens need to be sensitized for using non-plastic bags for shopping and not buying goods wrapped in polythene, and to minimize packaging and use reusable bags and avoid satchels for ketch-up/ coffee/ shampoo, etc.

As an instance, the Supreme Court has been examining the demand for a ban on *gutka* products packed in plastic satchels and had asked the municipalities in Delhi, Chennai and Kolkata to suggest ways to control the problem and had also demanded replies from the civic bodies of Bangalore, Agra, Faridabad and Jaipur. With 23 states having banned the sale and manufacture of *gutka*, the Supreme Court is surprised at the overall inaction in practice.

[Other sources:] Ireland instituted a ‘Plastic tax’ on plastic bags and their use dropped by about 90%. In Washington D.C., a 5 cent/bag charge too led to a dramatic decrease. San Francisco had banned plastic bags, but then even throwaway paper bags were seen to be a major waste of precious resources. Hence, a 10 cent/bag fee was levied to discourage single use.

Plastics recovery is working well only in areas having laws requiring producers to be responsible for their plastic goods and packaging, by being required to pay for the schemes for their recovery. In some European countries having take-back programs, 60-80% of these valuable materials are recovered.

Another solution to the problem of ‘Plastic waste’ is visible in the moves just started to have plant based ‘bioplastics’. Here too we need to ensure non-use of toxic/ hazardous chemicals in making these and to make these biodegradable.

Poly-Green, a Philippine company, turns plastic trash from Landfills into gasoline, diesel and k. oil through pyrolysis under an environmentally safe patented system, obtaining 1,600 litres fuel from 2 t. trash daily.

For those wanting to minimize plastic waste generation, two tips may help: a) Avoid disposables as far as possible, e.g. throw-away mineral water bottles and plastic cups and plates, and b) find out exactly what kind of plastics can be recycled locally, and limit yourself to those.

2.8.4.4 Biomedical (Hospital) Waste

[Press reports, up to *Hindustan Times* 23.5.2013]: Biomedical waste includes any solid or liquid waste generated during diagnosis, treatment or immunization of people or animals or in associated research activities, and some of it can be: tissues, organs, body parts, needles, syringes, scalpels and blades. It is potentially highly infectious. Its output volume is growing fast because of the rising number of health care centres of varied categories. Under Bio-Medical Waste (Management and Handling) Rules, 1998, hospitals are required to use colour coded containers for different types of wastes, and employ only authorized agencies to collect and dispose of such wastes at their facilities through methods such as incineration, shredding and deep burial. Delhi, which generates over 15 t./day of biomedical waste (the Comptroller and Auditor General’s estimate puts it at 70 t./day), has two biomedical waste treatment plants and three firms appointed by Delhi Pollution Control Board (DPCC) for handling biomedical waste including its collection, storage, treatment and disposal. In actual practice, a number of hospitals have closed down their incinerators. About 3,800 healthcare units have tied up with the three operators. At present 10 incinerators, 22 autoclaves and three microwave ovens are in place. As yet only a small part is being treated and its management and handling rules are largely not observed.

According to a May 2013 press report, a joint team of CPCB and DPCC, appointed by the National Green Tribunal, had reported that in 33 major hospitals in Delhi (including AIIMS, Safdarjung Hospital, and Ram Manohar Lohia Hospital, and Indraprastha Hospital), bio-medical waste was being disposed of in a most unscientific manner. These hospitals have been given a notice to set things right or face prosecution. Similarly, a large number of hospitals are also violating rules of bio-medical waste management in the National Capital Region. The National Green Tribunal has also directed inspection teams to report on the progress made by the hospitals in the ‘phase out mercury’ programme.

2.8.5 ***Waste-to-Energy (WTE) Approaches***

[ref.2, June 2000 report, &, Sep. 2000 report] : These commonly involve use of methane gas (CH_4) produced from waste treatment through anaerobic digestion from biogas reactors or from Landfills as fuel which may be used for various purposes such as heating or power generation. As biogas from various wastes usually also has H_2S above the limit prescribed for engines for power production, IISc, Bangalore, has developed technology for scrubbing H_2S from biogas being used in such cases. Large quantities of urban and industrial wastes, which are now being disposed off without treatment and lead to pollution of water, air and land, if treated by using scientific technologies, will not only result in reduction of wastes but also in generation of energy. A conservative estimate shows that about 30 million t. solid waste plus 44,000 cum liquid waste being generated/ year from urban areas, and the industrial wastes from sugar mills, distilleries, pulp and paper mills, slaughter houses, tanneries, dairies and poultries etc., have a potential of generating energy to the tune of nearly 1,000 MWe and 700 MWe respectively.

MSW may be converted into fuels broadly under either of the WTE technologies: a) Biological route (such as bio-methanation, sanitary Landfill with gas extraction, alcohol production, etc.); or, b) Thermal route or RDF (refuse derived fuel) (such as incineration, pyrolysis, co-generation, etc.).

WTE projects, using new, innovative and proven renewable energy technologies, in both Demonstration and Commercial types, have been sponsored under the initiatives of National Bio-energy Board (NBB) under MNES. Financial and fiscal incentives have been offered under Ministry of New and Renewable Sources' National Program on Energy Recovery from Urban and Industrial Wastes and under other Programs, including those involving use of high rate bio-methanation processes as a means of reducing Greenhouse Gas (GHG) emissions.

Some interesting examples of successful WTE projects undertaken in recent years are referred below.

A WTE Project at Kanoria Chemicals, Ankleswar [ref. 2, June 2000 report] involves a biogas based 2 MWe capacity plant for handling distillery effluent and also a bio-composting plant for concentrated distillery effluent. The spent waste from molasses based distillery is treated in anaerobic digesters, and then goes for secondary and tertiary treatment before disposal. An advanced technology is used to convert the 1.5-2% H_2S in biogas to elemental sulfur, so that cleaned biogas can be used in special BG engines, and the flue gas is used to generate steam in waste recovery units with each unit. The whole process generates net profit after treatment.

[ref. 5, 2013 report]: Some of the recent examples in Delhi include Timarpur-Okhla WTE Plant and Narela-Bawana MSW Management Facility. The Timarpur-Okhla plant, the first commercial WTE facility in India to convert garbage into electricity, is one of the pilot projects under the Ministry of New and Renewable Energy's (MNRE) programme for MSW. The project has been awarded on a build-own-operate-transfer (BOOT) basis with a 25 years' concession period. It has been developed on the "zero-waste" concept to prevent dumping of MSW at the Bhatti mines. It comprises a refuse-derived fuel (RDF) plant for processing 1,350 t./day of MSW, the treated sewage being used as the process water. It is in operation since 2012 and has also been registered with the UNFCCC (United Nations Framework Convention on Climate Change) and will earn 2.6 million certified emission reductions over 10 years.

The Narela-Bawana facility, expected to be fully operational from 2014, entails burning 4,000 t./day of MSW, and will have facilities for material recovery, treating leachate and trapping harmful gases and RDF, and includes installation of a 24 MW MSW-based power plant. This project is also being developed on a BOOT basis.

[ref. 2, June 2000 report]: An interesting example of converting wastes into bio-fuels in the US is seen in the Biomass Energy Conversion Facility (BECON) of Iowa Energy Centre gearing up to make gasoline substitutes out of the waste stuff, such as ethanol from corn stalks, from bagasse, and from California rice straw, and setting up an Orange Recycling and Ethanol Production Facility. A Company in Kentucky working for organic waste recycling and bringing renewable biodiesel fuels into the market, is setting up 10 rendering plants and 13 plants for handling bakery waste. They annually divert 1.25 million t. of materials including 150,000 t. of restaurant grease. Another Company in Chicago has built a bio-refinery to use recycled yellow grease, and consider that 20 million gallons bio-diesel annually is possible solely from grease collected in the city, thus also reducing the grease going into the wastewater treatment stream. Energy Technology Research Institute, Japan, has developed a high efficiency methanol hydrogen fermentation plant to degrade organic waste like kitchen waste, paper, etc. anaerobically. In the US, experiments have been made to convert agricultural biomass into hydrogen fuel and charcoal (becomes a nitrogen-enriched fertilizer with addition of ammonia formed by a third of hydrogen, remaining hydrogen used as a fuel).

[*Indian Building Congress*, V. 7, Issue 3, March 2013]: Another interesting example of WTE is that of an Australian pilot having planned a 16,898 km Sydney to London flight using 1000 gallon aviation grade diesel derived from melting down 5 t. packaging plastic waste by using a pioneering technology. A Dublin firm, Cyner, will help process the 'end of life' plastic that cannot be recycled and would otherwise go to a Landfill. The technology enables distilling of the plastic most of which is petroleum based, into fuel through pyrolysis. This fuel has already been tested in cars.

2.9 Some Important Implications of Waste Management

Brief comments are given below in order to emphasize certain vital implications of the way the subject of waste management is pursued. These concern important areas of resource and environmental effects, evaluation of alternatives, and 'total costs' involved and their accountability.

2.9.1 *Resource and Environmental Effects*

The subject of waste management has crucial implications in regard to resource conservation, sustainable development and environmental protection. It is closely related to the subject of conservation of scarce material and energy resources, particularly in the context of prevalent consumerist and throw-away life styles, and issues of efficiency of energy consumption in sectors such as buildings and transportation sectors. In major industrial sectors, efficiency in production processes can be considerably improved to minimize the inputs of energy and material resources. Reuse and recycling of industrial, municipal and other wastes in order to recover usable energy and materials resources have a tremendous scope. Recycling of fly-ash (Indian coals typically have 40% ash content), which otherwise presents massive waste disposal problems, for uses such as brick manufacture is an important example.

India's present 'ecological footprint' is 0.87 global hectare (ha)/capita as against 0.48 ha/capita available bio-capacity. The corresponding figures for the US, China, and the World respectively are: 3.86, 0.87, and 1.8 for bio-capacity, and 7.19, 2.13, and 2.87 for ecological footprint. Further, if the world continues to use its finite resources at the present rate, it would need 2.75 planets to meet its needs while it is already eating into the future by using equivalent of 1.5 planets. India is committed to reduce its carbon footprint by 20-25% under the UN Millennium Development Goals. Many industrial and corporate units in India and abroad too are waking up to the reality of scarcity of resources and adopting sustainable production and business models. Some shining examples of the big business in India innovating for a sustainable mode in the field of waste management are: the WIPRO collecting back the e-waste to recycle it (over 260 t. taken back from the users in 2010-11), and Pepsico reducing water usage in paddy transplantation by using direct seeding technology (similarly, Jain Irrigation Works, Jalgaon, making great advances in the propagation of 'drip irrigation' in order to effectively use every drop of water in irrigation). [*Hindustan Times*, 28.4.2013]

[ref. 11(a) & 11(b)]: An illustrative case at the national level is that of the extensive use of the limited water resource in municipal, industrial, agricultural and other sectors and the resultant generation of wastewaters. India has 17% of world's population but only 4% of world's renewable water resources. The National Water Policy, 2002, was adopted as a revised version of the 1987 policy, in order to check overuse, abuse and pollution of the vital water resource and maintain water quality, to ensure maintenance of the river systems and other water bodies, including maintenance of minimum water flows and control on pollution of water sources, and to step up the reuse and recycling of water and observance of the *Polluter Pays Principle*. However, with the still worsening state of the water bodies in India, it is obvious that a much more effective water policy is needed which will ensure demand management based on principles of optimum efficiency in water use, equity, sustainability, high priority in meeting basic needs, and being in consonance with the available resources. This requires action by Government in all fields—such as those of education and regulation, of incentives and disincentives in order to minimize wastages and pollution and optimize reuse and recycling; a much stricter check on leakages and wastages in distribution networks--especially in the municipal sector—and on losses through evaporation-transpiration; progressive tariffs and metering of all consumption; recycling in industrial sector and reuse of treated sewage water; improved efficiency of water use in irrigation and use of micro irrigation (such as 'sprinkler' and 'drip' irrigation), use of saline water for the tolerant crops and other similar practices (e.g., resource-appropriate cropping patterns); use of least water-intensive sanitation and sewerage systems and decentralized sewage treatment plants to the extent possible; and proper treatment and optimum recycling of all sewage and other wastewaters/ wastes before being discharged into rivers and other water bodies in order to ensure their ecological health and needs against heavy pollution.

Most of these requirements have been covered under the 'Draft National Water policy (2012)' (as recommended by National Water Board in its meeting held on 7 June, 2012). However, these recommendations will become effective only to the extent these are duly adopted by the Central and State Governments and are provided with necessary legal, infrastructure, policy and administrative support to ensure implementation.

Similarly effective policies and controls must be pursued in other areas of vital resources.

[ref. 8]: Another example is that of the construction industry in India, which gives little attention towards emission of carbon which badly affects the environment. Low carbon buildings can be designed to release little or no carbon during their life span. Modern buildings consume energy and release carbon in five phases: 1) manufacture of building materials and components (Making 1 t. of steel involves 3,000 kg carbon emission and of cement 900 kg, and making 1000 bricks involves 380 kg of carbon emission), 2) transport of materials, 3) during construction, 4) during use of the building, and 5) on demolition, etc. Some of the techniques available for reducing carbon emission are: to use eco-friendly building materials and 'green' architecture, to have insulated cavity walls and suitable brick laying bonds, and to use local, durable and renewable materials as far as possible.

2.9.2 *Evaluation of Alternatives*

In the case of many large-scale wastes, out-of-box thinking and research and experimentation are needed to evolve and identify suitable alternatives to the traditional treatment and disposal methods which involve an enormous cost in terms of lost material and energy resources. Management of human waste is a typical example. As explained in para 2.8.1, there are numerous options here, such as, a) the flush-cum-long distance sewer transportation plus massive sewage treatment systems; b) the flush-cum-short distance sewer transportation with decentralized sewage treatment; c) decentralized septic tank type solutions; d) decentralized aqua-privies (bio-latrines) type solutions; and, e) composting. The choices made involve significant resource, cost and health implications. Each major waste management option will require comprehensive and on-going studies for socially acceptable and affordable as well as efficient and appropriate waste management systems.

2.9.3 *'Total Costs' and Accountability for various Alternatives*

Traditionally, apparent 'cost' of handling a waste would cover only the direct cost of its 'management' (including the costs of collection, treatment and disposal). However, for a realistic perspective, it is necessary to know the 'total' cost involved in the management of a waste. This would include both the direct as well as the various 'external' (or 'indirect') costs, which also include: (i) 'environmental' costs of pollution and other environmental damage, (ii) 'social' costs to cover health hazards and other effects of insanitation, and (iii) 'resource' costs to account for the loss of scarce resources (which may be minimized by recovery of reusable and recyclable resources). Most of the 'external' costs, being 'notional', need to be carefully worked out. It is, thus, necessary to develop appropriate costing and accounting systems for both the direct and indirect costs of various processes involved in management of different categories of wastes.

It is also necessary to identify various agents accountable for the generation of different wastes so as to determine their respective responsibilities for the 'total costs', and the extent to which the principles of '*Polluter to Pay*' and '*Extended Producer Responsibility*' can be applied in order to discourage waste generation and to ensure its proper and optimized management.

2.10 Policy Issues in Waste Management

2.10.1 *'Vision'*

The national policy regime for waste management in India must start with a bold and inspiring 'vision' or 'goal' which may be defined thus: 'To evolve and implement waste management systems in

India that aim to: (a) minimize waste generation, optimize waste reuse and recycling potential, and adopt sustainable waste collection, treatment, and disposal processes; (b) maximize conservation of material and energy resources; (c) minimize pollution, health hazards and environmental distress; and (d) be technologically sound, socially compatible, and financially affordable and prudent.'

2.10.2 *Need for an Appropriate Institutional System*

The need for having an appropriate institutional set up to provide for administration, studies, science and technology, R&D, surveys, data collection and analysis, management and other institutional services for the multi-faceted and vast subject of waste management in India is obvious. There are a number of institutions, units, and departments, which are presently working on technical and management aspects of wastes in specific fields. Each such institution, unit or department has its own limited scope and range of activity and objectives. For obvious reasons, it would not be concerned with the holistic issues related to the overall subject of waste management, and particularly the related issues of resource conservation, of the scope for waste minimization, of reuse and recycling of wastes, of appropriate collection, treatment and disposal technologies and systems in the national context, and of determination of the 'indirect' cost implications of generation of every kind of waste.

The CPCB and the state level PCBs have been formulating a series of action points for waste management under numerous headings. However, their primary function and emphasis would remain control of various forms of 'pollution' and not 'waste management'.

Therefore, for building up all-India perspectives in respect of all aspects of management of the growing quantum and problems of different categories of wastes, for functioning as a store-house of information and documentation and as a medium of survey, research and development in every field of waste management, and for ensuring that the policies and practices pursued for waste management are socially, materially, financially and environmentally sustainable, it is essential that an appropriate and dedicated institutional network is set up broadly on the lines as proposed below:

(a) At the apex, a National Waste Management Authority, and similar institutions at state levels, in order to deal with policy issues, to advise the Government with regard to necessary legal and regulatory provisions, and to broadly oversee the functioning of other numerous institutions, departments and agencies in areas of administration, R&D, data collection and appraisal and other vital areas related to the subject of waste management.

(b) A corresponding National Institute of Waste Management, and similar set-ups at state levels, having following 'Aims and Objects':

    (i) Conducting studies and surveys of varied categories of wastes being generated in order to build up an all-India database, and documentation and analysis resource structure.

    (ii) Formulation of qualitative and quantitative norms and standards, procedures and evaluation benchmarks in the field of waste management.

    (iii) Development of associated costing and pricing regimes, including 'external' or 'indirect' costs, for various operations in the field of waste management.

    (iv) Providing information and technical services to the Central and State Governments, Local Bodies, industries, and other agencies involved in waste management.

    (v) As coordinating units for the varied agencies engaged in different aspects of waste management, for promotion of R & D activities, for the development of affordable and sustainable waste management systems including undertaking research for technological up-gradation and integration, and for recycling and developing value-added products.

(vi) Providing consultancy and technology transfer services; functioning in partnership with other agencies in various industrial and non-industrial sectors.

(vii) Creating manpower expertise and excellence in the field of waste management through academic courses, specialized courses, and training programmes.

(viii) Creating public awareness through campaigns, seminars and conferences about waste generation, waste reduction, waste reuse/recycling and other aspects of waste management.

(ix) Promotion of environmentally sustainable and resource-conserving options in municipal, transportation, agricultural, industrial, building and construction, and energy production sectors.

(c) Introducing courses and degrees on subjects related to 'Waste Management' in Engineering/ Technology institutions.

(d) Work on specialization in specific categories of wastes in R&D institutions, such as, NEERI, Nagpur, CLRI, Chennai, CPPRI, Saharanpur, and IISc, Bangalore.

(e) Work on 'Waste Management' as a special subject in professional organizations, such as, INAE, and IE (I), for an ongoing review and critical appreciation of its technical, economic and environmental aspects.

2.10.3 ***Need for Legal and Regulatory Frameworks and for Standards and Norms***

Existing legal frameworks tend to prioritize the polluter and not the society or the environment. Existing laws reflect the 200 years old situation when the present implications and consequences of industrial and economic development and population growth in areas such as those relating to non-renewable and scarce resources, pollution, depletion of fossil-fuels, climate change, and waste generation could not have been visualized. Now legal and regulatory frameworks and standards and norms need to emphasize the pursuit of 'clean', 'green' and sustainable technologies and lifestyles. For example, use of toxic materials in manufacturing of various products should be minimized under law. Wastes being 'resources out of place', these need to be reused, recycled and remanufactured to an increasing degree. For example, a 'Waste Recovery – International Partnership (WR)' was formed in Boras (Sweden) in 2006; it inter-connects clusters of universities, municipalities, companies, NGOs in different parts of the world to share knowledge and technology through education, research, collaboration and project management regarding the best practices in waste management and resource recovery, leading to setting up of Demonstration plants.

For a sound Waste Management System, suitable process parameters and methods, and performance indicators, norms and standards, both qualitative and quantitative, are required to be established, covering technological, environmental, social, financial and institutional aspects. The basic objectives would remain minimization of waste generation and optimization of waste reuse and recycling, and efficient waste collection and effective waste treatment and disposal.

2.10.4 ***Need for Accountability Systems as Integral to 'Waste Management'***

Legal and regulatory systems need to be guided more and more by the principles of '*Polluter to Pay*' (PtP) and '*Extended Producer Responsibility*' (EPR) – see para 2.1.6 -- in order to bring about an element of accountability in the generation of any waste. All bodies dealing with 'Waste Management' need to build up a system of accounting of costs and their recovery, fines and punishments as well as incentives, tax concessions and rewards, in order to encourage and optimize compliance with the objectives of minimizing waste generation, efficient waste collection and segregation, maximum possible waste recovery, and effective waste treatment and disposal. For example, "Pay as you throw system" is operating in many cities in the US. Higher amounts are charged for the waste sent to the dumps than for that sent for being recycled. In Kansas, households pay heavy monthly charges so that the waste treatment plants are self-sustaining.

Municipalities should adopt frameworks requiring 'producers' to devise systems for taking back and reprocessing their products at end-of-life. Recycling of their products under the EPR principle should be legally enforced in case of hazardous wastes such as automotive waste, e-waste and plastics.

2.10.5 *Need for Innovative and Evolutionary Approaches*

We need to consider the whole life cycle of any item which comes to the market and have an ongoing process for evolving innovative approaches in pursuance of the basic aims of minimization of wastes, efficient waste collection and segregation, optimal waste recovery and effective waste treatment and disposal. Three striking examples of innovative approaches adopted outside India for 'transforming trash' are being given below in order to emphasize the issue.

1) Food for Waste Programmes [ref. 1, p.13]: A number of Latin American countries have initiated programmes for inducing citizens to recycle food throwaways. In Mexico city, 20 million residents throw about 12,600 t. of trash/day. To curb it, under a program they can exchange recyclable materials, such as glass, paper, cardboard, cans, and plastic bottles for 'green' points, which are redeemed at a local farmers' market for food or seedlings, and the farmers are paid by the City. A similar programs operates in Jundial city in Brazil, while in Curitiba, recyclable materials are exchanged for public transport passes.

2) Converting Waste to Wealth (Boras city—population 0.1 million, Sweden) [ref. 1, p.5]: Boras city has been a pioneer in converting wastes into value-added products since 1986. Laws and regulations, technology, and related economic, environmental and social plans have been developed. Household wastes are now separated into 30 categories. Currently, about 27% of the waste is recycled through private companies, 30% is converted to biogas with the digester sludge being composted, and 43% is combusted to yield electricity and heat. Necessary education programmes for both children and adults have been suitably structured. The municipality provides an instruction booklet to households on how to handle 130 types of waste materials, and black bags for organic and white bags for other wastes. Recycling containers are located within walking distances. Organic waste collected in black bags plus wastes from restaurants, slaughter houses, etc., yield 3 million cum biogas/year, which is upgraded as fuel for buses, trucks and light vehicles. Waste in white bags and other similar industrial waste are taken to the two 20 MW combustion plants, yielding 960 MWh heat and electricity/day.

3) TerraCycle stubs out Cigarette Butts, sets sights on all kinds of 'Non-recyclable' Waste: Recycling entrepreneur, TerraCycle CEO Tom Szaky, who started his company in Trenton, New Jersey (US), has created an alternative to leaving cigarette butts on roadways or into Landfills. In a programme now running up to Spain, TerraCycle collects the butts from volunteers. The butts are broken up, the paper and tobacco are composted, and the filter, made of cellulose acetate, is turned into an ingredient for a wide range of industrial plastic products. It takes 1000 to 2000 butts to make a plastic ashtray and over 200,000 to make a garden chair. Szaky says that up to 2 trillion butts are thrown yearly. TerraCycle similarly handles all manner of other refuse usually bracketed as impossible to recycle. Juice sachets, plastic bottles, pens, coffee capsules, sweet wrappers, tooth-brushes and computer keyboards are all grist for its mill. Some items go to classic recycling and others are up-cycled (e.g. sweet wrappers are used to bind books or joined to make backpacks). Soon it will be doing chewing gum and dirty nappies. Szaky says: "I want to solve the problem of every kind of garbage that exists in the world."

[ref. 12:] Another striking example is that of trying *to convert downtown Atlanta in the US into a 'Zero Waste Zone' (ZWZ)*. In the Atlanta convention district, lakhs of tons of recyclable waste was being sent to the Landfills. In 2008, the Hyatt Regency Atlanta served on average 8,143 meals/ week, whose remains were being sent to Landfills. Now, about 928,000 lb residual food is being sent for composting every year. Every dining plate is scraped clean into the compost containers. Excess food is being donated to the Atlanta Community Bank for the hungry. Even spent fryer oils are collected and converted into biodiesel for use in trucks and buses. The Greenco Environmental collects the residual food from places such as the Hyatt and blends that with wood and yard 'waste' from tree companies, landscapers and municipalities and in 90 days it is composted to high grade manure. The recycling process is also good economics---it is at least cost neutral. In Georgia, 82% of the over 17 million t./year solid waste going to the Landfills included recyclables (paper, plastics, organics). Under the ZWZ concept, the reusable products are being recycled. It is hoped to extend the ZWZ program across the state and beyond.

2.10.6 *Need for Human Resource Development*

Institutionalization of diverse categories of human resource required/ employed in the vast waste management sector, including the issues of training, categorization, and working conditions, is necessary. It is also necessary to build up, and keep upgrading, skilled cadres required for working on various processes for management of different kinds of wastes in an organized manner.

At the same time, the existence of a vast unorganized sector collecting and disposing off a large variety of wastes must also be duly recognized. Sanitary and other workers handling wastes are typically under-paid, their working conditions are mostly unsatisfactory, and their role is under-appreciated. The condition of workers in the informal sector, such as rag-pickers and those dealing with hazardous and other kinds of wastes in unorganized sector, is even worse. We need to develop a policy framework for bringing order into the unorganized sector also.

2.11 Conclusions

'Wastes' are 'resources' gone astray. Evolution of 'modern' civilization, characterized by rising population and growing consumerist lifestyles, has led towards generation of increasing amounts and varieties of 'wastes'. These wastes, not being reused or recycled through natural processes, tend to accumulate more and more and, hence, require to be disposed of suitably, with or without treatment. In a way, the level of 'progress' in modern society may also be indexed to the quantum, complexity, problems and hazards associated with the generated wastes.

The biological species that have co-evolved on earth, tend to ingest natural substances, including 'wastes' produced in nature, and ecological systems subsist more or less on intricate webs of such mutual exchanges and recycling, with practically no resultant 'wastes'. But modern societies produce growing amounts of wastes, which mean loss of scarce and valuable material and energy resources, pollution and ecological degradation, health hazards, and increasing costs of waste management, including further loss of scarce resources, such as land, materials and energy.

Wastes may be as varied as the sources of their generation. Major categories include 'municipal' wastes (solid and liquid), industrial wastes, equipment and machinery wastes, building construction and demolition (C&D) wastes, mining wastes, wastes related to energy production complexes (such as, thermal power plants and petroleum refineries), agricultural and other plant wastes, hazardous and toxic wastes, and animal-related (dairies and slaughter houses) wastes. Extensive studies and experience in the field of waste management show that different types of wastes may require varied action and approaches suited to each specific category and the attendant situations. Important stages relevant in most cases of waste management may be listed as: a) Minimization of waste generation ('prevention' and 'reduction'); b) Efficient waste collection and classification ('sorting' and 'segregation'); c) Optimal recovery ('reuse' and 'recycling') of wastes as resources at each stage; and d) Effective waste treatment and disposal, so that the minimum possible amounts remain to be disposed at the end of the waste management cycle. Special types of action may be necessary in management of 'hazardous' or 'toxic' wastes, such as, automotive wastes, 'electronic' waste, plastic waste and bio-medical waste, and other special wastes such as, radioactive wastes.

Governments and other authorities need to develop appropriate institutional systems, including legal and regulatory frameworks, standards and norms, and incentives and disincentives for adequate controls on generation of wastes and their subsequent management. Social accountability for waste generation may be ensured also through application of principles such as *Extended Producer Responsibility* (EPR) and *Polluter to Pay* (PtP).

We need to keep learning from nature as well as from instances of innovative waste management being continuously evolved globally. Authorities and other major actors should spread awareness about the subject among general public, and ensure that necessary R&D efforts, academic courses and studies, documentation and suitable training courses and technologies are developed and instituted in the field of waste management.

We have no option but to progressively change over from a 'throw-away' society to a society which minimizes waste generation, practices utmost reuse and recycling of wastes, and effectively treats and disposes of the non-recoverable wastes.

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This Paper was initially based on the Concept Paper prepared by the author (Dr. Y. P. Anand) for establishment of an 'Indian Institute of Waste Management', which was finally set up by Vignan Bharati with financial assistance from the MP State Government, as 'International Institute of Waste Management' at Bhopal in 2009. Thereafter, this Paper has been progressively updated and enlarged in its scope based on the following main sources, apart from numerous newspaper reports:

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Chapter 2(S)

Waste Management

Brief Synopsis and Suggested Plan for Action

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Chapter 2(S)

Waste Management

Brief Synopsis and Suggested Plan for Action

S.2.1 Brief Synopsis

S.2.1.1 A 'waste' is 'a resource *out of place*'. It represents inputs of valuable and scarce material and energy resources, it causes environmental pollution and damage and health hazards, and its collection-cum-disposal systems are themselves becoming increasingly costly and cumbersome.

S.2.1.2 Effective 'Waste Management' is especially relevant for modern societies as modern civilization has come to mean an increasingly avoidable consumption of resources including those for transportation, packaging, storage, and distribution. A sustainable future for humankind means minimizing generation of wastes, reuse and recycling of wastes as resources, and developing a personalized responsibility for management of the wastes generated. It also means a growing need for appropriate laws and regulations, studies and documentation, R&D and training infrastructures in areas relating to the management of wastes.

S.2.1.3 Categories of wastes may be as numerous as their sources of generation. However, the main categories include Municipal/ 'Sanitation' Wastes (e.g. human wastes, solid wastes, and wastewaters), Hazardous/ Toxic Wastes (such as automotive waste, electronic waste, plastic waste and bio-medical waste), Industrial Wastes, Equipment and Machinery Wastes, Construction and Demolition (C&D) Wastes, Dairy and Slaughterhouse Wastes, Mining Wastes, Wastes from Energy Production Complexes, and Agricultural and other Plant Wastes.

S.2.1.4 Management of different wastes requires varied approaches suited to the respective waste categories as well as their attendant situations. The 'waste management' solutions should try to mimic nature's "no waste" and "full recycle" principles. Important Options and Stages in 'Waste Management' are: '*Minimization of Waste Generation*' ('prevention' and 'reduction'), '*Collection and Classification*' ('sorting' & 'segregation'), '*Recovery through Reuse & Recycling*', and '*Treatment and Disposal*'. Highly polluting, hazardous or toxic wastes may require specialized treatment before being recycled or disposed of into land, water or air.

S.2.1.5 As material and energy resources go into the formation of all products which end up as 'wastes' and even into the 'waste management' processes, the first option in Waste Management should be how to minimize the generation of wastes itself through 'prevention' and 'reduction', such as, by increasing the efficiency of production processes, enhancing the durability of products, minimizing packaging, storage and transportation inputs, and improving 'repair' and upgradation services, and discouraging the 'throwaway' tendencies by levying suitable costs.

S.2.1.6 Different categories of wastes, e.g., organic *v*. inorganic wastes, hazardous *v.* non-hazardous wastes, isolated *v*. concentrated wastes, municipal *v*. industrial *v*. mining *v*. agricultural wastes, will require different strategies for their collection and classification. For example, suitable classification and segregation is the key to the Municipal Solid Wastes (MSW) management, but in India this task has been usually left to the ubiquitous 'rag-pickers'.

S.2.1.7 The subject of reuse/ recycling of different categories of wastes, both organic and inorganic, to the extent it may be practically, technologically and financially feasible, needs much greater study and technical and management inputs than is being done.

S.2.1.8 The processes of 'Minimization of Waste Generation' and 'Optimum Waste Recovery' remain as relevant during the stages of 'Waste Treatment and Disposal' as before. In most cases, a waste is required to be suitably 'treated' before it may be disposed off lest it may pollute and damage the environment or may become a serious health hazard. The capacity of particular land or water bodies (sinks) and the concentration of particular wastes also determine the limits to what the wastes may be treated before being disposed off.

S.2.1.9 The various stages in treatment of different wastes maybe categorized as preliminary, primary, secondary, and tertiary, and the treatment processes may be physical, chemical or biological, or a combination of these. Hazardous and radioactive wastes would require special treatments.

S.2.1.10 The most common methods of treatment and disposal adopted for municipal and industrial wastes are use of Landfills, Incineration, Bio-methanation (Anaerobic Digestion), and Aerobic treatment including Activated Sludge method and 'Composting', or a combination of these. Landfills are the most commonly employed method for municipal solid wastes (MSW), but present problems of generating methane (a Greenhouse Gas), seepage of toxic leachate and inadequate treatment of unsegregated wastes. CPCB's directions such as for use of only 'Secured/ Engineered' sanitary Landfill practices, separate disposal of hazardous wastes, the wastes being inert, and Landfill sites being an adequate distance away from the localities, etc. are rarely observed. A 'Scientific' Landfill would have provision for segregation and waste recycling/ processing through production of compost and fuel, and for prevention of seepage of pollutants.

S.2.1.11 Incineration reduces the waste volume substantially, but can handle only such non-biodegradable waste which can be burnt. Anaerobic digestion is an ideal option for treatment-cum-recycling of organic wastes and much more advanced technologies are being evolved in this field.

S.2.1.12 The Paper deals in detail with the issues related to the most common categories of wastes, viz. of human waste, of MSW, of construction & demolition (C&D) waste, of slaughterhouse waste, of municipal and industrial wastewaters, of toxic/ hazardous wastes (typically automotive waste, e-waste, plastic waste, and bio-medical waste), as well as those related to 'Waste-to-Energy' (WTE) conversion options during treatment. It includes a detailed study of the system of solid waste management in Delhi, particularly the state of its four Landfills, and the unique case of 'East Kolkata Wetlands Management System' for Kolkata wastewater.

S.2.1.13 The Paper highlights certain vital implications of the way a waste is 'managed', including those concerning resource and environmental effects, evaluation of alternatives, and accountability for the 'total costs' involved. Out-of-box approaches are needed to evolve suitable alternatives to the traditional treatment and disposal methods. The 'total' cost of management of a waste would include the 'direct' as well as the 'indirect' costs, such as, 'environmental', 'social' and 'resource' costs. It is also necessary to determine to what extent the application of principles of '*Polluter to Pay*' and '*Extended Producer Responsibility*' can ensure proper waste management.

S.2.1.14 The paper defines an inspiring 'vision' for the national policy of waste management and recommends an appropriate institutional system for this, including setting up of 'Waste Management Authority' and 'Institute of Waste Management' at national and state levels, legal and regulatory frameworks, standards and norms, and accountability systems. We need to keep learning from instances of innovative waste management being evolved globally, spread awareness about the subject, and develop necessary R&D efforts, academic studies, documentation, training courses and technologies.

S.2.1.15 We have no option but to progressively change over from a 'throw-away' society to a society which minimizes waste generation, practices utmost reuse and recycling of wastes, and effectively treats and disposes of the non-recoverable wastes.

S.2.2 Suggested Plan for Action

S.2.2.1 '**Vision'**

The national policy regime for waste management in India must start with a bold **'vision'** defined thus: 'To evolve and implement waste management systems that aim to: (a) minimize waste generation, optimize waste reuse and recycling potential, and adopt sustainable waste collection, treatment, and disposal processes; (b) maximize conservation of material and energy resources; (c) minimize pollution, health hazards and environmental distress; and (d) be technologically sound, socially compatible, and financially affordable and prudent.'

S.2.2.2 **Need for an Appropriate Institutional System**

The need for having an appropriate institutional set up to provide for administration, studies, R&D, surveys, data collection and analysis, other institutional services for the vast multi-faceted subject of waste management is obvious. There are a number of institutions and departments presently working on technical and management aspects of wastes in specific fields. Each such institution or department has its own limited range of activity and objectives. For obvious reasons, it would not be concerned with the holistic issues related to the overall subject of resource conservation, of waste minimization, of reuse and recycling of wastes, of appropriate collection, treatment and disposal technologies and systems.

S.2.2.2.1 The Central Pollution Control Board and the state level Pollution Control Committees have been formulating a series of action points for waste management but their primary function would remain control of various forms of 'pollution' and not 'waste management'. Therefore, for building up all-India perspectives in respect of all aspects of management of growing quantum and problems of different categories of wastes, and for ensuring that the policies and practices pursued for waste management are socially, environmentally and financially sustainable, a dedicated institutional network is necessary, broadly on the lines as proposed below:

a) A National Waste Management Authority, and similar institutions at state levels, in order to deal with policy issues, to advise the Government and to oversee the functioning of other institutions, departments and agencies in areas of administration, R&D, data collection and appraisal and other areas related to the subject of waste management.

b) A corresponding National Institute of Waste Management, and similar institutions at state levels, in order to conduct studies and surveys of varied categories of wastes for an all-India database and analysis resource structure, to formulate norms and standards, procedures and evaluation benchmarks in the field of waste management, to develop associated costing and pricing regimes, to function as advisory bodies to the Government, Local Bodies, industries, and other agencies involved in waste management, to provide consultancy and technology transfer services, to create manpower expertise and excellence in the field of waste management, to create necessary public awareness, and to promote environmentally sustainable and resource-conserving options in major sectors of waste generation.

c) Introducing courses and degrees on subjects related to 'Waste Management' in Engineering/ Technology institutions.

d) Work on specialization in specific categories of wastes in R&D institutions, such as, NEERI, Nagpur, CLRI, Chennai, CPPRI, Saharanpur, and IISc, Bangalore.

e) Work on 'Waste Management' in professional organizations, such as, INAE, and IE (I).

S.2.2.3 **Need for Legal and Regulatory Frameworks and for Standards and Norms**

Existing laws reflect the 200 years old situation when the present implications and consequences of industrial and economic development and population growth in areas relating to non-renewable and scarce resources, pollution, fossil-fuels and waste generation could not have been visualized. Now legal and regulatory frameworks need to emphasize pursuit of 'clean', 'green' and sustainable technologies and lifestyles. Use of toxic materials in manufacturing of various products should be minimized under law. Wastes being 'resources out of place', these need to be reused, recycled and remanufactured to an increasing degree. For a sound Waste Management System, suitable process parameters and methods, and performance indicators, norms and standards, both qualitative and quantitative, are required to be established, covering technological, environmental, social, financial and institutional aspects.

S.2.2.4 **Need for Accountability Systems as Integral to 'Waste Management'**

Legal and regulatory systems need to be guided more and more by the principles of '*Polluter to Pay*' (PtP) and '*Extended Producer Responsibility*' (EPR) in order to bring about an element of accountability in the generation of wastes. All bodies dealing with 'Waste Management' need to build up a system of costs and their recovery, fines and punishments as well as incentives and tax concessions, in order to optimize compliance with the objectives of minimizing waste generation, efficient waste collection and segregation, maximum possible waste recovery, and effective waste treatment and disposal of wastes. Recycling of their products by 'producers' under the EPR principle may be got legally enforced in case of hazardous wastes such as automotive waste, e-waste and plastics.

S.2.2.5 **Need for Innovative and Evolutionary Approaches**

We need to consider the whole life cycle of any item which comes to the market and have mechanism for evolving innovative approaches in pursuance of the basic aims of minimization of wastes, efficient waste collection, optimal waste recovery and effective waste treatment and disposal. There are striking examples of innovative approaches being adopted outside India for 'transforming trash', such as, 'Food for Waste Programs' in a number of Latin American countries for inducing citizens to recycle food throwaways, 'Converting Waste to Wealth (in Boras city, Sweden) Program' for converting wastes into value-added products, and TerraCycle in New Jersey, USA, for collecting cigarette butts in various countries and turning the paper and tobacco components into compost and the filter into an ingredient for industrial plastic products, and also recycling/ upcycling all manner of other refuse usually bracketed as impossible to recycle, such as juice sachets, plastic bottles and computer keyboards. Another example is that of trying to convert downtown Atlanta in the US into a 'Zero Waste Zone', by measures, such as, by sending the residual food for composting, donating excess food for the hungry, converting fryer oils into biodiesel, and recycling the reusable products in the solid waste.

S.2.2.6 **Need for Human Resource Development**

Institutionalization of diverse categories of human resource required in the waste management sector, including the issues of training, categorization, and working conditions, is necessary. At the same time, the existence of a vast workforce already employed for collecting and disposing off a large variety of wastes must also be recognized. Working conditions of sanitary and other workers handling wastes are mostly unsatisfactory. The condition of workers in the informal sector, such as rag-pickers and those dealing with hazardous and other kinds of wastes in unorganized sector, is even worse. We need to develop a policy framework for bringing order into the unorganized sector also.

Chapter 3

Water – Meeting the Future Challenges

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Chapter 3

Water – Meeting the Future Challenges

3.1 Introduction

3.1.1 *Water Resource – A Global Perspective*

Water is a natural resource, fundamental to life, livelihood, food security, and sustainable development. It is also a scarce resource. Although more than 70% of our Earth's surface is covered by water, only about 2.5% of all water on earth is fresh water. Nearly 70% of that fresh water is frozen in the icecaps of Antarctica and the Arctic region. Most of the remainder is present as soil moisture, or lies in deep underground aquifers as groundwater, not accessible for human use. Less than 1% of the world's fresh water is accessible for direct human use. This is the water found in lakes, rivers, reservoirs and those underground sources that are shallow enough to be tapped at an affordable cost. Only this amount is regularly renewed by rain and snowfall, and is therefore available on a sustainable basis.

(http://www.globalchange.umich.edu/globalchange2/current/lectures/freshwater_supply/freshwater.html)

Humans are over-consuming natural resources at an unsustainable rate. Around 3.5 planet earths will be required to sustain the current lifestyle of the average European or North American. Water scarcity already affects almost every continent and impacts more than 40 percent of the world's population. By 2025, an estimated 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world's population could be living under water stressed conditions (FAO, 2012). Most population growth will occur in developing countries, mainly in regions that are already experiencing water stress, and in areas with limited access to safe drinking water and adequate sanitation facilities. (World Water Development Report , 2012.)

In its latest report for 2013, The World Economic Forum has identified Water Supply Crisis as one of the top 5 global societal risks; in top 5 under both the selected parameters of "Impact" as well as "likelihood of occurrence"

3.1.2 *Water Resource -Indian Perspective*

3.1.2.1 Overview

India is lucky to have plenty of rainfall. Actually it ranks among the top 10 countries of the world with regard to the availability of total fresh water resources. However, due to India's very large population (17.5% of the world's population), the per capita availability remains low. Moreover, a substantial portion of available water remains unutilized due to an uneven distribution of rain fall over India's geography, a short window of rainy season, inadequate storage capacity, lack of efforts on rain water harvesting and artificial recharge of ground water, and a lack of a unified perspective in planning and management of this scarce resource. Out of a total annual rainfall of 4000 bcm only about 1086 bcm remains available for utilization (about 25% of total rain fall). This too is unevenly distributed across the regions and river basins. As a result, except for a few water surplus basins, all other basins remain water stressed . The problem is further compounded by the contamination of water due to untreated domestic and industrial waste , pesticide intrusion from agriculture, and saline intrusion. According to the water availability figures of 2010, about 113 million people are living in zones of absolute water shortage and another 210 million in the zones of chronic water shortage. It is felt that if the present trend continues India will face a major crisis both for its food security as well as drinking water needs of its large population. Water scarcity will also threaten India's delicate ecological system. The Impact of climate change will in all likelihood worsen the situation further. It is felt that water, if not properly managed, could become a limiting factor to India's social and economic growth.

3.1.2.2 Demand and Usage

The National Commission for Integrated Water Resource Development (NCIWRD) has estimated that by 2050 the total demand of water to cater for the projected population of 1581 m will be 1180 bcm.

The availability of utilizable water at 1086 bcm seems to be just about adequate to cater to the total projected water demand in 2050 of 1180 bcm. However, unequal distribution of the available water across regions and most of the rain falling in a short window of 4 monsoon months leaves many areas severely water stressed. There will be an additional demand of at least 353 bcm for maintaining the ecosystem to category D (largely modified ecosystem), which may deepen the water crisis. Water Resource Group has estimated a supply- demand gap of 756 bcm by 2030. (This estimate appears to be on the higher side). Inter-basin transfer of water through river linking projects has remained sluggish due to high capital costs, opposition from social activists on the grounds of adverse social and ecological impact, and reluctance on the part of the donor states. In business as usual scenario India seems to be heading towards a serious water crisis.

The agriculture sector is the most dominant sector for water consumption. In 2050 it is projected to consume 68% of the total water requirement, followed by 9.5% for drinking water, 7% for industry and 6% for energy. The balance 9.5% will be required for other uses. Since canal irrigation has reached a plateau in the agriculture sector, most of the additional demand will met by the ground water. Efficient management of canal and ground water irrigation therefore takes the central stage. Requirement of drinking water is projected to be 9.5 % of the total water demand and therefore should not be a cause of concern, provided it gets the right priority in allocation and is efficiently managed and regulated. Although at the macro level water availability seems fine but due to unequal distribution of the available water across geographies, many basins will remain water stressed. Rain water harvesting and artificial ground recharge can help, but only to a limited extent. Demand side management and inter- basin water transfer from surplus basins to deficient ones, therefore, assumes great importance.

3.1.3 *Scheme of Presentation*

There are severe competing demands for water from several sectors such as agriculture, drinking water, sanitation, energy, industry, environment etc. The scope of this Paper is limited to analyzing and discussing the demand from the two most important sectors viz water requirement for agriculture, and drinking water for urban and rural population. The paper also includes a discussion on the impact of climate change, National River linking Project, and future challenges in meeting the water demand in the near term (2025) and in the long term (2050).

The Paper begins with an overview of the water resources development in India (para 3.2), followed by the requirement of water for agriculture, which includes both surface (canal) and underground water resources (para 3.3). This is followed by an analysis of the demand for drinking water in urban areas and the rural areas (para 3.4). An analysis of the impact of climate change is next (para 3.5) followed by the much debated project of the inter basin water transfer (National River Linking Project-para 3.6)). The Paper ends with analyzing the challenges India faces for food and water security in the near and the long term (para 3.7), followed by the recommendations (para 3.8)

Each para has its own conclusions and references at the end. The National Water Policy and a Case Study of Manila Water and Sewerage Concessions have been annexed at the end.

3.2 Water Resource Development in India

3.2.1 *Earth's Water Resources*

Over 70% of our Earth's surface is covered by water. Although water is seemingly abundant, the real issue is the amount of fresh water available.

- The total volume of water on Earth is about 1.4 billion cu km

- 97.5% of all water on Earth is salt water, leaving only 2.5% as fresh water
- Nearly 70% of that fresh water is frozen in the ice-caps of Antarctica and Arctic regions; most of the remainder is present as soil moisture, or lies in deep underground aquifers as groundwater, not accessible for human use.
- < 1% of the world's fresh water is accessible for direct human use. This is the water found in lakes, rivers, reservoirs and those underground sources that are shallow enough to be tapped at an affordable cost. Only this amount is regularly renewed by rain and snowfall, and is therefore available on a sustainable basis.

  (http://www.globalchange.umich.edu/globalchange2/current/lectures/freshwater_supply/freshwater.html)

Humans are over-consuming natural resources at an unsustainable rate. Around 3.5 planet Earths would be needed to sustain a global population achieving the current lifestyle of the average European or North American. (Source: World Water Development Report, 2012.)

3.2.2 *Indian Overview*

India is lucky to have plenty of rainfall. Actually it figures in top 10 countries of the world with regards to availability of total fresh water resources.(Table 1).

Table 1 : List of top 10 Countries by total Renewable Water Resources

Rank	**Country**	**Total renewable water resources (bcm)**	**Year of Information**
1	Brazil	8,233	2000
2	Russia	4,498	1997
3	Canada	3,300	1985
4	United States	3,069	1985
5	Indonesia	2,838	1999
6	China	2,830	1999
7	Colombia	2,132	2000
8	Peru	1,913	2000
9	India	1,908*	1999
10	Congo, Democratic Republic of the	1,283	2001

Source: Wikipedia

*Present estimate is 1953 bcm

India gets nearly 4000 billion cubic metres (bcm) of annual rainfall. Of this, after considering the natural evaporation/transpiration, only about 1953 Billion Cubic Meter (bcm) flows naturally through rivers and aquifers (48.8% of the total annual rainfall). The Ministry of Water Resources (MoWR) estimates that of this, the total utilizable water is only 1086 bcm; the remaining 867 bcm which remains unavailable is made up of 831 bcm as surface water and 36 bcm as ground water. Out of available 1086 bcm utilizable water , 690 bcm is surface water (63.6%) and the remaining 396 bcm is ground water (36.4%). (Fig. 1)

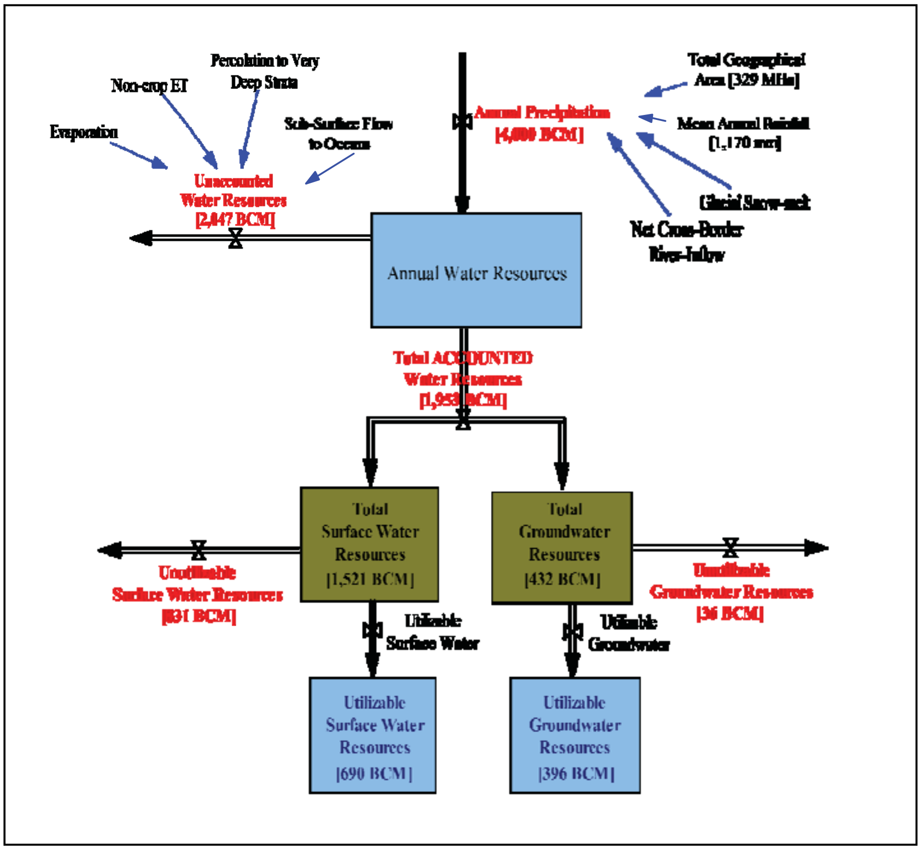

Fig. 1 : India's Water Resources

3.2.3 *Resources and Demand*

Inspite of India being in top 10 countries of the world in terms of total availability of fresh water, its per capita availability is very low due to its large population. India has 16% of the world's population but only 4% of the total available fresh water. A global overview puts this in perspective. (Table 2) :

Table 2 : Water Availability and Population

Region	Water Availability	Population	Ratio
Australia and Oceania	5%	<1%	5.00
South America	26%	6%	4.33
North and Central America	15%	8%	1.85
Africa	11%	13%	0.85
Europe	8%	13%	0.65

(As per Census 2011, India's population stands at 17.5% of the world's population)

India’s finite and fragile water resources are stressed and depleting, while sector demands (including drinking water, industry, agriculture, and others) are growing rapidly in line with urbanisation, population increases, rising incomes and industrial growth. This has resulted in declining per capita availability. (Table 3).

Table 3 : Per Capita Availability of Water in Cubic Metres Per Year

Year	Per Capita Water Availability in m3 per year
1947	6008
1951	5177
1991	2209
2001	1820
2004	1700

*Projections

Source : Ministry of Water Resources - Report of the Standing Sub Committee (according to CWC ,per capita availability in 2010 has reduced further to 1588 m3 /year)

According to the Food and Agriculture Organisation (FAO), **the per capita availability of less than 2,000 m3/year is defined as a water-stressed condition, and the per capita availability below 1,000 m3/year is termed as a water-scarce condition.**

Due to a 3-fold increase in population during 1951–2010, the per capita availability of water in the country as a whole decreased from 5,177 m3/year in 1951 to 1,588 m3/year in 2010 (CWC 2010).

This suggests, that at a macro level, India is in a water-stressed state. The story at the local/regional level is far starker. Increasing shortages are felt at local levels which can spread to the regional level as the population continues to grow. India is divided into 20 river basins. Out of these, 14 basins are in a water-stressed condition . The disparity among river basins is wide. The Brahmaputra-Barak basin has a total water availability of 11,782 m3/per person. On the other hand in river basins, such as Sabarmati and east flowing rivers (Pennar and Kanyakumari), the availability of water is as low as 260 m3 per person per year . (India Infrastructure Report - 2011)

According to water availability figures of 2010, about 113 million people are living in the zone of absolute water shortage and another 210 million in the zone of chronic water shortage (derived from data from CWC and CGWB).

How dire is India's water situation? UNICEF states that only one-quarter of the population in India has access to drinking water on their premises, and only 88 percent of those living in the region are able to drink from improved water sources. According to the organization's most recent statistics available from 2008, only 31 percent of India's population has access to improved sanitation, and in rural areas, that number drops to a meagre 21 percent.

The stress on water resources (both surface and groundwater) is increasing rapidly due to rising demands of various users and the deteriorating quality of water. In many regions in India the extraction of groundwater is more than the recharge .The pollution of water resources caused by discharge of untreated municipal sewage and industrial effluents in rivers and the sea, and agro-chemicals penetration in groundwater has further exacerbated the availability of good quality water.

In short, the country’s fragile resources are stressed and are depleting fast, both in quantity and quality.

Preserving the quality of water and managing multiple demands on it require an integrated water management strategy. The problem, however, is that water is a state subject and its management is spread across multiple organizations with hardly any coordination. This has posed difficulties in streamlining management issues. Another challenge in the management of water is that state boundaries do not coincide with the geographical boundary of the resource i.e the river basin. Though the National Water Policy, 2002 (as also the draft NWP 2012) recognize that river basins should be the basic hydrological unit for integrated planning and development of water resources, this has not happened so far.

Climate change is expected to exacerbate the problem by causing erratic and unpredictable weather, which could drastically diminish the supply of water coming from rainfall and glaciers. As demand for potable water starts to outstrip supply by increasing amounts in coming years, India will face a slew of consequential problems. There will be a constant struggle over water, between farming families and urban dwellers, environmental conservationists and industrialists, minorities living off natural resources and entrepreneurs seeking to commodify the resource base for commercial gain.

3.2.4 *Demand and Usage*

Working with the assumption that irrigation efficiency will increase to 60% from current levels of 35-40%, water demand in bcm by different sectors has been estimated by the National Commission for Integrated Water Resource Development as, (Table 4) :

Table 4 : Water Demand (in bcm) by Different Sectoral Users in India

Sector	2010	2025*	2050*
Irrigation	557	611	807 (68)
Drinking	43	62	111 (9.5)
Industry	37	67	81 (7)
Energy	19	33	70 (6)
Others	54	70	111 (9.5)
Total	**710**	**843**	**1180 (100)**

*projections for a population of 1581 m in 2050.

Source : Planning Commission - Report of the Steering Committee on Water Resources for XIth Plan. The figures are based on projections made by NCIWRD (National Commission of Integrated Water Resources Development). While projecting the above figures NCIWRD has assumed that by 2050 irrigation efficiency will increase to 60% from the current levels of 35-40%. NCIWRD has also projected a lower total demand of 973 bcm in case the population in 2050 is lower at 1346 m instead of 1581m.

Availability of utilisable water at 1086 bcm seems to be just about adequate to cater for total projected water demand in 2050 of 973/1180 bcm. Unequal distribution of the available water across geographies and across time horizon has left many areas severely water stressed. NCIWRD in their demand projection for 2050 have assumed a very nominal quantity of 20 bcm of water required towards maintaining the ecosystem. However, Amarasinghe and others (IWMI Research Report 123) have assessed that there will be an additional demand of at least 353 bcm for maintaining the ecosystem to category D, which may deepen the water crisis. Water Resource Group has estimated a supply- demand gap of 756 bcm by 2030 (paras 3.7.1 & 3.7.2). (This estimate appears to be on the higher side).

Rainfall is confined to the monsoon season, June through September, when India gets, on an average, 75% of its total annual precipitation. Once again, due to India's storage crunch, the government is unable to store surplus water for the dry season. Such uneven seasonal distribution of rainfall has not stimulated the development of better capturing and storing infrastructure, making water scarcity an unnecessary and yet a critical problem.

Trans border transfer of water through river linking projects has not taken off due to high capital costs, opposition from social activists on the grounds of adverse social and ecological impact and reluctance on the part of donor states. So far the Government has been focusing on supply side management, a strategy which has not been successful. Demand side management therefore assumes a greater importance .

Water scarcity in India is predominantly a man-made problem; therefore if India makes significant changes in the way it thinks about water and manages its resources, it could ward off, or at least smoothen, the impending crisis. India has had success with water infrastructure development, which allowed the country to take advantage of its water resources in the first place to achieve food security. These projects did enable the expansion of urban and industrial sectors and increased availability of safe drinking water, but then they were allowed to dilapidate. India needs to make water supply a national priority the way it has made basic education and food security. The water crisis in India would set the stage for major international water wars because many rivers that originate in India, supply water to other countries. India has the power to avoid this dark future if people take action immediately; start conserving water, begin to harvest rainwater, treat human, agricultural, and industrial wastes effectively, and regulate how much water can be drawn out of the ground.

Agriculture sector is the most dominant sector for water consumption. In 2050 it is projected to consume 68% of the total water requirement, followed by 9.5% for drinking water, 7% for industry and 6% for energy. Balance 9.5% will be required for other use (Table 4). In the agriculture sector , canal irrigation having reached a plateau, most of the additional demand will come from ground water . Efficient management of canal and ground water irrigation therefore takes the central stage. Requirement of drinking water is projected to be 9.5 % of the total and therefore should not be a cause of concern provided it gets the right priority in allocation and is efficiently managed and regulated. Although at macro level water availability seems fine , due to unequal distribution of the available water across geographies , many basins will remain water stressed. The rain water harvesting and artificial ground recharge can help but only to a limited extent.. Trans- boundary water transfer from surplus basins to deficient one, therefore, assumes a great importance. This Paper covers two main drivers of water demand namely Irrigation and drinking water. The Paper also examines the need for inter- basin water transfer, impact of climate change and water security in the near term (2025) and in the long term (2050).

3.3 Agriculture Water Demand

3.3.1 *Canal Irrigation*

3.3.1.1 Overview

Public irrigation systems are losing their position of dominance with more and more farmers switching over to groundwater irrigation. Key problem is poor maintenance and system management, especially below the outlet. Farmers at the upper-end over-appropriate water to cultivate high-value crops, leaving little for tail-end farmers. As a result, farmers in the periphery have started relying on groundwater, which also gives them greater control of timing their water use. In contrast to the meteoric rise in groundwater irrigation, the net irrigated command area under canals has continued to decline. To reverse the deceleration in canal irrigated areas, the Government of India instituted the Accelerated Irrigation Benefits Programme to step up the investment in the last-mile projects. More than US$ 7.5 billion have been invested in these projects since 1997. However, instead of acceleration, public irrigation command areas have continued to decelerate during this period. A recent study of 210 major and medium irrigation projects by a Delhi NGO used data from the Ministry of Agriculture to show that after investing Rs 130,000 crore, these projects delivered 2.4 million ha less irrigation during the period 1990–01 to 2006–7. Similar results were obtained by comparing the data from three minor irrigation censuses. The public irrigation policy seems unhelpful as governments have to invest twice as fast in canal irrigation projects every year just to keep their command areas from shrinking (Shah - 2011)

More recent thinking on improving the performance of surface systems has promoted rehabilitation of irrigation schemes combined with institutional reforms relying on the participation of farmers and local bodies through participatory irrigation management (PIM). Accordingly, many states have instituted laws empowering farmers' participation in the management of irrigation systems through the creation of water users' associations (WUAs). Involving WUAs in the operation, maintenance, and management of water facilities was expected to improve the performance of canal systems. However, the evidence with regard to WUAs ability to improve systems management has been inconclusive. The large scale impact of these institutions on restoring the canal irrigation system is limited and has worked only in some cases where large NGOs have been involved over a long period

3.3.1.2 Future Options

What then can be a solution for improving the performance of public irrigation systems? Shah (2011) suggests that the biggest opportunity for unlocking value from canal systems is by spreading their water on much larger areas to expand the areas under conjunctive management of surface and groundwater. The canal systems can be transformed into extensive systems as they were originally meant to be, without much investment. However, the key lies in improving the management of the main systems, which can only be achieved by reforming the irrigation bureaucracy. This may require unbundling of the Irrigation department into smaller independent management units with operational autonomy and greater accountability. A basic precondition for any management turnaround will require a reliable management information system for proper performance evaluation.

Another proposal is to evolve a public-private partnership between farmers and irrigation departments for efficient utilization of canal water. There are a number of schemes where the irrigation department has constructed weirs or otherwise ensured supply of bulk water at regular intervals through lift irrigation for distribution through underground pipe systems. Water lifting, conveyance, and distribution are done by the private and cooperative sector which charges farmers for the water supplied. Evidence suggests that the cost recovery in such schemes is better than under gravity flow irrigation systems. These lift irrigation schemes are also more equitable since the tail-end weirs are filled first and the head-end last.

Post-colonial India is confronted with a wholly new array of socio-technical conditions in which neither irrigation communities nor disciplined command areas are able to thrive. The Welfare State's revenue interests in agriculture are minimal; the prime motive for irrigation investments is food security and poverty reduction, and not maximizing government income. Governments have neither the presence and authority nor the will to collect even minimal irrigation fees that are needed to maintain the systems. Adapting system design and management to cope with the phenomenal expansion in pump irrigation is arguably, by far, the most formidable challenge to government canal irrigation systems and their managers. There could be three possible options as follows :

(a) Expanding the Area under Conjunctive Management of Surface and Groundwater

The simplest step that canal irrigation management in India can take to significantly enhance its impact is to maximize areas under conjunctive use of ground and surface water. Presently, this is not happening because India's irrigation systems irrigate only a fraction of the area they were designed for. A potentially gigantic opportunity for unlocking value out of India's canal systems is by spreading their waters on much larger areas to expand the areas under conjunctive management of surface and groundwater. The biggest road block to conjunctive use is generally the reluctance of command area farmers to invest in groundwater irrigation. In India, this is no longer a problem since irrigation wells dot the entire landscape of the country. The investments made so far in rehabilitation and modernization projects have not succeeded as huge sums were spent on construction and very little on management improvement and capacity building. Improving the management of main systems holds the key to unlocking value in India's public irrigation. Doing this, however, requires reform and revitalization of irrigation bureaucracies.

(b) Unbundling of Irrigation Bureaucracy

Unbundling of the monolithic irrigation bureaucracy is one possible way. A successful example of improvement in performance through unbundling exists in the state electricity sector in some of the states in India. However any such proposal is bound to be met with stiff resistance specially when it involves vital service such as water . The draft NWP 2012 did suggest involvement of private sector but it drew an immediate negative response by a group of eminent scientists and citizens . To quote ;

> "..no case for privatisation. In this context we would like to suggest that the draft NWP 2012 suggesting privatisation of water services should be deleted as it is in .... The global trend is also for re-municipalisation, reversing the privatisation of water that was implemented in few places, including in France (e.g. Paris), US (e.g. Atlanta), Italy, Uruguay, Netherlands, among others".

(c) Morphing into Hybrid Systems with Public Private Partnerships

A third scenario of where Indian canal irrigation might go in the future is for the irrigation agencies to enlist the WUAs as a partner and leverage it to enhance their reach and performance. A good example is provided by developments in the upper- Krishna basin in Maharashtra. In 1976, the Bachhawat Award allocated 560 TMC(Thousand Million Cubic feet) of water to Maharashtra which the state had to develop by the year 2000.Maharashtra was not in a position to build reservoirs and canal networks needed to use this water and by 1996, it had constructed only 385 TMC of storage and little had been done by way of establishing a canal network in the Krishna basin. Therefore, the government first began allowing farmers to lift water from Krishna and its tributaries. This encouraged small-scale private lift schemes most of which could not convey water to longer than 1–1.5 km distance. In 1972, only 200 private and co-operative lift schemes were operating in Maharashtra. As pressure to utilize the water mounted, the government adopted a far more proactive posture towards lift irrigation schemes. It introduced a capital cost subsidy for irrigation cooperatives and also facilitated bank finance from nationalized and cooperative banks. Most importantly, the Irrigation Department (ID) constructed a series of Kolhapur Type (KT) weirs across many tributaries of Krishna to use them as storages for lift irrigation schemes. Each scheme has to be approved by the ID, whereupon it qualifies for an electricity connection and bank finance. Each scheme also has to pay irrigation fees to the ID for the actual area irrigated; it also has to pay electricity charges to the State Electricity Board at prevailing rates for agricultural use. Between December and June each year, the ID implements a fortnightly schedule of water releases to fill up the dykes, starting with the last dyke first. This ensures that lift schemes have access to reliable water supply during the irrigation season.

A good example of the kind of partnership that Maharashtra's policies have spontaneously promoted between the ID and irrigation cooperatives is the Radhanagari project that serves 91 villages in Kolhapur district (studied by Choudhury and Kher 2006; Padhiari 2006; and Chandra and Sudhir 2010). The dam never had any canals; water is released from the dam into Bhogavati River on which the ID has constructed a series of KT weirs. The ID has three roles: (i) to approve proposals for new schemes; (ii) to release water into Bhogavati river every 15 days to fill up all the KT weirs; and (iii) to collect irrigation fees from all lift schemes based on crop and area irrigated. Water lifting, conveyance, and distribution are all done by some 500 ISPs in private and cooperative sectors.

Radhanagari's performance over the past two decades has been very good compared to surface irrigation systems anywhere in India. Against a design command of 26,560 ha, the average area irrigated by ISPs during 2001–6 was 30,341 ha. The ID managed to collect only 58 per cent of the irrigation charges that were due; however, against the annual O&M cost of Rs 79 lakh, irrigation charges collected in 2005–6 were Rs 179 lakh. In terms of the area irrigated as well as irrigation charges recovered, tail-end areas were found no worse off compared to head; the practice of filling up KT weirs last to first seems to address the head–tail inequity. An informal survey suggested that the number of irrigations the project provides is 80 to 90 per cent of the number needed and that over 80 per cent of the farmers interviewed were happy with irrigation provided by the ISPs (Choudhury and Kher 2006). In terms of offering irrigation-on-demand, Radhanagari comes close to tube well irrigation. Choudhury and Kher (2006) interviewed eight private and nine cooperative ISPs that irrigate a little over 1000 ha in Radhanagari project. These have together invested nearly Rs 22 crore in systems that include 2280 hp of pumps and 41 km of buried pipe network and employ 92 staff to manage water. Typically, every system has a rising main—sometimes, multi-stage—to a chamber from where water is conveyed by buried pipes to fields. These ISPs thus invested Rs 2.2 lakh/ha in the system, use 2.3 hp/ha of power load, employ a water manager for every 12 ha irrigated and collect an irrigation charge that is high enough to pay off debt, pay electricity charges to the Electricity Board, irrigation charges to the ID, and salary to employees, and save enough for prompt repair and maintenance.

Where-ever canals offer reliable water supply, private investors have invested in turning water into an 'irrigation service' that mimics on-demand groundwater irrigation. If we were to learn from this experience, a variety of management models emerge in which the irrigation agency has a new, more limited role of delivering bulk water at pre-designated points in the command area and a variety of private arrangements are allowed to provide an irrigation service. Regardless of whether governments support these or not, they are emerging and playing a major role in water distribution in many systems. This is the closest that canal irrigation can come to mimicking the flexible, on-demand groundwater irrigation. Such hybrid systems involving piped distribution have several advantages over the conventional gravity flow systems:

(i) private partners take up a large part of the capital investment of a canal system by constructing the distribution system;

(ii) a buried pipe distribution system faces much less 'right-of-the-way' problems that canals face;

(iii) piped distribution saves land used up for sub-minors and field-channels;

(iv) it minimizes water-logging that is rampant in canal-based distribution systems;

(v) piped distribution is considered too costly in comparison to earthen canals but is actually quite cost-effective if the land required for canals is valued at market price;

(vi) a canal network is a vast evaporation pan especially at the level of the distribution system where surface area to depth ratio of channels is low; piped distribution can save some of this non-beneficial evaporation loss;

(vii) piped water delivery from canals mimics tube well irrigation and raises productivity of irrigation water applied even more so because users pay a high price for the irrigation service;

(viii) done right , piped distribution can help spread canal water over a much larger area than surface canals can;

(ix) it can put into place a regime of conjunctive use of ground and surface water that may tackle the acute problem of ground water depletion;

(x) while pipelining is more energy-intensive compared to gravity canals, if managed well, it can significantly improve the overall farm energy balance of the country by spreading surface water on a larger area, reducing the need for groundwater pumping, by integrating micro-irrigation technologies, and enhancing recharge from canal waters thereby reducing the energy used for groundwater pumping;

(xi) while farmer participation in canal irrigation management has been hard to come by, under such a hybrid PPP model, farmer participation in irrigation management begins at the construction stage itself.

If the Maharashtra experience is any guide, inviting farmers to participate in creating such hybrid systems is not difficult. To promote farmer investments in piped distribution in a planned and systematic manner, all that the agencies need to do is the following:

(i) not only recognize and legalize but also register and incentivize lifting of water from canal systems and its piped distribution;

(ii) make firm commitments -- during the irrigation season each year -- of weekly water deliveries in each tributary/minor according to a strict schedule, as in the Radhanagari system described above;

(iii) existing tube well owners should be encouraged to convert their electricity connections to canal lift;

(iv) electricity connections should be provided to approved piped distribution schemes planned

3.3.1.3 Canal Irrigation – Conclusions

India's public irrigation management will begin to change for the better when drivers of change will outweigh the forces that restrain change. For the moment, the latter far outweigh the former .At present one can hardly find any notable 'driver' that would create pressure for a major change programme in the public irrigation sector. Governments and donors have been throwing good money after bad; and they will keep doing so regardless of what the past investments delivered or failed to deliver. If a battery of 'change drivers' were to be created, the work would need to begin by creating a credible information and monitoring system about how public irrigation systems are performing against their original designs, their current objectives, and vis-a-vis each other.

Irrigation bureaucracy requires to be unbundled into smaller independent management units with operational autonomy and greater accountability. Also, Authors feel that limiting the role of Irrigation department to that of a bulk supplier and leaving the distribution below the outlet to concerned user groups with or without private participation is the best available option for India.

The simplest step that canal irrigation management in India can take to significantly enhance its impact is to maximize areas under conjunctive use of ground and surface water. Presently, this is not happening because India's irrigation systems irrigate only a fraction of the area they were designed to. A potentially gigantic opportunity for unlocking value out of India's canal systems is by spreading their waters on much larger areas to expand the areas under conjunctive management of surface and groundwater

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3.3.2 *Ground Water Irrigation*

3.3.2.1 Overview

Groundwater irrigation has been expanding at a very rapid pace in India since 1970s and now accounts for over 60 percent of the total area irrigated in the country. About 85% of the rural drinking water supply is also met from ground water sources. Growing demands of ground water has brought problems of over-exploitation of the resource, continuously declining water levels, sea water ingress in coastal areas and ground water pollution in different parts of the country. The falling ground water levels in various parts of the country have threatened the sustainability of ground water resource, as water levels in several blocks have gone down beyond the economic lifts of pumping. (CGWB)

As the reliance on groundwater, especially for irrigation, increases further, many basins will have severe groundwater depletion. According to IWMI research,in case of BaU (business as usual) scenario, many basins will have groundwater abstraction more than 75 % of their utilizable groundwater resources by 2050. (The States of Haryana, Punjab and Rajasthan have already reached a stage of over exploitation exceeding more than 100 % of the annual replenishment -Gandhi 2009). As the water use patterns are not uniform within basins, many regions of these basins will have unsustainable water use patterns. On the supply side several basins will reach physical water-scarce condition by 2050, where the remaining utilizable water supply can not be developed further without making a severe impact on the environment and riverine water users down stream. The total available groundwater through recharge from natural rain fall and return flows in some regions may not be adequate for meeting the increasing demand. (V. P. Gandhi and Vaibhav Bhamoriya - 2011)

3.3.2.2 Growth of Ground Water Irrigation and its impact

The water resources are available either as surface water or groundwater and the principal source for both the resources is precipitation. The erratic nature of precipitation and near utilization of surface water resources has turned the onus on groundwater. Electricity supply ,that too highly subsidized if not free, made pumping of groundwater easy and economical. The reach of institutional credit expanded making credit more widely available. Farmers realized that they could develop and apply water 'just in time' from groundwater sources, something which was not possible in the institutionally-complex and poorly managed canal systems.

The result was a revolution, in which groundwater irrigation developed at a very rapid rate, while tank irrigation declined and surface water irrigation grew only marginally. Cheap and un-metered electricity, slow development of surface irrigation, and poor management of canal systems further encouraged groundwater development. Over the last two decades, 84 per cent of the total addition to net irrigated area has come from groundwater, and only 16 per cent from canals. Groundwater offers control and reliability of water in irrigation which is missing in rainfed as well as canal irrigation. Numerous micro-level studies based on sample surveys show that pump irrigated farms perform much better compared to those irrigated by any other source. Groundwater can also be a key resource for poverty alleviation and economic development. Evidence indicates that improved water supply can generate many positive externalities in the overall household micro economy. In areas dependent on irrigated agriculture, the reliability of groundwater and the resulting higher crop yield generally achieved, often enables farmers with small holdings to considerably increase their income.

3.3.2.3 Future Options

The National Commission of Integrated Water Resources Development (NCIWRD) projections show that the irrigated area should increase by about 35 million ha to reach the food self-sufficiency goals in 2050 (GOI 1999). A major part of the NCIWRD additional irrigated area projection is from the surface water, and it is a key factor for the proposed national river linking project (NRLP) concept of India. The NRLP envisages transferring 178 bcm water from the water rich Himalayan rivers to water stressed southern and western part of India and irrigating additional 34 million ha (GOI 1999). However issue of NRLP is mired in controversies and there is strong opposition from the States and Civil Society.

India is therefore on a cross road of its future direction of irrigated agriculture. The increasing reliance on groundwater is projected to continue further. India abstracted about 300 bcm of groundwater in 2000 of which 273 bcm (91 %) was for the agriculture sector and 27 bcm (9%)for industrial and domestic sector . The future projections based on IWMI research are given in Table 5.

Table 5 : Abstraction of Ground Water

(Unit – Bcm)

Year	For Agriculture Use	For Other Users	Total (Bcm)
2000	273	27	300
2025	300	66	366
2050	322	74	396

1. Projections are based on IWMI research papers by Amarsinghe & others.

2. Other users include domestic, industrial and power users.

The estimated total replenishable groundwater resource in India is 433 bcm per year. According to CGWB another 36 bcm could be added with rain water harvesting and artificial recharge taking the total figure to appx 470 bcm . Utilizable groundwater resource will be some what lower than that . In face of this, the projected abstraction of 396 bcm may not appear so alarming. However, this number does not reveal the true picture of geographic variation, which is rather extreme. Out of the total replenishable groundwater resource of 433 bcm, the Ganga basin alone accounts for nearly 40 per cent. Thus, the resource is highly concentrated and none of the other basins even cross 10 %. The basins with more than 5 % of the total replenishable potential are Godavari (9.42 per cent), Brahmaputra (6.15 per cent), Indus (6.14 per cent), and Krishna (6.12 per cent). This shows that the distribution of groundwater is highly skewed, and averages and aggregates may hide the real picture on the ground in various areas. Over exploitation in different river basins could be a serious constraint for sustaining groundwater expansion in the future . The impact of this over exploitation of ground water would tend to be particularly pronounced during drought periods when a large number of small/marginal farmers could simultaneously lose access to groundwater when their wells dry up. During non-drought periods, water-level declines would undermine the economic position of small/marginal farmers forcing them onto already saturated unskilled agricultural and urban labour markets. (Adapted from IWMI research and Gandhi 2009)

3.3.2.4 Current initiatives

The CGWB, under the Ministry of Water Resources had implemented a Central Sector Scheme on “**Study of Recharge to Ground water**“ in which recharge structures were constructed in various parts of the country in co-ordination with State Government and user groups. Under the scheme, recharge projects were taken in areas having water scarcity, surplus monsoon runoff and sufficient subsurface storage space, coastal areas affected by seawater ingress and areas of ground water pollution. Under this, 174 schemes were taken up and monitoring/ impact assessment has been carried out. The performance evaluation studies indicate that the recharge structures have contributed to increased availability of ground water especially in lean months (summer) when the demand is more. These schemes have provided point source recharge.

During **Xth Plan,** a demonstrative scheme on “Rain Water Harvesting and Artificial Recharge to Ground Water” was taken up in over-exploited blocks of four states (Andhra Pradesh, Tamil Nadu, Karnataka and Madhya Pradesh).

During **XI th Plan** the Central Ground Water Board implemented the artificial recharge and rain water harvesting studies under the scheme “**Ground Water Management & Regulation**” for augmentation and sustainable management of ground water resources in priority to over-exploited /dark blocks, urban areas showing steep decline in ground water levels, drought-prone & water scarcity areas, coastal areas and sub-mountainous /hilly areas in different parts of the country. This included a programme of recharging groundwater across the 65 per cent of India that has hard-rock aquifers. As a result, the Indian government allocated Rs 1800 crore (US$ 400 million) to fund dug-well recharge projects (a dug-well is a wide, shallow well, often lined with concrete) in 100 districts within seven states where water stored in hard-rock aquifers had been over-exploited. These geological formations have a much lower capacity to store rainwater than alluvial areas with porous sand or clay rocks, hence being given priority. The money is sufficient to fund seven million structures to be installed on dug-wells to divert monsoon runoff. *(possible solution to over-use of groundwater in indiahttp://en.wikipedia.org/wiki/Groundwater)*

3.3.2.5 The Role of Land Tenure, Water Rights, and Groundwater Markets in Influencing Equity and Efficiency

As per the law, groundwater is under private regime in India and the rights to groundwater belong to the owner of the land . The right to groundwater is transferred to anyone to whom the land is transferred. There is no limitation on how much groundwater a particular land owner can draw. Therefore, a land-owner can legally abstract any amount of water unless the geo-hydrology or technology limits it. The consequence of such a legal framework is that only the landowners can own groundwater in India.

For wider access and control it is necessary to separate water rights from land rights, but no such provisions have been made so far in the national groundwater law .

There is no charge on groundwater itself and the present groundwater pricing structure provides minimal incentives for efficient and sustainable groundwater utilization. For electric pump sets, throughout almost the whole of India, charges are levied on a flat rate basis in proportion to the size/horse-power of the pump set. Such non-volumetric charging has only a very indirect weak impact on actual water use. Moreover, in most areas power is supplied to the rural areas with a heavy subsidy element. As a result, at the local level, a huge number of productive localities are already under severe groundwater stress.

3.3.2.6 The Efficacy of Water Institutions (Laws and Policies) in Managing Groundwater Challenges

In June 2012, the Ministry of Water Resources published its Draft National Water Policy 2012 (NWP - 2012), which sought to address issues such as the scarcity of water, inequities in its distribution and the lack of a unified perspective in planning, management and use of water resources. Under the Constitution, states have the authority to frame suitable policies, laws, and regulations on water. The NWP proposed an overarching national legal framework of general principles on water that can be used by states to draft their own legislation on water governance. The draft NWP was placed before the National Water Board and National Water Resources Council and adopted in Dec 2012.

Provisions proposed in the Draft NWP – 2012 relating to ground water were –

- Groundwater, though part of hydrological cycle and a community resource, is still perceived as an individual property and is exploited inequitably and without any consideration to its sustainability leading to its over-exploitation in several areas.
- Ground water needs to be managed as a community resource held by the State under public trust doctrine to achieve food security, livelihood, and equitable and sustainable development for all . Existing act may have to be modified accordingly.
- Adaptive strategy to cater for climate change could include better demand management, particularly through adoption of compatible agriculture strategies and cropping patterns and improved water application methods.
- Natural water bodies and drainage channels are being encroached upon, and diverted for other purposes. Groundwater recharge zones are often blocked.
- There is a need to map the aquifers to know the quantum and quality of ground water resources (replenishable as well as non-replenishable) in the country. This process should be fully participatory involving local communities. This may be periodically updated.

- Declining ground water levels in over-exploited areas need to be arrested by introducing improved technologies of water use, incentivizing efficient water use and encouraging community-based management of aquifers. In addition, where necessary, artificial recharging projects should be undertaken so that extraction is less than the recharge. This would allow the aquifers to provide base flows to the surface system, and maintain ecology.

- Integrated Watershed development activities with groundwater perspectives need to be taken in a comprehensive manner to increase soil moisture, reduce sediment yield and increase overall land and water productivity. To the extent possible, existing programs like MGNREGA may be used by farmers to harvest rain water using farm ponds and other soil and water conservation measures.

- Use of very small local level irrigation through small bunds, field ponds, agricultural and engineering methods and practices for watershed development, etc, need to be encouraged. However, their externalities, both positive and negative, like reduction of sediments and reduction of water availability, downstream, may be kept in view.

- There should be concurrent mechanism involving users for monitoring if the water use pattern is causing problems, like unacceptable depletion or building up of ground waters, salinity, alkalinity or similar quality problems, etc., with a view to planning appropriate interventions.

The present institutional arrangements in India which involve central, state, and local institutions, and both formal and informal structures, are having issues in bringing about water allocation, and management on a comprehensive / scientific basis.

Bold steps have been taken by many countries in the face of similar challenges concerning groundwater ownership. In the early 1980s the legislatures of the American arid states of Arizona and New Mexico replaced the common law/rule of absolute ownership of groundwater, with a government administered permit system of groundwater extraction. The legislature of the Australian state of Victoria did the same thing with the 1989 Water Act. In England and Wales, government-administered licensing requirements were superimposed on the existing riparian rights in groundwater under the 1963 Water Act. The Spanish legislature passed legislation in 1985 whereby all hitherto private groundwater resources became public property of the state. Italy's parliament passed legislation in 1994 vesting all private water resources, including, in particular, groundwater in the state. These legislations effectively curtailed the significant attributes of land ownership, such as the right to sink a well, and the right to extract any amount of groundwater from beneath one's own land (*The World Bank*)). Similar changes are urgently required in India.

3.3.2.7 Ground Water Irrigation – Conclusions

Groundwater has grown in importance to occupy a dominant place in India's agriculture, food security and water supply for domestic and industrial use. Groundwater management is, however, heading for a crisis in India and needs urgent attention and understanding. Assessments show that India has a huge groundwater resource but its availability and status varies substantially between basins, states, and areas. Forty per cent of the groundwater resource is in the Ganga basin alone, and no other basins even crosses 10 per cent. Given this variation, the management of groundwater would need to be different in different areas. A government department initiative to measure the groundwater level/ situation (already existing in some areas) on a monthly or quarterly basis extensively across blocks/villages is required along with reporting and dissemination of this information . Since electric pumps are extensively used to pump the water, controlling the availability of electricity supply for operating pumps can go a long way in reducing over-exploitation. Metering and charging of electricity at the real economic price also needs to be implemented.

Other direct measures would include restricting the number of tube-wells through licensing or through imposing institutional credit restrictions. Pumping of water can also be restricted through installation of water meters on tube-wells as done in many developed countries. Overall, new legislation is required to control groundwater exploitation, and a constitutional amendment separating the right to groundwater from the right to land would help provide the necessary foundation for stronger laws and institutional controls. Promotion of alternatives such as irrigation through furrows, drip irrigation, and sprinkler irrigation can greatly improve water use efficiency and even these should be done after assessment of soil moisture and critical stages of crop water need. To signal the scarcity of water, formal and informal controls and proper pricing of water is a must. If water is expensive, farmers will use it more efficiently. Pricing should be based on the type of crop, and high water charges should be there for high water using crops .

Institutional developments such as the setting-up of elected and empowered water user associations are extremely important to improve the efficiency and equity in groundwater management. However, the ability of such institutions to implement control would be substantially enhanced by the separation of water rights from land rights.

Apart from reducing overexploitation, increasing the recharge of groundwater through harvesting of rain and surface flows would prevent the dewatering of aquifers, and also greatly improve equity by making water available in the wells affordable to small and marginal farmers.

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3.4 Drinking Water

3.4.1 *Urban Water Supply*

3.4.1.1 Global View

The United Nations has assessed that at present almost fifty percent of the global population lives in the cities and towns. Globalisation is increasing and in twenty years almost 60 per cent of the world's people will be in urban areas. This rapid urban growth is seen predominantly in developing countries. Here cities gain an average of about 5 million residents every month. This exponential growth of urban population is creating serious challenges of which, provision of water (and sanitation) are the most pressing.

One of the main challenge related to water that is impacting the sustainability of these urban areas is the lack of access to safe water (and sanitation). This has had enormous consequences on human health, environment, safety , development and economic growth. The lack of adequate water (and sanitation) facilities leads to health issues such as malaria, diarrhoea, and cholera outbreaks. Though water supply (and sanitation) coverage increased between 1990 and 2008, the growth of the world's urban population has been faster. Between 1990 and 2008, more than 1050 million urban dwellers gained access to improved drinking water (and around 813 million to improved sanitation).The urban population meanwhile grew by about 1089 million people during the same period . This can be seen from the graph (Fig 2).

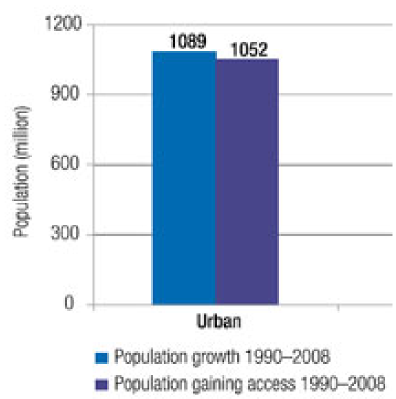

Fig. 2 : Urban population gaining access to improved drinking-water compared to urban population growth 1990-2008

(Source : Progress on Sanitation and Drinking-Water: update 2010. WHO/UNICEF JMP. 2010)

It is seen that the increase in the use of drinking-water resources is barely keeping pace with the growth of urban population.

For cities to be sustainable, ensuring reliable access to safe drinking water and adequate sanitation is a prime need. Meeting the growing needs of water and sanitation services within cities is one of the most pressing challenges of this century. Sustainable, efficient and equitable management of water in cities has never been as important as in today's world.

3.4.1.2 Water, Cities and the MDGs

Two Millennium Development Goals (MDGs) targets are closely related to water and cities :

- One MDG target calls for the reduction by half of the number without sustainable access to safe drinking water and sanitation.
- Another MDG target articulates the commitment of UN member states to significantly improve the lives of at least 100 million slum dwellers by the year 2020.

At the current rate of progress, the world is expected to achieve the MDG drinking-water target. Currently, 96% of the urban population has access to improved drinking-water sources. The challenge is to keep pace with the rapid urbanisation.

3.4.1.3 Issues and Options for India

Urban water supply in India is facing chronic shortages in investments adversely affecting the operation and maintenance (O&M). It also faces challenges of inadequate coverage, intermittent supply, inequitable water access, deteriorating infrastructure, and environmental unsustainability of water.

These are largely due to insufficient capacities of urban local bodies (ULBs), political issues in tariffs (levy and recovery), lack of benchmarking norms, and poor service from public utilities. The situation points towards an urgent need for policy and governance improvements in the urban water sector.

The performance review of the Urban Water Supply Sector (UWSS) reforms in various Indian states brings out important gaps in achieving the four key objectives of reforms. The review suggests that the process of initiating and undertaking reforms is disjointed at various levels of governance institutions. States have implemented different elements of the reform proposals. There is unevenness in prioritizing financial, techno-economic, and institutional aspects of reforms in most states. This has resulted in reforms being adopted differently at the state and local levels and only marginal improvement in water sector service delivery. Further, the reform initiatives undertaken in the UWSS also need a review and overhauling at the conceptual and practical levels.

In the recent past however, there has been some progress by utilities to undertake institutional reforms. (JNNURM had mandated that states and utilities undertake a set of reforms before they can access their project grants). Cities were asked to think holistically when they prepared ‘city development plans’. Another development has been the adoption of service level benchmarks by the Ministry of Urban Development, and its endorsement by the 13th Central Finance Commission and the High Powered Expert Committee on Urban Infrastructure (HPEC).This has placed the onus to provide prescribed water supply standards to urban residents, on water utilities.

Also, the process of governance reforms, (these are a clutch of measures for institutional and financial restructuring of the UWSS, which were started almost two decades ago, now require to be accelerated on priority. The need for focussed attention to the water sector,(given the water stress in the country), is now well recognized and speedier action is called for.

3.4.1.4 Rational Pricing of Water

Normally, efficient use of scarce resources requires appropriate pricing, but pricing of water is a sensitive issue. This problem can be solved by providing ‘lifeline’ water supplies for drinking and cooking at very low prices, while charging appropriately for additional water use by domestic consumers. There is a stronger case for rational pricing reflecting the scarcity of water for commercial and industrial use.. The proportion of water recycled in urban areas, and by Indian industry needs to be significantly increased. This will happen if supply for commercial purposes is appropriately priced.

Even if we succeed in bringing about a major rationalisation of water prices, by itself it will not lead to optimal use. For this, rational pricing must be accompanied by regulatory measures to ration water to different agricultural users, and stronger measures to discourage pollution.

3.4.1.5 Manila Water and Sewerage Concessions – A Case Study

In this connection, the Case Study “Manila Water and Sewerage Concessions” (Annex 2) is relevant. Some similar attempts have been made in India too, especially at Karnataka, Tamil Nadu and Latur, amongst others. The experience gained will be useful for subsequent similar projects.

3.4.1.6 Urban Water Supply – Conclusions

As discussed above, in urban areas, urban local bodies (ULBs) are responsible for providing drinking water to households, industrial, and commercial establishments . This includes bulk water abstraction, creation of storage and treatment facilities, distribution, and management of wastewater.

Historically, drinking water supply and irrigation, both have been provided by state or local government entities which are largely in the public sector, and usually are vertically integrated regional monopolies .Of late, different public-private partnership (PPP) models are being considered for improving services by the central and state governments and initiatives are being taken to improve the management of the assets of the water sector and the delivery of public services through this alternative.

The need and advantages of increased private sector participation in the water sector are evident when one looks at the success achieved in terms of improved quality of service to users in other sectors (with PPP), such as national highways, telecom and power. What may be required to attract private sector participation is creating an appropriate operating framework combined with an effective regulatory mechanism. Private participation in the water sector could achieve objectives of various public-private partnership (PPP) models, viz. improvement of water use efficiency, capital mobilization, better harnessing of renewable resources, professionalism and access to better technology, and provision of an improved service by creating a demand for superior quality of service through market mechanism.

Towards this end, steps have to be taken to improve the current legal/regulatory framework to facilitate such private sector involvement. Institutional strengthening is another important aspect that needs to be taken care of so as to make it amenable for establishing PPPs in the sector.

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3.4.2 *Rural Water Supply*

3.4.2.1 Overview

India, having 6,40,867 villages, 2,65,000 gram panchayats, 640 districts, is currently facing a daunting set of water-related challenges as the demand for fresh water is increasing day-by-day. More than 68 % of India’s population lives in rural areas and 85 % of rural water supply of India is ground-water based. Therefore, bore-well/ tube well with hand pump have become most important in the life of villagers. Women have to face numerous difficulties while getting water for drinking. They have to carry water from a pump away from their homes.

Rural India has more than 688 million people residing in about 16,50,000 habitations spread over 15 diverse ecological regions. Meeting the drinking water needs of such a large population can be a daunting task. The non-uniformity in level of awareness, socio-economic development, education, poverty, practices and rituals and water scarcity add to the complexity of the task. Despite an estimated Rs 1,105 billion spent on providing safe drinking water since the First Five year plan was launched in 1951, lack of safe and secure drinking water continues to be a major hurdle and a national challenge.

Around 37.7 million Indians are affected by water borne diseases annually, 1.5 million children are estimated to die of diarrhea alone and 73 million working-days are lost due to waterborne diseases each year. The resulting economic burden is estimated at $ 600 million a year. While ‘traditional diseases’ such as diarrhoea continue to take a heavy toll, 66 million Indians are at risk due to excess fluoride and 10 million due to excess arsenic in groundwater.

The number of habitations in India where drinking water sources are polluted is nearly 1.2 lakhs, out of nearly 16.6 lakhs in the country. Of course, most of these are naturally contaminated by elements like arsenic, fluoride, iron nitrate etc.

(*Adapted from Paper “Role of Participatory Ground Water Management in Sustainable and Efficient Domestic Water Supply in Rural Areas” (Water Conference ,New Delhi, Apr 2013), Prabir Kumar Naik,Scientist, RGNGWT&RI, CGWB, Raipur.(Figures updated for 2011 census*).

3.4.2.2 Sector Reforms- Policy and Initiatives

Historically, drinking water supply in the rural areas in India has been outside the government's sphere of influence. Government of India’s effective role in the rural drinking water supply sector started in 1972-73 with the launch of **Accelerated Rural Water Supply Programme** (**ARWSP).** This was followed up with a second initiative by way of a **Technology Mission** on Drinking Water in 1986. In 1991-92, this Mission was renamed **Rajiv Gandhi National Drinkng Water Mission**. In the year 1999, a separate Department of Drinking Water Supply (DDWS) was formed under the Ministry of Rural Development, for focused attention on drinking water and sanitation in Rural India. This led to the **third generation programme** in 1999-2000 , when **Sector Reform Projects** were evolved to involve community in planning, implementation and management of drinking water related schemes, later scaled up as **Swajaldhara** in 2002. As sanitation became an important adjunct to rural health and quality of water, the DDWS was renamed as the Department of Drinking Water & Sanitation in 2010. Keeping in view the extreme importance of the sector ,the Government went a step further and on 13th July, 2011 the **Ministry of Drinking Water and Sanitation** was created and notified by the Government of India as a separate Ministry. The Ministry of Drinking Water and Sanitation is now the nodal Ministry for the overall policy, planning, funding and coordination of the flagship programmes of the Government for rural drinking water viz. the National Rural Drinking Water Programme and for rural sanitation.

The Rural Water Supply (RWS) sector has now entered the **fourth phase** with major emphasis on ensuring sustainability of water availability in terms of potability, adequacy, convenience, affordability and equity while also adopting decentralized approach involving PRIs and community organizations. Adequate flexibility is afforded to the States/UTs to incorporate the principles of decentralized, demand driven, area specific strategy taking into account all aspects of the sustainability of the source, system, finance and management of the drinking water supply infrastructure. Adoption of appropriate technology, revival of traditional systems, conjunctive use of surface and ground water, conservation, rain-water harvesting and recharging of drinking water sources have been emphasised in the new approach. *The subject of ‘Rural drinking water supply’ is in the State list. It is also included in the Eleventh Schedule of the Constitution among the subjects that may be entrusted to Panchayats by the States. Empowerment of the PRI (Panchayati Raj Institutions) in rural drinking water supply is one the most important areas of focus in the sector*.

From an institutional perspective, the new policy recommends supporting the transfer of management and financial responsibility to the lowest level to the Panchayati Raj Institutions and, in particular the Village Water Supply and Sanitation Committees formed as Standing Committees of the Gram Panchayat..

Based on these considerations the ARWSP has been modified as **National Rural Drinking Water Programme (NRDWP)** for the Eleventh Plan period. The NRDWP, is a Centrally sponsored scheme aimed at providing adequate quantity of safe drinking water to the rural population of the country. The NRDWP is the vehicle through which the rural water supply component of Bharat Nirman is implemented.

National goal under NRDWP has been set as under:

> "providing every rural person with safe water for drinking, cooking and other domestic basic needs on a sustainable basis. This basic requirement should meet certain minimum water quality standards and be readily and conveniently accessible at all times and in all situations"

At the request of GOI , The World Bank (WB) reviewed Effectiveness of Rural Water Supply Schemes in 10 states of India and submitted their findings in June 2008. The World Bank has summarized these recommendations through the following policy Papers :

Paper 1 (Policy Paper 44790) : Willingness of Households to Pay for Improved Services and Affordability

Paper 2 (Policy Paper 44791) : Inefficiency of Rural Water Supply Schemes in India

Paper 3 (Policy Paper 44792) : Multi Village Water Supply Schemes in India

Paper 4 (Policy Paper 44793) : Operation and Maintenance Expenditure and Cost Recovery

Paper 5 (Policy Paper 44794) : System of Monitoring and Evaluation

Paper 6 (Policy Paper 44795) : Norms for Rural Water Supply in India

To keep in line with the above stated National goals and perhaps based on the WB recommendations and the actual experience on the ground ,the existing rural water supply guidelines were modified effective from 01.04.2009. The major changes in approach were in regards to:

- Source sustainability, community managed programmes and recognition of the gap between infrastructure created and service available

- Installation of a water source will not be considered as the criteria for fully covered habitation, but adequate water supply received by all household of the habitations will be the criteria.

- Change the lpcd (litres per capita per day) standard as a mean of measuring availability of water, but look at larger and various indicators of water security;

- Focus on ensuring household level drinking water security through preparation of village water security plans and household level water budgeting.

- Conjunctive use of surface and groundwater and focus on rainwater harvesting for recharge. For old and new ground water schemes, recharge mechanisms will be made mandatory;

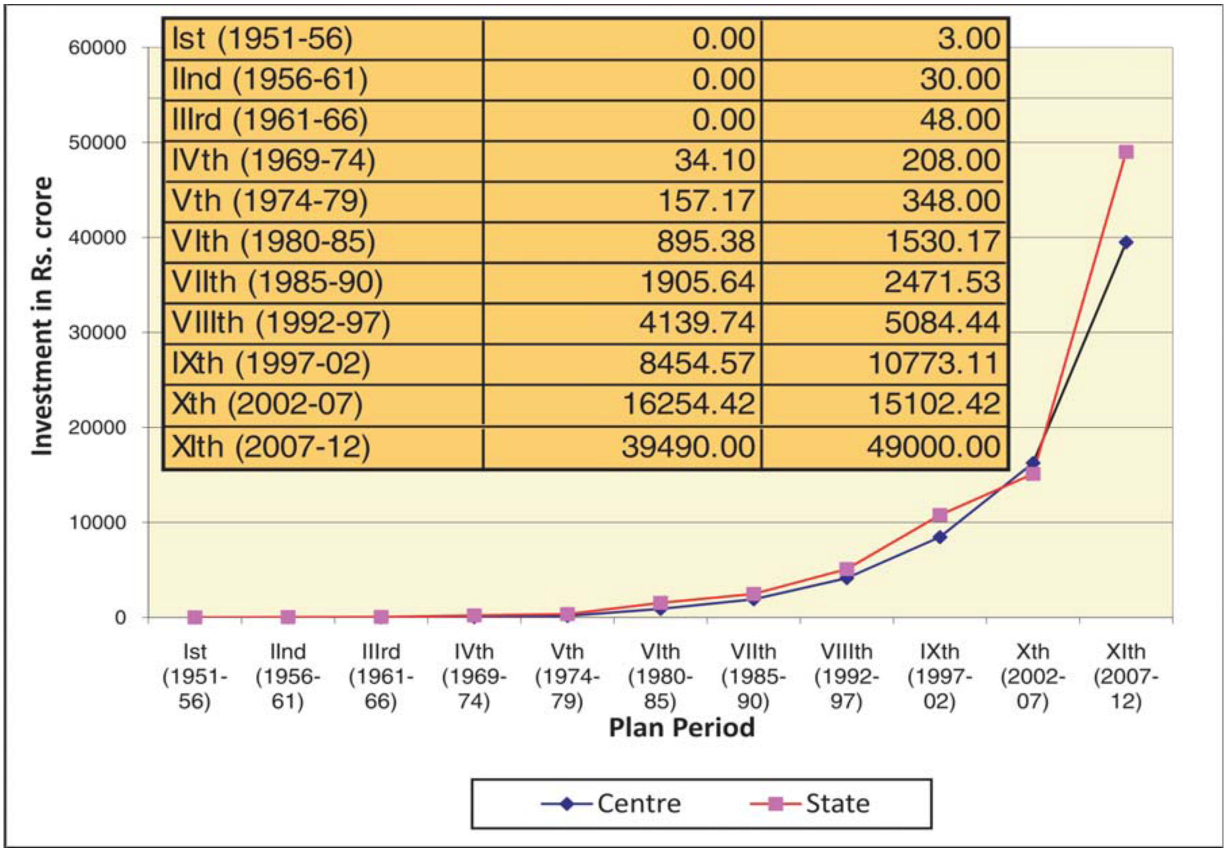
- Need for social regulation of agricultural water for meeting the demand of drinking water;

- Revival of traditional systems of water conservation and introduction of catchment protection schemes for surface water;

  (http://www.mdws.gov.in/sites/upload_files/ddws/files/pdf/RuralDrinkingWater_2ndApril)

3.4.2.3 Current Status of Rural Drinking Water Supply

Since the First Five Year Plan (1951-1956), Government of India (GoI) and State governments, have till December, 2011, spent about Rs. 1,45,000 crore on rural drinking water. Plan-wise allocation of funds by Central and State Governments for Rural Water Supply is shown in the following table and graph.



Ist (1951-56)	0.00	3.00
IInd (1956-61)	0.00	30.00
IIIrd (1961-66)	0.00	48.00
IVth (1969-74)	34.10	208.00
Vth (1974-79)	157.17	348.00
VIth (1980-85)	895.38	1530.17
VIIth (1985-90)	1905.64	2471.53
VIIIth (1992-97)	4139.74	5084.44
IXth (1997-02)	8454.57	10773.11
Xth (2002-07)	16254.42	15102.42
XIth (2007-12)	39490.00	49000.00

Fig. 3

Source : Annual Report 2011-12, The Ministry of Drinking Water and Sanitation – (MDWS)

3.4.2.4 Status of Coverage of Habitations with Drinking Water Supply

The current status of provision of drinking water in rural areas as measured by the (percentage of habitations where the population is fully covered with adequate (40lpcd) and safe drinking water), as per information entered by States on the online monitoring system of the Ministry, is about 72% of total rural habitations. The rest are either partially covered or have drinking water sources contaminated with chemical contamination.

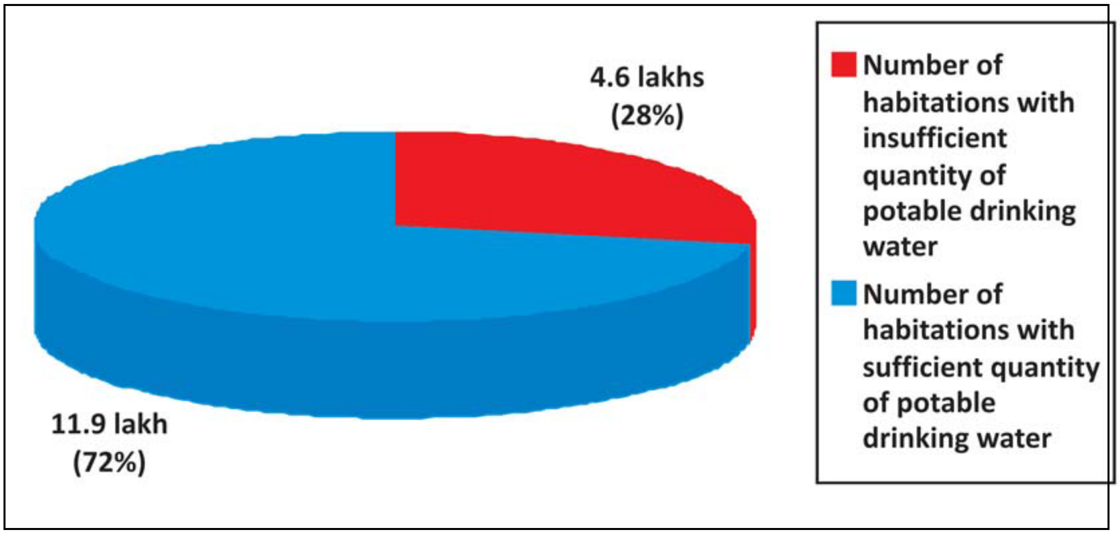


Fig. 4

As per official data of the Ministry, the coverage of habitations is as under (as on 1.4.2011)

Total Rural habitations	-	16,64,186	
Uncovered	-	0	
Partially covered	-	3,75,871	
Quality Affected	-	1,21,501	(*1,72,386 as on 1.4.2006*)
(i) Fluoride	-	23,512	*(29,070 -------do----------)*
(ii) Arsenic	-	5,339	*(7,067 --------do-----------)*
(iii) Iron	-	64,213	*(1,04,437 ---do-----------)*
(iv) Nitrate	-	3,867	*(19,387 -------do---------)*
(v) Salinity	-	24,570	(*12,425 -----do-----------)*

(Figures in brackets pertain to 1.4.2006, from Bharat Nirman targets, Phase 1)

While addressing of the water quality problem, arsenic and fluoride affected habitations have been accorded priority followed by iron, salinity, nitrate and other contaminants.

(There is minor variation in the figures between the pie chart and the absolute figures given above. Actual figures on ground may be considerably lower due to conscious data inaccuracy for additional funding, slip back of habitations due to incomplete projects, inadequacy of source of water and poor O&M etc.)

Although coverage of habitations is stated to be 72% ,coverage of piped water supply as per the online Integrated Management Information System(IMIS) of the Ministry is only 35% in 2011-12. There are large inter-state variations in the piped water supply, which vary from 1.1% in Bihar to 99.1% in Puducherry and 87.3% in Tamilnadu. There are 8 States viz. Bihar, Uttar Pradesh, Jharkhand, Orissa, Assam, Chhattisgarh, West Bengal and Madhya Pradesh that have less than 10% coverage of households with piped water supply.

The status of provision as estimated by the NSSO 65th Round Survey of 2008-09, shows that about 90% of rural households obtain their drinking water from improved sources (see the chart below).

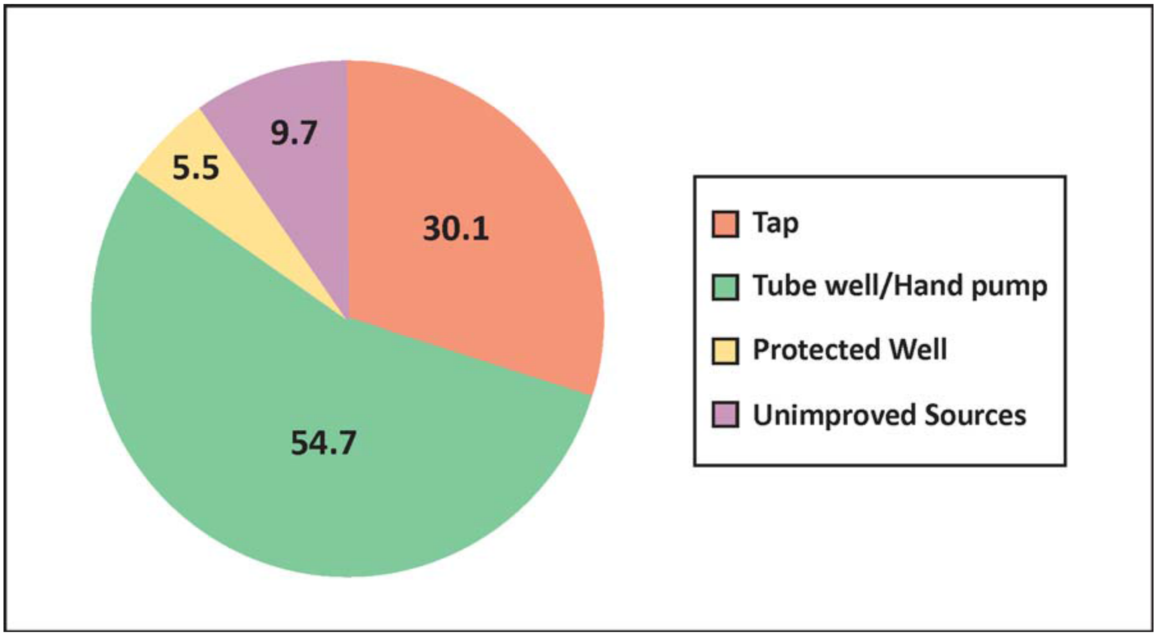


Fig. 5

Source : Annual Report 2011-12, The Ministry of Drinking Water and Sanitation – (MDWS)

(According to a critical analysis conducted by Dr Brij Pal, the figure is close to 80%. Ministry sources elsewhere have stated that about 85% of households are dependent on ground water for their drinking water use).

3.4.2.5 Strategic Plan – Rural Drinking Water Supply

The process of preparation of a Strategic Plan for the rural drinking water sector in India, by the Department of Drinking Water and Sanitation, was started during the year 2010. An extensive multi-sectoral consultation process was followed, which included the formation of Working Groups, regional and national workshops etc. The Strategic Plan has the following goals

By 2017,

- Ensure that at least 55% of rural households are provided with piped water supply; at least 35% of rural households have piped water supply with a household connection; less than 20% use public taps and less than 45% use hand-pumps or other safe and adequate private water sources.
- Ensure that all households, schools and anganwadis in rural India have access to and use adequate quantity of safe drinking water.
- Provide enabling support and environment for Panchayati Raj Institutions and local communities to manage at least 60% of rural drinking water sources and systems.

By 2022,

- Ensure that at least 90% of rural households are provided with piped water supply; at least 80% of rural households have piped water supply with a household connection; less than

10% use public taps and less than 10% use hand-pumps or other safe and adequate private water sources.

- Provide enabling support and environment for all Panchayati Raj Institutions and local communities to manage 100% of rural drinking water sources and systems.

Provision for SCs and STs

In the criteria for fund allocation to States under the NRDWP, the rural SC and ST population of the State has a weightage of 10%. Thus States with higher SC and ST population get a higher allocation of NRDWP funds

Norms for Providing Potable Drinking Water in Rural Areas

Under the ARWSP guideline the norm that has been adopted since the inception of the programme (1972) for providing potable drinking water to the rural population based on basic minimum need was 40 lpcd. From the 12th Five year Plan the focus has shifted to provision of piped water supply. The vision for rural domestic water supply in the Strategic Plan of the Ministry is to cover all rural households with safe piped drinking water supply @ 70 lpcd.

Considering the fact that the norm is 40 lpcd has been continuing for the last 4 decades and there is a large population that has to be provided with higher service levels, as an interim measure the norm is 55 litres per capita per day (lpcd) has been adopted

Quality Affected Habitations

Under the NRDWP, chemical contaminants which are sought to be tackled are excess arsenic, fluoride, iron, salinity and nitrate. Except for nitrate, all others occur naturally. Nitrate occurs in drinking water due to leaching of chemical fertilizers and sewerage. The strategy of the Department is to prioritize addressing the problems of arsenic and fluoride in drinking water through alternative surface water sources. The treatment technologies that are available for removal of excess arsenic and fluoride are still not foolproof in respect of reject management and operation & maintenance issues.

The focus of the Department is to tackle excess iron problem through aeration based technology or low-cost terra-cotta based filtration technique. States such as Karnataka and Orissa have already taken up the challenge of tackling this contamination through low-cost terracotta based filtration technology.

In respect of salinity, although there are a number of technologies like distillation, ion-exchange, reversible osmosis, electro-dialysis etc., these being expensive solutions, the focus of the Department is to tackle this problem through dilution of groundwater through artificial recharge of groundwater.

The strategy of the Department to tackle excess nitrate is by improving sanitary conditions. (Source : Five Year Plans and Rural Water Supply in India: A Critical Analysis, Dr. Brij Pal - 2012).

Allocation of Funds

The financial allocation under ARWSP/NRDWP has been increased substantially since the launch of Bharat Nirman in 2005-06.

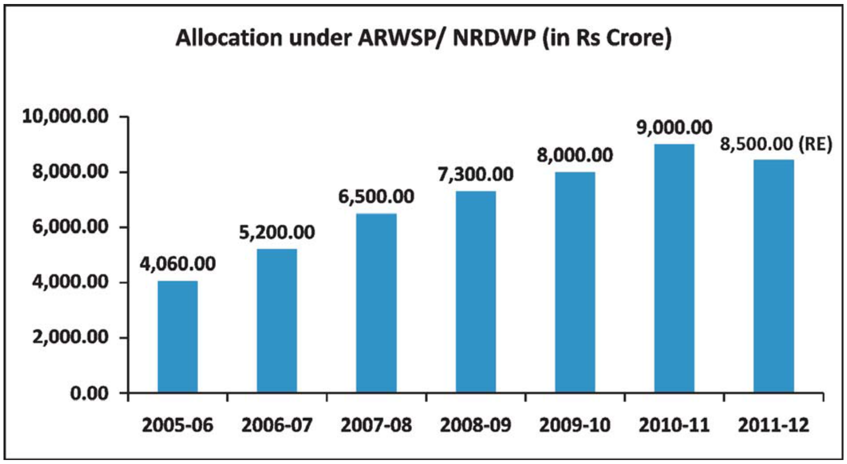


Fig. 6

Further Modifications to NRDWP Framework

During implementation of NRDWP Framework certain strengths and weaknesses of the system surfaced; these are –

Strengths

- 86% of rural population have access to safe drinking water
- About 11.51 lakh rural habitations are fully covered with safe and adequate drinking water

Weaknesses

- Nearly 5.70 lakh habitations slipped back to partial coverage
- 1.44 lakh habitations are having contaminated drinking water
- 85% dependence on Groundwater - Severe depletion
- Only about 35% habitations are with piped water supply
- Only 12% (2005) households with tap connections
- Problem of weak O&M
- Inadequate attention to software activities, sustainability
- Neglect of traditional sources

(Source : National Rural Drinking Water Programme – 2008)

Based on the analysis, it was felt that certain modifications are needed in some components and further clarity is needed on some other issues of the programme. After consultations with States, amendments were brought about in the framework, some of which have already been implemented while others are being implemented.

The principal changes include:

- Focus on piped water supply rather than on hand-pumps, so as to decrease the pressure on ground water extraction and also ensure potability of water;

- Enhancement of service levels for rural water supply from the norm of 40 lpcd to 55 lpcd for designing of systems;

- Greater thrust on coverage of water quality affected habitations with earmarked funding for chemical contamination and Japanese Encephalitis and Acute Encephalitis Syndrome (JE/AES) affected areas;

- Moving towards the target that, by 2017, at least 50 per cent of rural population in the country has access to 55 lpcd within their household premises or within 100 meters radius, with at least 30 per cent having individual household connections, as against 13 per cent today;

- Conjoint approach between rural water supply and rural sanitation so as to achieve saturation of habitations with both these services;

- Incentivise substantive devolution of functions, funds and functionaries to the Gram Panchayats with respect to rural water supply schemes, through a Management Devolution Index (MDI) with clear and specific indicators on the basis of which distribution among States of 10% of National allocation would be decided;

- All new drinking water supply schemes to be designed, estimated and implemented to take into account life cycle costs and not just per capita costs;

- Waste water treatment and recycling to be an integral part of every water supply plan or project; bringing the concept of Renovation and Modernization (R & M) into the planning process;

- Prioritisation of States which are lagging in terms of coverage with piped water supply;

- Focus on States with Integrated Action Plan (IAP) districts, with an innovative dual powered Solar pumps for remote, small habitations and those with irregular power supply, with convergent funding from the National Clean Energy Fund (NCEF);

- Making available additional resources for operation and management of water supply schemes;

- Participative planning and implementation of integrated water resource management practices through water budgeting and both supply side and demand side planning;

- Earmarking of funds for coverage of SC and ST population concentrated habitations;

- Incentive to ASHA workers for encouraging households to take household connections;

- Setting up of the Block Resource Centres (BRC) ;

- Strengthen financial control of the funds released by the Government of India to the States ;

- Facilitating the above, detailed manuals for Operation and Maintenance of schemes. Sustainability activities, Model DPRs for water supply schemes and a Water Quality Monitoring and Surveillance protocol have been prepared;

- Strengthening the procedure for Accounting and Auditing of the Programme.

The above changes and amendments have now been incorporated into the NRDWP Framework and are being published in this updated Framework of implementation. (ddws.gov.in new web site of the Ministry).

3.4.2.6 Discussion on critical Issues

(a) The Right to Water in the Indian Context

On July 28, 2010, the United Nations' General Assembly adopted a draft resolution recognising access to clean water and sanitation as a human right. The resolution was adopted with 122 votes in favor, no votes against, and 41 abstentions. The resolution called on "States and international organizations to provide financial resources, build capacity and transfer technology, particularly to developing countries, in scaling up efforts to provide safe, clean, accessible and affordable drinking water and sanitation for all." India voted in favor of this resolution

Later in the year, the Human Rights Council of the United Nations went even further. In September 2010, the Human Rights Council clarified that the right to water and sanitation is part of existing international human rights law and as such, States can no longer deny their responsibilities to provide safe water and sanitation. Since India voted in favour of the General Assembly resolution and is a signatory of the International Covenant on Economic, Social and Cultural Rights and the Convention on the Rights of the Child, its responsibilities are clear under International law.

Do the national law and the Constitution of India bestow on its citizens the right to water? The right to clean and safe drinking water and sanitation is not explicitly detailed in either the Constitution, or laws of the Republic of India. The Constitution guarantees every citizen fundamental rights to equality, life and personal liberty.

Several court judgments in post-Independent India have affirmed that all natural resources – resources that are by nature meant for public use and enjoyment – are held by the State in public trust and as a trustee, the State has "a legal duty to protect the natural resources," and "these resources meant for public use cannot be converted into private ownership."

Various courts have upheld that the right to clean and safe water is an aspect of the right to life. But court judgments do not constitute law or policy. At best, they provide directions for the formulation of laws and policies. To date there have been no laws or policies enacted in India asserting that water is a fundamental and inviolable right enjoyed by every citizen of the country. The "right to water" can therefore only be obtained in India on a case-by-case basis by going to court.

In the light of its obligations under international laws, various court judgements and recent UN resolutions, people's movements and civil society will have to push the government to draft federal laws in line with the human right to water and sanitation. As of now, the proposed draft National Water Policy falls short. (Madhuresh Kumar & Mark Furlong - 2012)

Extract of letter to National Water Resources Council, the Prime Minister, & Chief Ministers, from eminent citizens and scientists, is reproduced below :

"Right to Water The first draft of the NWP 2012 made public in January 2012 had said in its clause 1.3(v): "Access to safe and clean drinking water and sanitation should be regarded as a right to life essential to the full enjoyment of life and all other human rights." However, in the subsequent drafts, this sentence has been deleted. We urge the NWRC to add this in the NWP 2012 with an emphasis that right to water should be considered a fundamental human right. In this context we would like to add that the Indian government is a signatory to the UN General Assembly resolution number 64/292 of 28th July 2010 "Human right to water and sanitation", approved by 120 countries. This is now legally binding in international law; UN Human Rights Council decision of September 28, 2011 also is relevant in this context, as also the SC pronouncements reading Right to water in the constitution provisions.

It is felt that since a person can live without food for many days but cannot survive without water even for a few days, Right to Water is as important as the Right to Food. Such a legislation on water will help in bringing in the right focus on water security.

(b) Inefficiencies in the System

Despite longstanding efforts and considerable funding by the various levels of government , coverage of piped water supply continues to be inadequate. Local government institutions in charge of operating and maintaining the infrastructure are seen as weak and lack the will and technical expertise to carry out their functions specially with regards to planning, execution and subsequent maintenance and recovery of user charge.(World Bank Paper 2 - Policy Paper 44791)

Most rural water supply schemes in India use a centralised, supply-driven approach, i.e. a government institution designs a project and has it built with little community consultation and no capacity building for the community, often requiring no water fees to be paid for its subsequent operation. Since 2002 the Government of India has rolled out at the national level a program to change the way in which water and sanitation services are supported in rural areas. According to a 2008 World Bank study in 10 Indian states, demand driven schemes result in lower capital costs, lower administrative costs and better service quality compared to the supply-driven approach. Among the surveyed systems that were built using supply-driven approach system, breakdowns were common, the quantity and quality of water supply were less than foreseen in designs, and 30% of households did not get daily supply in summer. The poor functioning of one system sometimes leads to the construction of another system, so that about 30% of households surveyed were served by several systems. As of 2008 only about 10% of rural water schemes built in India used a demand-driven approach. Since water users have to pay lower or no tariffs under the supply-driven approach, this discourages them to opt for a demand-driven approach.

Drinking water supply schemes have also suffered from poor upkeep. Responsibility for operation and maintenance of water supply schemes lies with the PRIs but in many states this responsibility is poorly defined and not supported by transfer of adequate funds and trained manpower to the PRIs. PRIs and Village Water and Sanitation Committee (VWSCs) are not willing to take over completed schemes in which they were not involved at the planning and implementation stages. Inadequate water resource investigation, improper design, poor construction, substandard materials and workmanship and lack of preventive maintenance also lead to rapid deterioration of water supply schemes.

Over the last several years, many rural habitations have been provided drinking water supply. However, the number of ‘slipped back’ habitations has increased every year because the same aquifer is also being tapped for irrigation. This has also led to wetlands and rivers drying up due to reduction in base flows, which had earlier sustained them. The lowering of water tables has also caused, in many cases, contamination with arsenic, fluoride and other harmful substances (Approach Paper to XII Plan).

The operation and maintenance (O&M) expenditures incurred on rural water supply schemes in India is commonly much less than required and this has serious implications on their performance. The low expenditure on the O&M of water supply schemes can be traced to inadequate fund allocation and low cost recovery from beneficiary households. (World Bank Paper 4 - Policy Paper 44793)

(c) Willingness to Pay

The World Bank study shows that rural households already spend a considerable part of their limited incomes on acquiring clean drinking water, often having to tap a range of different schemes running in their villages, in addition to private provisions like investing in bore-wells, storage tanks, and so on. The average spending on water by a rural household is Rs 81 per month, and the study finds that families are quite open to spending up to Rs 60 a month on just operating and maintaining a water scheme, provided they are assured a regular and dependable supply .The level of cost recovery can be substantially raised by improving the services and charging the households according to their willingness to pay. The analysis shows that an additional Rs. 4 billion could be made available each year, if households are charged according to their willingness to pay. With these additional resources, the coverage can be increased by 14 percent. Another conclusion that may be drawn is that it would not be right to insist on 100 percent O&M cost recovery in all demand-driven schemes. In certain circumstances, the cost can be prohibitively high and 100 percent O&M cost recovery may be unaffordable. In such cases, the beneficiary household could be asked to pay up to a 'ceiling' level, say, Rs. 60–70 per month, and the cost beyond that level should be subsidized**. For BPL households the ceiling should be lower for capital and O&M cost contributions, based on the affordability criteria.** (World bank Paper 1 - Policy Paper 44790)

The authors feel that World Bank's recommendations seem to be conservative. In fact, Author's own experience, while launching skid mounted defluoridation units across several villages in India in 2005, showed that villagers willingly came forward to buy water at Rs. 2 per can of 20 ltrs which would translate to more than Rs. 300 a month (approx) for a meager supply of 20 lpcd per family of 5.. (More than 500 units- mostly in AP and Punjab- have been successfully operating in several villages for past 8 years. These Units were co-launched by Tata Projects Ltd. under their CSR scheme).

(d) Unbundling and Privatization

One of the recommendations of the World Bank for improving the effectiveness of the implementation of the water policy was to unbundle the bulk water supply and water distribution in multi village schemes (in areas where such schemes are justified). Bulk supply could be managed by a professional public or private operator, who could enter into enforceable contracts with the GPs and/or user committees that are responsible for distribution at the local level.

The Government seems to be veering around to accept this recommendation as would be seen from a passing reference in the draft NWP 2012 as under:

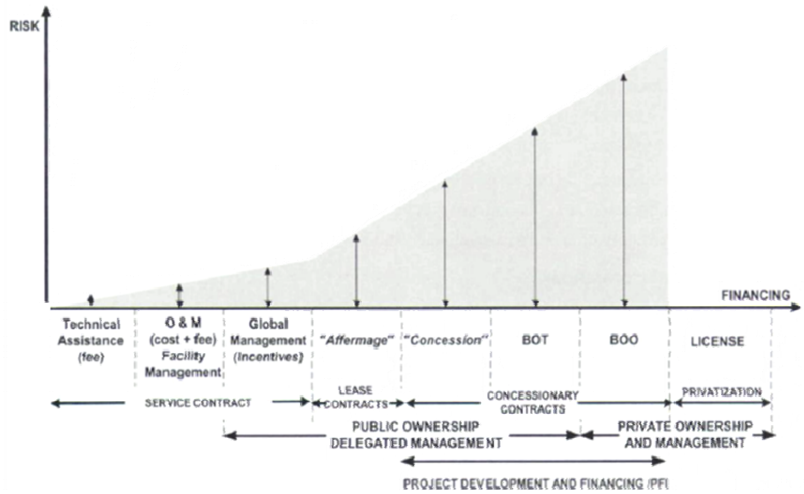
Water resources projects and services should be managed with community participation.

Wherever the State Governments or local governing bodies so decide, the private sector can be encouraged to become a service provider in public private partnership model to meet agreed terms of service delivery, including penalties for failure.

Any proposal of privatization relating to water will have a very serious opposition from most sections of the society specially when it concerns villages inhabitated with poor farming community in rural India. On the other hand it will be equally difficult to attract private capital given the level of opposition and the inherent risks associated with the complex and emotive issue of drinking water supply specially in rural areas

It is felt that perhaps there is a case for partial privatization by way of a service contract / Lease Contract thereby retaining the public ownership and yet having the advantage of a delegated management. See chart below on alternative structures for PSP.(courtesy Dr. Prem Pangotra of IIM / Ahmedabad)

PSP OPTIONS (ALTERNATIVE STRUCTURES)



Source: Gillespie, Financing Urban Water Supply and Sanitation, International Review for Environmental Strategies, 2005

Fig. 7

3.4.2.7 Rural Water Supply – Conclusions

1) From the analysis of policy and programmes of rural water supply and sanitation, it is evident that sincere efforts have been made by the government to provide water security across the whole country. Enhanced funds were earmarked under the Five Year Plans but on the whole, limited success could be obtained at the operational level. No doubt, a variety of programmes were launched to cope with the problems but their implementation could not yield commensurate results as the goal of providing safe drinking water for all is still way behind the intended levels . Special attention on the part of the State governments with strong political will is required to get the programmes implemented effectively by devolution of requisite powers to the PRIs.

2) It is time to consider bringing a legislation for water security to guarantee a minimum quantity of clean water to every person. Drinking water should also be accorded top most priority in sectoral distribution and its demand should be met ahead of agriculture and industrial demand. These measures will bring together all political parties on one platform for formulation and acceptance of a sound policy framework.

3) Since almost 85% of the demand is met from ground water, management of ground water assumes a greater importance .Conjunctive use of ground and surface water would go a long way in moving over increasingly to demand-driven programs. Restructuring of the behemoth Irrigation department and limiting its role to bulk supply leaving the distribution to PRIs /WUAs will go a long way in sustainability of the water resource .

4) All multi-village schemes must be subjected to an independent appraisal before being approved and should be made in consultation with the user associations.

5) There is need for a change in the attitude of state governments towards private sector agencies in the context of rural water supply. States need to encourage private consultants, contractors, and operators becoming more active in rural water service delivery, as several examples show that they are often more effective in improving service delivery. This is

particularly important for the planning and implementation of multi village schemes. A beginning can be made by entering into service contracts / lease contract thereby retaining public ownership.

6) There is a need for greater efforts at cost recovery and the allocation of more funds for the maintenance of schemes so that their useful life can be extended. To improve operations as well as cost recovery, the ownership of single village schemes should be handed over to the Panchayati Raj Institutions (PRIs) and/or user committees, after proper rehabilitation, and their O&M costs should be recovered from user charges. Similarly, multi village schemes and regional schemes may be unbundled into smaller schemes at the village level and the responsibility handed over to the Gram Panchayat/village community with contractual agreements and performance improvement targets between user groups and the bulk water providers. The desirable state to achieve is one in which the O&M cost needs to be properly assessed and fully recovered through user charges. State-wise, uniform cost sharing principles need to be worked out, irrespective of types of programs or sources of financing. For high cost schemes, it is not necessary, nor desirable, to recover fully the O&M cost through user charges. Rather, a transparent criteria needs to be developed to determine 'affordable' contributions, **including a criteria for socially disadvantaged groups.**

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(Dr. Prem Pangotra, IIM / Ahmedabad.)

3.5 Water and Climate Change

3.5.1 *Impact of Climate Change*

Climate change is one of the biggest challenge facing mankind and is impacting almost every aspect of human activity. And it is ironical that it is human activity which is triggering it. Its effect on Water – the ultimate resource, is engaging the anxious attention of the world.

3.5.2 *On Water Availability in Various Basins*

Climate change, challenges the view held till now that past hydrological experience is a good guide to future conditions. The consequences of climate change may alter the reliability of current water management systems and water-related infrastructure. (Climate Change and Water – Intergovernmental Panel on Climate Change (IPCC) Technical Paper VI - 2008). The quantitative assessment of changes in precipitation, river flows and water levels at the river-basin scale are uncertain and need to be projected in detail. Gosain, et.al. (2011) used the simulated climate outputs from PRECIS (Providing REgional Climates for Impacts Studies) RCM (Regional Climate Model) for the present (1961–1990, BL), near term (2021–2050, MC) and long term (2071–2098, EC) for A1B (balance across all sources) IPCC-SRES (Special Report on Emissions Scenarios) socioeconomic scenario to determine the quantitative projections at the river basin scale. This scenario is characterized by a future world which would have rapid economic growth, a global population that peaks in the mid-century (MC) and declines thereafter. It does take into account the likely rapid introduction of new and more efficient technologies, and the balanced development across energy sources.

The spatio-temporal availability of water in the various river basins (for three scenarios namely BL – base line, MC – mid century and EC – end century) was computed using SWAT (Soil and Water Assessment Tool) distributed hydrological model. The results of the study were analyzed to find the impact of Climate change on blue[a] and green[b] water for these three scenarios. The quantitative projections are tabulated in Tables 6,7&8. (The water related infrastructure in place in various basins has not been considered in the simulation exercise). Therefore, the rate of change projections are only valid for forecasting the future. **The trends indicate that blue water, and green water availability increases with time in all except Brahmaputra, Cauvery and Ganga basins**. The green water storage decreases in the mid-century scenario and then increases to the baseline scenario by the end of the century. The coefficient of variation for blue water, green water and green water storage mostly improves by mid-century and then reduces to base line scenario by the end of the century.

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[a] Renewable surface runoff and groundwater recharge which has been the main focus of water management.

[b] Rainwater stored in the soil that supports terrestrial ecosystem and the rain-fed crops.

Table 6 : Change in Precipitation -Basin wise

(-ve Value denotes increase from the BL)

	MC	EC
Baitarni	- 2.5	- 9.9
Brahmani	- 8.1	- 8.9
Brahmaputra	2.3	-20.7
Cauvery	1.7	-10.2
Ganga	- 2.5	-23.0
Godavari	-16.1	- 8.0
Indus	-16.6	-9.3
Krishna	- 1.5	-10.9
Luni	-13.8	- 2.5
Mahanadi	-13.3	- 9.0
Mahi	-11.5	- 3.9
Meghna	-25.0	-11.6
Narmada	-17.4	- 6.8
Pennar	3.5	- 6.2
Sabarmati	-13.7	- 2.7
Subernrekha	- 1.1	- 8.3
Tapi	-17.5	- 5.7

Table 7 : Change in Water Yield- Basin wise

(-ve Value denotes increase from the BL)

	MC	EC
Baitarni	- 2.8	-17.6
Brahmani	-12.6	-24.9
Brahmaputra	3.5	- 8.7
Cauvery	3.4	- 4.7
Ganga	0.5	-27.0
Godavari	-27.2	-33.6
Indus	-20.0	-17.5
Krishna	- 4.3	- 4.4
Luni	-51.9	- 7.5
Mahanadi	-19.0	-29.3
Mahi	-26.0	-25.0
Meghna	-33.8	-37.8
Narmada	-27.0	-34.5
Pennar	-30.9	- 7.4
Sabarmati	-38.6	-29.8
Subernrekha	- 1.4	- 17.1
Tapi	-32.5	-32.6

Based on the trends in this study, the average flow in various sub-basins in mid-century and end-century scenarios is indicated in Table 7.

Table 8 : Availability of Surface Water in bcm –Basin wise

	Present Estimates	**Mid Century Flow Estimates**	**End Century Flow Estimates**
Baitarni	5.42	5.57	6.37
Brahmani	23.06	25.97	28.80
Brahmaputra	585.6	565.10	636.55
Cauvery	21.36	20.63	22.36
Ganga	525.02	522.39	666.78
Godavari	110.54	140.61	147.68
Indus	73.31	74.78	86.14
Krishna	78.12	81.48	81.58
Luni	15.1	22.94	16.23
Mahanadi	66.88	79.59	86.48
Mahi	11.02	13.89	13.78
Narmada	45.64	57.96	61.39
Pennar	6.32	4.37	6.79
Sabarmati	3.81	5.28	4.95
Subernrekha	12.37	12.54	14.49
Tapi	14.88	19.72	19.73

All basins except Brahmaputra, Ganga, Cauvery and Pennar show improvement in average flows by mid-century. The maximum increase from 15.1 bcm to 22.94 bcm is indicated in Luni. However this increase is not sustained till the end of the century and yield decreases to 16.23 bcm. Brahmaputra, Ganga, Cauvery and Pennar also show increase in water availability by End of the Century in comparison to present availability. This is also true for all other basins.

3.5.3 *On Glaciers in India*

Glaciers 'mother' several rivers and streams with their melt run-off. A significant portion of the low flow contribution of Himalayan Rivers during the dry season is from snow and glaciers melt in the Himalayan region. The results of Sagarmatha project conclude that for the Ganga, the response of the river, near the headwaters in Uttarkashi is significantly different from what is seen downstream at Allahabad. At Uttarkashi, flows peak at between +20 percent and +33 percent of baseline within the first two decades and then recede to around –50 percent of baseline by decade 6; further downstream the deglaciation impacts are barely noticeable. Most of the other modeling studies carried out recently support these findings that it is at a seasonal level and in the higher reaches of the streams that Himalayan glacier runoff changes will be felt most significantly. The probable impact would become progressively greater as one moved upstream in a basin, decreasing the distance to the glacier terminus. The status of glaciers in the Indus, the Ganga and the Brahmaputra and their contribution to flows are given in Table 9.

Table 9 : Status of the Glacier Inventory of Indus Basin

Basin	No. of glaciers	Glacierised area (Km^2)	Icevolume (km^3)
Jhelum	133	94.0	3.0
Satluj	224	420.0	23.0
Others	3398	33382.0	-
Total	3755	33896.0	26.0

Summarising

India receives 1083 mm of average rainfall over a geographical area of 329 million hectares (mha). However, rainfall distribution varies widely across the land, both spatially and temporarily. Some areas in western Rajasthan receive an average annual rainfall of less than 300 mm, whereas some areas in the Northeast receive more than 2500 mm of Average rainfall. Most of this rainfall occurs in the monsoon months of June, July, August and September and its variability is highest in low rainfall areas of North western India and some pockets in the leeward side of the Western Ghats. The runoff generated in various sub-basins of India varies from 25 to 35 percent of rainfall except in the Luni, the Pennar and the east flowing rivers south of the Pennar. This average value is not a true representation of the variation in runoff even within the basin as can be seen by the average runoff coefficient in the sub-basins of the Krishna basin. These runoff coefficient values also change with the quantum of rainfall experienced in the sub-basins. These values increase with increasing rainfall requiring a different water resources management strategy to optimally use the resource from year to year requiring adaptive management techniques as in managing other natural resources.

Climate Change is not likely to decrease the average water availability in most of the basins. The frequency of extreme events could result in increased flooding and perhaps longer droughts. **Climate Change is also going to result in melting of glaciers.** The impact could be much more in the North western basins (such as the Indus) as compared to that in the eastern basins. (INAE Report-Water Resources Management, 2012).

3.5.4 *Climate Change and Agricultural Water Demand*

Climate change may become an important driver of agricultural water demand. The two important parameters of climate change are, global temperature rise and higher carbon dioxide levels. Plants need carbon dioxide for photosynthesis. Logically, high CO2 should lead to increased photosynthesis, especially in C3 Plants which account for more than 95% of earth's plant species and flourish in cool, wet, and cloudy climates, where water is plentiful, and the stomata can stay open and let in more carbon dioxide. However, water losses through photorespiration are high. Crops like non-glutinous rice, wheat, barley, tapioca and potato fall in this category. C4 plants, which inhabit in hot and dry environments, have very high water-use efficiency. Thus in C4 plants, there can be twice as much photosynthesis per gram of water as compared to C3 plants. However, C4 metabolism is inefficient in shady or cool environments. Less than 1% of earth's plant species are classified as C4 crops like maize, sugarcane, etc. Efforts are on to convert C3 plants to C4 category for increased water use efficiency. Further, experiments done (on the assumption that carbon dioxide levels will double), show that "carbon dioxide fertilizer" can increase the average yield in C3 plants by almost 30 percent.

The effect of increased CO2 may get neutralized by the rise in temperature which will increase evaporation and thereby irrigation demand. The changes in monsoon cycle and drier soil conditions may lead to decreased yields or increased water demands. Hence, the impact on water demand and productivity will vary with geographical location. **Agriculture will be adversely affected not only by an increase or decrease in the overall amounts of rainfall, but also by shifts in the timing of the rainfall.** Higher temperatures reduce the total duration of a crop cycle, leading to a lower yield per unit area, especially for India's wheat and paddy crops. The effects of climate change on water demands in agriculture are summarized below. (Agrawal, P.K., Ed.2009)

In Short

- Increase in CO2 to 550 ppm increases yields of rice, wheat, legumes and oilseeds by 10-20%.
- A one deg.C increase in temperature may reduce yields of wheat, soyabean, mustard, groundnut, and potato by 3--7%. There are much higher losses at higher temperatures.
- Productivity of most crops would decrease only marginally by 2020, though by 2100 this decrease could be between 10-40%.
- There could be some improvement in yields of rabi maize, millets and sorghum and coconut in west coast.

The distress in Animals due to heat could have an impact on reproduction and a estimated loss of around 1.5 million tons of milk by 2020 *. (INAE Report-Water Resources Management, 2012).*

3.5.5 *Climate Change – Adaptation for Agriculture and Agro Eco-systems*

It is said that climate change mitigation is about gases and that adaptation is about water.

In a world where 70 percent of water withdrawals are used for agriculture, it is important that we develop adaptation strategies to manage the impacts of climate change on water availability, agriculture, and the environment. Adapting to changes in water availability and seasonal distribution is possible, but we need to know the direction and magnitude of these potential changes and their degree of certainty. Given the likelihood of increasing water scarcity and variability, especially in the world's poorest countries, we have to ask whether we are saddled with outdated 20th century paradigms on how we manage water supplies that are fit for agricultural production, as well as domestic, industrial, and environmental uses. The facts are:

(a) World's Population is expected to increase by 2 billion in the next 20 years

(b) Climate change, particularly in the tropics/subtropics, where most of the poor live, is likely to impact both total rainfall and seasonal distribution;

(c) Burgeoning urbanization and concomitant demand for water means productive land will be lost to degradation and other non-agricultural uses;

(d) Increasing acreage will be devoted to plants grown for biofuel production; and

(e) There will be increasing demands for environmental water for wetlands and environmental flows that support valuable ecosystem services.

All of these trends are going to put existing water, land, and agricultural resources under significant pressure.

A key feature of future water management will involve adaptation to changing conditions associated with competing demand and variability in supply. Recently, provision of supply to those without clean water and sanitation was recognized as a key Millennium Development Goal. In some countries, particularly in Africa and South America, lack of finance—termed economic water scarcity—has been the key impediment to the expansion of access to clean water and adequate sanitation.

In many countries in the Middle East and Asia (for example, China and India), however, the new challenge is how to manage the growing demand for water in the face of supplies that are effectively fully allocated or utilized. This can be described as physical water scarcity. Increasing physical water scarcity means that real trade-offs among irrigation, other beneficial water uses, and the environment are inevitable and will require new sets of bio-physical and socio-economic tools to determine the most appropriate strategies. Climate change will undoubtedly put water users in many countries under more pressure. The good news is that a recent comprehensive assessment of water management in agriculture (Molden 2007), prepared with input from over 700 scientists, provides us with some clear directions as to what has to be done if the challenges of coping with competition for reducing water supplies are to be met in a future of climate change and population growth. The assessment asks a key question: "Is there enough land, water, and human capacity to produce food for a growing population over the next 50 years?" It concludes that while it may be possible to produce the food, it is probable that today's food production and environmental trends, if continued, will lead to crises in many parts of the world. The assessment details seven policy actions that must be taken to deal with the challenge They indicate that **we must rethink the old paradigms about water in order to successfully manage adaptation to climate change and other risks to our water resources**, food production, and environment.

3.5.6 *Water and Climate Change – Conclusions*

If we are to adapt to climate change, we will need to :

(a) Think creatively about water storage systems, including groundwater storage and reuse;

(b) Improve basin management and water allocation processes; and

(c) Develop drought response strategies, including early drought warning systems, crop insurance, changing land use and cropping patterns, and increasing water productivity. All of these will have to be embraced by policy makers, governance and institutional processes, water managers, and water users. (IWMI)

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3.6 Inter-Basin Water Transfer / National River Linking Project

3.6.1 *Backdrop*

The idea of having a National Water Grid for transferring surplus water available in some regions to water deficit areas dates back to 1972 when the then Minister for Irrigation late Dr. K.L. Rao proposed a 2640 km. long river linking grid with Ganga - Cauvery link as its main component . Dr. Rao had estimated this proposal to cost about Rs. 12,500 crores, which at 2002 price level comes to about Rs. 1,50,000 crores. The Central Water Commission, which examined the proposal, found it to be grossly under estimated and economically unviable.

This was followed by a proposal from Capt D J Dastur, a pilot and an electrical and engineering graduate from IIT, in 1977 which envisaged construction of two canals – the first 4200 km. Himalayan Canal at the foot of Himalayan slopes running from the Ravi in the West to the Brahmaputra and beyond in the east; and the second 9300 km Garland Canal covering the central and southern parts, with both the canals integrated with numerous lakes and interconnected with pipelines. The major criticism of the project by two committees of experts from the Central Water Commission, which led to its being given up, was its being technically unsound besides having an adverse cost-benefit ratio.

The idea of the water transfer however continued to draw country's attention and led to formulation of a National Perspective Plan (NPP) in 1980 by the then Ministry of Irrigation (now Ministry of Water Resources) and Central Water Commission with a view to minimize the regional imbalances and optimally utilize the available water resources.

After discussion at various Governmental levels, it was decided in 1982 to set up a National Water Development Agency (NWDA) to carry out detailed studies as a follow-up of the National Perspective.

The National Perspective as well as the NWDA studies have two components :

(a) Himalayan component and,

(b) Peninsular component.

The two do get linked on Mahanadi. When completed, the project would consist of 30 river links and 3,000 storage structures to transfer 174 bcm of water through a canal network of about 14,900 km.

3.6.2 *The Himalayan Component*

This envisages transfer of water from the water rich eastern rivers towards central, western and southern regions. The links proposed by the national perspective have been reduced in number after preliminary study by NWDA. The 14 Himalayan links taken up by NWDA for study are shown in Fig. 8..

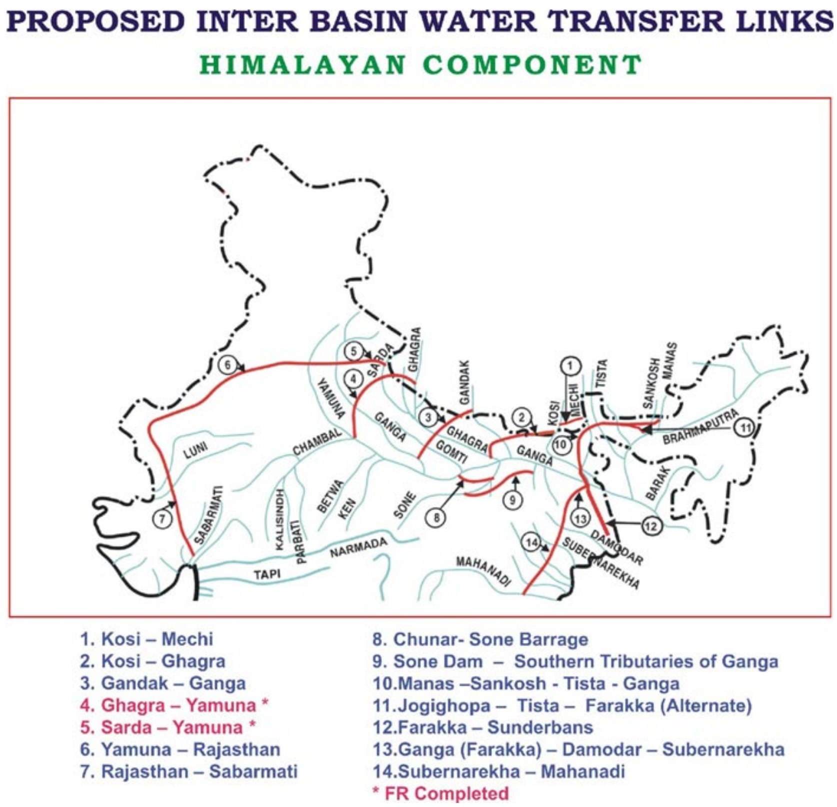

Fig. 8

Source : http://nwda.gov.in/writereaddata/linkimages/2079852609.JPG.

The Himalayan component proposes to transfer 141 bcm of water through 14 river links. It has two-subcomponents linking:

1. Ganga and Brahmaputra basins to Mahanadi basin (links 11-14), and

2. Eastern Ganga tributaries and Chambal, Sabramati river basins (links 1-10).

The scheme is estimated to irrigate an additional area of about 22 million hectares, generate about 30 million kilowatt of hydro-power and provide substantial flood control in the Ganga-Brahmaputra basin. It would provide 40,000 cusecs to Calcutta Port and would provide navigation facilities across the country. The scheme will benefit not only the States in the Ganga-Brahmaputra Basin, but also our neighbours – Nepal and Bangladesh as well as the Northern and the Western States in our country. Implementation of this scheme will however largely depend on the cooperation of neighbouring countries. *(*Amarsinghe - 2012)

3.6.3 *Peninsular Rivers Component*

The proposed links in the peninsular component are shown in Fig 9.

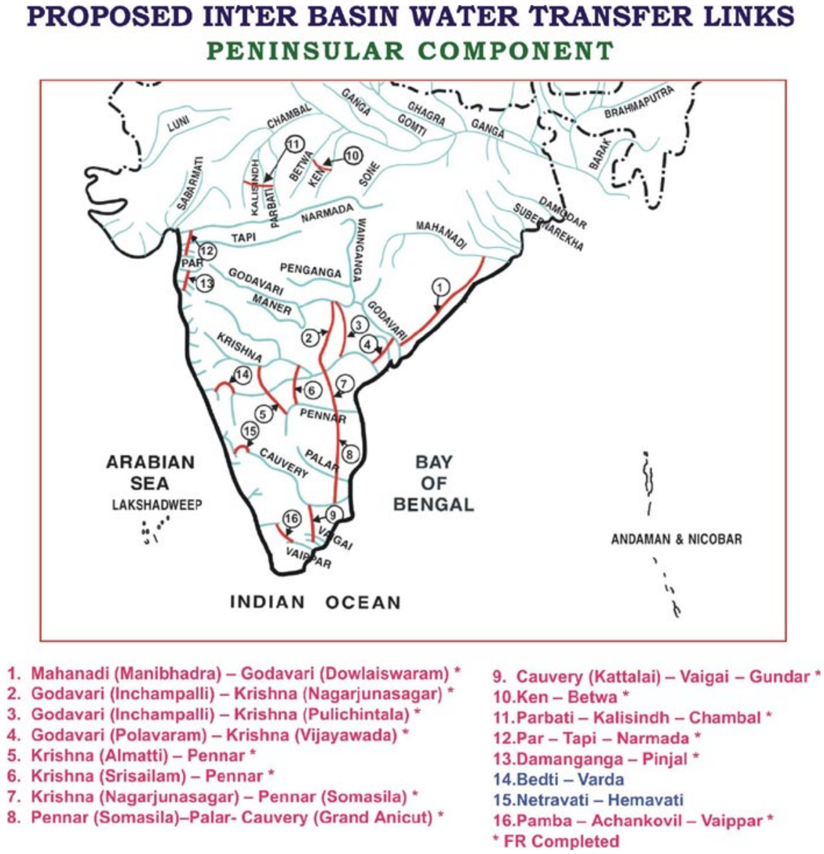

Fig. 9

Source : http://nwda.gov.in/writereaddata/linkimages/4771054686.JPG.

The Peninsular component proposes to transfer 33 bcm water through 16 river links. It has four sub-components linking

1. Mahanadi and Godavari basins to Krishna, Cauvery and Vaigai rivers (links 1-9);
2. West-flowing rivers south of Tapi to north of Bombay (links 12 and 13);
3. Ken River to Betwa River and Parbati, Kalisindh rivers to Chambal rivers (links 10 and 11); and
4. some west flowing rivers to the eastern rivers (links 14 -16).

3.6.4 *Project Benefits*

According to NWDA, the National Perspective Plan would give additional benefits of 25 million hectares of irrigation from surface waters, 10 million hectares by increased use of ground water, totaling to 35 million hectares and 34,000 MW of hydro-power generation. In addition the likely incidental benefits are:

- Mitigation of Droughts
- Flood Control
- Domestic & Industrial Water Supply
- Navigational Facilities
- Employment Generation
- Fisheries
- Salinity Control
- Pollution Control
- Recreation Facilities
- Infrastructural Development
- Socio – Economic Development

It is estimated that when completed, NRLP will increase India's utilizable water resources by 25 percent, and reduce the inequality of water resource endowments in different regions. The increased capacity will address the issue of increasing India's per capita storage which currently stands at a mere 200 m^3/person. It will help in ground water recharge and environmental flow of water-scarce rivers. (Amarsinghe - 2012)

3.6.5 *Project Costs*

The NRLP is estimated to cost more than USD 120 billion (at 2000 prices), of which

- the Himalayan component costs USD 22 billion;
- the Peninsular component costs USD 40 billion; and
- the hydro-power component costs USD 58 billion. *(Amarsinghe)*

(*Actual costs may vary substantially as considerable changes are anticipated during feasibility study and then on completion of the DPR. As per information from NWDA till 2012 only one DPR has been finalised for Ken – Betwa link - link no 10 of Peninsular- and two DPRs for Par-Tapti – Narmada –Link 12 and Damanganga –Pinjal – link no 13 -of Peninsular- are in hand since 2009)*

3.6.6 *Some Contentious Issues*

The NRLP concept has been contentious from the very beginning with several environmentalists and social activist opposing the idea due to concerns about environment, massive displacement of people, socio economic costs etc. Scientists and technical experts opposed the idea on the ground of hydrological and technical feasibility issues. Many of them disputed the need itself and wanted the Government to look at alternative methods of water conservation and regulating its demand. They felt that with improved water management demand can be met in all the basins except Cauvery and Vaigai basins which can be taken care of with limited water transfer from Godavari at Ichampalli and Polavaram towards the south. Some argued that it is paradoxical to talk of river basin concept on one hand and breach the basins through the interlinking on the other .The availability of surplus water in donor basins for inter basin transfer was itself hotly debated . Bangladesh was vehemently opposed to diversion of water from Ganges to Mahanadi in spite of assurance from GOI of not disturbing the agreed to share Under the India-Bangladesh Treaty of December 1996. It led to forestalling of the earlier gigantic proposal of Brahmaputra-Ganga gravity link canal taking off from Jogighopa(over Brahmaputra) in India, passing through Bangladesh, and joining the Ganga just above Farakka. An alternative link canal passing entirely through Indian territory (the Siliguri chicken-neck) involving large lifts has now been proposed. Commercial viability of this project due to very large lifts and power requirement is a grey area.Within India, Bihar already has a strong sense of grievance that its interests in respect of the waters of the Ganga system have not been given due consideration; and West Bengal has only reluctantly agreed to the large allocations to Bangladesh under the Ganga Treaty and has been pressing the needs of Calcutta Port. Neither State will look kindly upon any diversion of Ganga waters southwards. (*adapted from Ramaswamy R Aiyar and Sunita Narain))*

Various proposal were studied and considered by the Government but for obvious reasons never left the drawing board. However arising out of a PIL , Supreme Court in 2003 ordered the government to speed up implementation of the project and set the deadline of 2016 for its completion. The National Democratic Alliance then in power quickly announced the setting up of a task force for linking rivers rekindling a fresh interest in the subject.

In 2005, the International Water Management Institute (IWMI) and the Challenge Program on Water and Food (CPWF) started a three-year research study on “Strategic Analysis of India’s River Linking Project”. The primary focus of the IWMI-CPWF project was to provide the public and the policy planners with a balanced analysis of the social benefits and costs of the National River Linking Project (NRLP). The project consisted of research in three phases. Phase I analyzed India’s water future scenarios to 2025/2050 and related issues. Phase II, analysed how effective a response NRLP is, for meeting India's water future and its social costs and benefits. Phase III contributed to an alternative water sector perspective plan for India as a fallback strategy for NRLP.(The research papers have been published by IWMI under "Strategic Analysis of the National River Linking Project (NRLP) of India Series 1to 5)

IWMI studied the three major contentious issues, namely

(1) water surpluses of donor river basins; (2) key drivers of justification; and (3) the potential of alternative options of water management . Their findings and conclusions are as under- (*in italics by the author*) :

3.6.6.1 Contentious Issue 1 – Water Surpluses of Donor River Basins

Donor River Basins of the NRLP

The NRLP has three major donor river basins: the Brahmaputra in the Himalayan component, and the Mahanadi and the Godavari in the peninsular component. The project proposes to transfer 12.3 bcm from the Mahanadi to the Godavari basin (link 1 in the Peninsular component), and 21.5 bcm from the Godavari to the Krishna basin (links 2, 3 and 4 in the Peninsular component, which includes 6.5 bcm of water transferred from the Mahanadi basin. The proposed quantities of water transfer from Brahmaputra to Ganga, Ganga to Subarnarekha, and then from Subarnarekha to Mahanadi, however, are not available yet ,being a classified information. However, the issue of surplus surface water in the donor basins is a leading cause of disagreement in the NRLP discourses. An extreme view is that no river basin is water surplus. Some argue, "…from a holistic perspective there is no surplus water in a river basin, because every drop performs some ecological service all the time… there is no free surplus water in a basin that one can take away without a price." A moderate view is that a river basin can have surplus water if there is excess river flow after meeting the potential demand of agricultural, domestic and industrial sectors and an adequate allocation for the environment.

Water demand of the agricultural, domestic and industrial sectors for the three donor basins

The projections of the National Commission of Integrated Water resources Development (NCIWRD) are the first cut estimate for the development of the NRLP concept (GoI 1999). The NCIWRD scenario 1 and 2 correspond to low and high population projections of 1346 and 1581 million people by 2050. Amarasinghe (2012), based on recent trends of food consumption and water use patterns, has projected considerably lower demand for a population of 1581 million. (Table 10). For the lower projected population the demand will be even lower. NCIWRD figure for Brahmaputra basin are not available being classified but for the other two basins Amarasinghe's projections is 100 bcm as against 129 bcm for scenario 1 (lower side) against which current withdrawal is 64 bcm.

Table 10 : Water Demand of the Agricultural, Domestic and Industrial Sectors by 2050 (bcm)

River basin	**Water withdrawals in 2000**	**Estimates of total water demand by 2050**		
		Amarasinghe BAU	**NCIWRD Scenario 1**	**NCIWRD Scenario 2**
Brahmaputra	7	21	-	-
Godavari	44	65	76	98
Mahanadi	20	35	53	60
India	694	905	973	1180

Sources : Projections of NCIWRD scenarios 1 and 2 are from GoI 1999; Estimate of water withdrawal in 2000 and BAU (business as usual) projections for 2050 are from Amarasinghe.

Except for the NCIWRD high demand scenario of Godavari, the PUWRs (Potentially Utilisable Water Resources) of the three basins are more than adequate to meet the future demands of the three sectors. Based on Amarasinghe the total water demand by 2050 of the three basins are only 27, 56 and 54 percent of the total potentially utilizable water resources (PUWR) and the excess PUWR are available for other sectors, including the allocations for the environment. These projections are under the Business As Usual scenario (*Availability of surplus water can be much better with additional storages, improved water shed management and better demand management)*

3.6.6.2 Contentious Issue 2 – Key drivers of justification

Self-sufficiency

Three concerns dominate self- sufficiency assumption. **First**, India has a large population and food grain is the staple food; so no major grain deficits are acceptable. **Second**, agriculture is the main driver of economic growth and is the livelihood of a large part of the rural population. **Third**, low foreign exchange reserves do not permit large food gains imports. Many do not have any dispute with these assumptions, and indeed, they are reasonable for a large country like India. The contentious issues, however, are the estimates of food and water demand emanating out of these concerns.

Food grain demand

The NCIWRD projects that India will have to produce 450 million tonnes (or 284 kg/person/year) of food grains by 2050, and an additional 45 million tonnes for feed, seed and waste. However, recent trends show shifts in food consumption patterns. There are discernible trends of declining food grains consumption since 1990s. There are shifts from coarse cereals to superior cereals and to vegetables and fruit. Milk consumption is also increasing rapidly. As a result, while the share of nutritional supply from food grains is decreasing, the contributions of other vegetable and animal products in the diet are increasing.

Based on these recent trends, the likely projections of food grains demand (*and consequently the demand on water*)could be significantly lower than the NCIWRD projections.

(The Approach Paper for 12th five year plan seems to corroborate the above observation . In para 5.28 it says "The issue of food security is perhaps the easiest one to resolve. It is true that over the past decade there has been a decline in net sown area of approximately 2 million hectares. However it must be kept in mind that this is only 0.6 per cent of the total net sown area. Given that agricultural productivity is currently half of what it is in many other countries, the solution for food productivity lies not in stopping diversion of agriculture land in all circumstances, but in increasing food production through higher land productivity. Industrialisation, urbanisation and development generally will require a diversion of land to new uses. Efforts can and should be made to avoid diversion of highly productive agricultural land, "

Rural Livelihood Needs

Rural employment was a key driver of irrigation development in the past. However, today's younger generation in Indian villages have different perceptions and priorities. The likelihood that young rural farmers will move out of agriculture is high, or they will keep it as a secondary income activity, regardless of increased access to irrigation. This is more evident among rural youth who have different skills and better education. The tendency of moving out of agriculture is also higher where the distance to travel to town or urban centers is less. Certainly, the future generations of India will be more educated, and will be equipped with better skills. In addition, many rural centers will become small towns, and towns will become sprawling urban centers. Urban population will exceed the rural population before 2050. Infrastructure facilities such as access to roads, electricity, and telecommunication are also increasing. Thus, migration from full time agriculture to non-farm rural and urban livelihood will increase. In fact, there will be much less agriculture dependent population than today. This will be especially true in economically dynamic Southern states, which, in fact, are supposed to be the recipients of the NRLP water transfers.

(The recent census figures for 2011 indicate farmer population has fallen by 9m in 10 years and that the absolute number of cultivators has fallen for the 1st time in four decades. Also the cultivable land continues to shrink—Times Of India news1st May and 16 Aug 2013)

Costs and Benefits of Irrigation Water Transfers

Another raging issue in the NRLP discourse is benefits and costs. The NRLP water transfers envisage benefiting irrigation the most. It plans to add 35 million ha of new irrigated croplands (25 mha through surface and 10 mha through groundwater). The financial and social benefits, both direct (crop production) and indirect (backward and forward linkages), of irrigation are major components of the benefits. However, achieving this would require committing a huge outlay.

Going by the past trends, returns to investments in the major/ medium irrigation show an abysmal picture Since 1991, India has invested more than Rs. 1.88 lakh crores (USD 53 billion in 2005 prices) in major and medium irrigation alone, yet it has hardly resulted in any addition to net irrigated area by government canals .Tamil Nadu and Andhra Pradesh, two of the key water recipient states of River Linking project, spent over USD 7 billion (2005 constant prices) in canal irrigation since 1991 but lost close to 5 lakh ha of net irrigated area under major and medium schemes. Similarly, Gujarat has already spent more than Rs. 20000 crores in the Sardar Sarovar project, although the envisaged cost of construction in the planning was only Rs. 6840 crore (1986/87 prices). In spite of the enormous cost overruns, at present, it irrigates only 0.1 million of the 1.8 million ha of the proposed area.

The proposed water deliveries of the peninsular links start from the Northern-most link, Mahanadi, to Godavari. It substitutes water demand for the Godavari downstream, so that it can transfer the surplus water from the upstream of Godavari basin to Krishna basin. Similar substitutions occur in water deliveries from Godavari to Krishna, Krishna to Pennar and Pennar to Cauvery. Thus, this system of link canals is inter-dependent. Although the net value added financial benefit of water transfers to en- route command areas of some individual links exceeds the cost, peninsular system taken together has higher financial benefits than cost. In fact, if water transfers are for irrigating new high value crop areas, even the command areas of individual link could be highly beneficial, financially. If the irrigation cropping already exists in the proposed command areas, then appropriate high-value cropping pattern could make the system of links financially viable. This finding is consistent with the irrigation cost and benefits of existing schemes. That is, the large projects with many smaller schemes do perform positively from an economic perspective. Additionally, projects with diversified cropping patterns or those managed by farmers' or Water Users Associations (WUAs) tend to have better economic performance.

3.6.6.3 Contentious Issue 3 – Potential of Alternative Water Management Options

Many have criticized NRLP for inadequate attention given to alternative water management strategies namely increasing water productivity, improving rainfed agriculture in managing the water demand and artificial groundwater recharge in managing the supply.

Water productivity improvements

Water productivity improvements could reduce the water demand, reduce the surface and groundwater over-draft and protect the environment. In Indian agriculture, potential exists for both improving water productivity (WP) and increasing food grain production. The total Consumptive Water Use (CWU) from irrigation by food grain crops in 2000 was only about 155 km^3, while irrigation withdrawals for food grains were about 430 km^3.

Rainfed Agriculture

The rainfed agriculture contributes meagerly to current food production. It covers about 60 percent of the crop area but contributes to only one-third of the of the food grain production. NCIWRD has projected only a modest growth of rainfed grain yields from 1 tonne/ha in 1993 to 1.5 tonnes/ha by 2050. However, by doubling the rainfed yield, to about 2.0 tonnes/ha over the next 50 years, the grain production on the existing rain-fed lands can alone be increased by 81 million metric tonnes. This increase in grain yields - a proposition seemingly possible in 50 years - can meet a substantial part of the future food demand.

Artificial groundwater recharge

Contrary to what most claim, groundwater irrigation has spread everywhere, even outside canal command areas where recharge from surface return-flows could not have reached. The tube well boom has made a significant part of India's agriculture production and rural livelihoods depend on groundwater irrigation, but also made large areas prone to over exploitation.

For sustainable groundwater irrigation, India needs to invest more in artificial recharge in many locations and better managements of aquifer storages. India already has in place a National Master Plan for Groundwater Recharge, augmenting the resources annually by another 38 bcm. The program, costing Rs. 24,500 crore (USD 6 billion at January 2008 exchange rate), can achieve its potential benefits by addressing the shortcoming of the master plan.

3.6.7 *Inter-Basin Water Transfer / National River Linking Project – Conclusions*

There are clear trends that India will require substantial additional water supply to cater to increasing demand in the coming decades. The population and economic growth, increasing world trade, the changes in lifestyles will be primary drivers for increased demand. The climate change will become an influencing factor in the long-term with higher intensity of floods and drought cycles. Ground water has been the major source for meeting increasing demand in all sectors. It is highly likely that this trend will continue. Many river basins, particularly in peninsular India, will have severe water stress conditions. With increasing reliance on groundwater, particularly for irrigation, many river basins will have severe groundwater overexploitation-related problems. Meeting India's short to medium term water demand itself will be a challenging task. However, many options are available to meet this challenge. Recharging groundwater to increase the groundwater stocks; harvesting rainwater for providing the life-saving supplemental irrigation; promoting water saving technologies for increasing water use efficiency; formal or informal water markets and providing reliable separate rural feeders for reducing uncontrolled groundwater pumping; increasing research and extension for enhancing agriculture water productivity; and carefully crafted virtual water trade between basins are important policy options for meeting the increasing demand. With increasing disposable income, people's affordability and willingness to pay for a reliable domestic and industrial water supply will increase. This, along with a reliable water supply for diversifying high value cropping patterns, may require large surface water transfers. The inter basin water transfers, besides generating clean energy, could increase the recharge groundwater in much of the overexploited area. While artificial groundwater recharge, rainwater harvesting, and inter basin water transfers are a solution for meeting the water demand in the near-term, they are also solutions for increasing the potential utilizable water supply in many water scarce river basins. They will indeed have major benefits when full influence of the climate change starts to impact the utilizable supply in many water scarce river basins.

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3.7 Future : Water Scenario in 2025-2050 / Meeting the Water Challenges, 2025-2050

3.7.1 Introduction

The projected water demand for 2050, with 10 % improvement in irrigation efficiency and 46.5% increase in crop productivity, is assessed at 735 bcm. In addition, there would be requirements of industrial, domestic and other sectors (373 bcm). The water demand would thus be 1108 bcm; the total utilizable quantity would be about 1123 bcm. The environmental demands for ‘C’ category status (moderate modification in the ecosystem that would not seriously modify biodiversity and habitat, are assessed at 501 bcm (33 % of total renewable water resources) while for category ‘D’ (largely modified ecosystem), it is 353 bcm. (Amarasinghe et al, 2007). Hence, the current water situation is heavily imbalanced. The Basin-wise water supply and demand balance projections for 2025 and 2050 show that basins like the Indus are currently physically water-deficient and are surviving on groundwater overdraft, which is unsustainable.

Note : The slight variation in the projections for 2025 & 2050 from those given in para 3.2 emanate from different initial assumptions.

It is therefore imperative that we take serious note of the available water demand and supply management options.

The Business As Usual (BAU) scenario assumes that the current trends in population growth, urbanization, land and water productivity, irrigation efficiency, groundwater development etc, would continue in future. This scenario also assumes a substantially increased target for efficiency improvements; yet the total water demands are approaching the limits of potential utilizable water resources. However, there are some possibilities of shifting a few of the key drivers of water demand through technology interventions. These interventions would either augment the existing supplies or enable realisation of the production targets with reduced water diversions (Tyagi, 2009). It is therefore imperative to examine the domains, capacities, associated costs of technological interventions, and review the alternative scenarios for taking optimal decisions.

River basins in the country fall under various agro-climatic zones and are subjected to varying degrees of water stress, emphasizing the need for identifying the most appropriate mix of technological improvements for each region. The acceptability of the technology by the end users depends on the efficiency gains as well as the economic and financial viability. It may be relevant to mention that infrastructure development and implementation of water smart technologies are driven by public policies, not only in respect of direct investment by the State, but also for promoting public-private sector participation. Some of these issues affecting the sectors which follow water security programs are briefly discussed below.

3.7.2 *Demand and Supply Measures to Meet the 2050 Water Challenge*

Conceptually, three broad sets of options are available for meeting the growing water demand challenges:

One is demand management, the other is supply management and the third is a mix of both these options. Agriculture sector is the dominant user of water and its current level of low productivity and irrigation system inefficiencies provides greater scope for minimizing water demand as compared to other sectors. The 2030 Water Resource Group (2009) reported in their study that, of the estimated supply-demand gap of 755.8 bcm in 2030, nearly 80% (640 bcm) could be bridged through improvements in agriculture. The corresponding savings from the domestic and the industrial sectors were only 4.9 and 7.3 bcm, respectively. Though the gap in demand and supply estimated by this Group appears to be much on the higher side, the Study highlights the potential of water management technologies in reducing demands. Hence, improvement in agricultural productivity holds the key for meeting the water challenge, 2025-2050. *Source : 2030 Water Resource Group (2009)*

3.7.3 *Bridging the Water Availability through Demand Management in Agriculture*

Demand management can be done through:

(i) biological interventions like introduction of improved germplasm with higher yield potential or higher resistance to biotic and abiotic stress in both irrigated as well as rain-fed farming,

(ii) improved plant nutrient management and

(iii) improved water management technology.

Seed has been a major factor in agricultural productivity enhancement all over the world. The water and nutrient inputs-responsive germplasm was significant in triggering the green revolution in India. Continuing efforts to capitalize on new advances in molecular biology would play on important role in sustaining and increasing productivity growth in future. Probably, development of germplasm, resistant to biotic and abiotic stresses, for irrigated and rain-fed conditions and tolerant of heat stress(which is likely to increase with impending climate changes), will be a vital element in increasing productivity and reducing irrigation water requirement. Balanced fertilizer use, capturing interaction of water and fertilizers and enhanced fertilizer use is another group of technologies/practices that would reduce overall water demand in agriculture.

Agricultural production is spread over more than 140 million ha. While action for crop production takes place in the root zone in the soil, water has to traverse a large conveyance and distribution network and move over land of varying characteristics, before it becomes available to the plants. Hence, the efficiency in conveyance, distribution and application of water to the crop makes a substantial difference in water demand at the project head level. Even in case of rainfall, the watershed management authority would decide as to how much of it would be consumptively used as green water and what fraction will percolate down to the aquifers or flow into the rivers as runoff. Another point for consideration is that more than 60 % of water diverted to farms is consumptively used, offering limited scope for water reuse. On the other hand, the consumptive use fraction in domestic and industrial sector is less than 20% with higher possibilities for recirculation if quality aspects of the effluents are effectively taken care of.in short -- ***Agricultural Productivity Holds the Key to Water Security.***

3.7.4 *Agricultural Productivity – BAU and other Scenarios*

There are several options for bringing about productivity changes. Apart from water, two other important inputs which contribute to agricultural productivity are seeds and fertilizers. Under normal situations, contributions of these three production inputs are of the same order. As seed cost per unit area is generally the lowest, a preferred option always is to bring in productivity improvements. Such improvement through the water management route involves increase in the yield with a given quantity of water or getting the same yield with reduced water application. A third option could be increase in yield and reduction in water applied through appropriate changes in other inputs. Depending upon which resource is scarce, the yield per unit of water use (WP- Warer Productivity) or per unit of land (LP-Land productivity)) is maximized. A few feasible scenarios, involving various land water productivities and irrigation system efficiencies, are discussed here.

3.7.4.1 Crop Yield Growth Rates

The BAU scenario assumes an annual growth rate of 1.4% during 2010-2025 and 1.1% during 2025-2050, providing an average grain yield of 2.4 tons/ha in 2025 and 3.2 tons/ha in 2050. It may be added that the rate of growth of 3.4% during the 1980s, dropped to 2.1% during the 1990s. But recent growth rates for grain crops appear to be more encouraging, because except for wheat, the rate of increase for the period 2001 to 2009 is more than 1.9% (National Rainfed Area Authority (NRAA) 2011). Decadal growth rate for fruits and vegetable is more than 7 %. Hence it is likely that productivity growth might exceed the rates assumed in BAU. Further, significant gaps between the realized and the potential yields indicate a possibility of achieving higher growth rates in crop production.

3.7.4.2 Increasing Productivity through Irrigation Efficiency Route

Irrigation diversion requirement is greatly influenced by how water is conveyed from the source to the point of use and how it is applied to the crop. Technically, it is possible to improve the conveyance efficiency from the present range of 35-40% to 60-70% or even higher, at a cost of course. Change in conveyance efficiency does affect per unit area yields, but alters the water productivity at project level. Recent reports from the Directorate of Water Management of ICAR put currently operating project efficiencies between 30 and 38% (Singh and Kumar, 2011). The changes in BAU irrigation demand with surface irrigation efficiency at 50, 55 and 60% and groundwater irrigation efficiencies 70, 75 and 80% by 2050 bring in significant changes in water demands. A 5% increase in both canal irrigation efficiency (CE) and ground water efficiency (GE) would reduce irrigation demands by 60 bcm (8%), compared to BAU estimates without any reduction in crop yields and production per unit of irrigation diversion would go up. If efficiencies are raised by 10%, in case of canals and ground water, irrigation demands would come down by 18% (129.5bcm). Water so saved could be released for other uses e.g. meeting environmental demands.

3.7.4.3 Ways to Improve Irrigation System Efficiencies

System efficiency is the product of conveyance and application efficiencies. Water lost in conveyance or in application can be saved only through improvement in the respective subsystems. However, to a certain extent, it is possible to achieve the given system efficiency through an alternate mix of technology interventions. If the target efficiency of ground water system is set at 80%, it will have to achieve conveyance and application efficiencies of the order of 90 %, which are possible only through piped conveyance and drip irrigation. This will obviously put limits on the area which can be brought under such irrigation efficiency regime as not only the cost of improvement, but also the suitability of water application system, will become a limitation. At a low efficiency target of 65 %, the management can have recourse to a larger basket of options. Various technologies which help achieve water saving and higher yields at farm level are briefly discussed hereunder.

Laser leveling has the potential for making positive contributions to increasing the productivity and incomes of farmers. The manifold benefits of technology are realized in terms of water saving and increased water use efficiency, and reduced energy in pumping water (Tyagi 2009). For example, seasonal irrigation requirement of rice-wheat in the Indo-Gangetic Plain (IGP) ranges between 1800 and 2250 mm (18000-22500 m3). At the least, 50 % of the irrigation requirements are met by ground water which has to be pumped for 50-70 hrs/ha/yr, from increasingly depleting groundwater reserves. Surface application being the dominant method of water application in rice-wheat system, laser leveling can achieve a high efficiency of 75% and reduce farm water diversion by 20-30%, apart from increasing crop yields (Ambast, et al, 2005). It is worth noting that introduction of laser leveling in surface application, which has wider applicability, can help achieve higher application efficiency comparable to the sprinkler method. In less than a decade, the number of laser leveling equipments in Punjab alone went up to 4000 indicating its effectiveness in achieving the desired objective.

3.7.4.4 Micro Irrigation

Numerous studies show the potential of the micro irrigation system, including drip, for improving the overall productivity and profitability of several widely-spaced row crops, particularly fruits and vegetables. Current revolution in horticulture can be promoted further with micro-irrigation. It is worthwhile to note that horticultural crops have a higher productivity per unit area. For example, we produce only 4-5 t/ha of rice as against 22 t/ha of banana and 40 t/ha of pine apples. In terms of nutrition also, these crops outperform cereals. For example, supplying the total per capita per year 1.1x106 kcal energy requirements, requires about 0.4 ha of land under paddy, 0.013 ha under banana and 0.15 ha under pineapples. Fruit crops are now playing a key role in contributing to the food and nutrition security of the country.

Micro irrigation provides triple benefits: reduction in irrigation requirements, fertilizer saving and increased crop yields. The return on investment on micro irrigation (with subsidy) could be as high. 1:6, and even without subsidy, it may be more than 1:2. The area under micro irrigation (drip and sprinkler) in India is growing steadily and has the potential of being introduced in about 25 Mha.

3.7.4.5 Some Other Resource Conserving and Yield Enhancing Technologies

The third group of technologies was developed to increase mechanization and reduce cost of cultivation. Incidentally, measures like Zero-Till Farming (ZTL), System of rice intensification (SRI) not only increase productivity per unit area, but also reduce cost of cultivation, besides saving water. Reduced labour and fertilizer cost and decreased green house gas emissions are some of the other benefits of Zero-Till Farming. (Lumpkin and Sayre, 2009 and Tandon and Singh, 2009).The benefits from increased production and reduced cost, more than compensate the cost of intervention. Water saving is an additional benefit at no cost.

3.7.4.6 Efficiency and Yield Enhancement Potential of Important On-farm Technologies

The total water saving potential of a technology application depends on an increase in efficiency from the base value and the extent of the area in which it can be implemented. For example, SRI is applicable only in rice; hence its usefulness is limited to rice cultivation. However, Zero tillage can be introduced in a large number of crops and would lead to higher savings. Introduction of technologies like Improved Germplasm or Balanced Fertilizer application has no direct water savings. But these increase land productivity and enable us to achieve food production target from a smaller area.

3.7.4.7 Relative Cost of Water Saving and Productivity Increasing Technologies

Cost differentials attached to various types of water savings are helpful in ranking and choosing various technologies for implementation. Incremental cost for saving a water unit, suggested by 2030 WRG (2009), is one of the tools for planning implementation of technologies. The cost curve, developed by them, indicates that incremental cost per unit of water saved may vary, from less than one Rupee to more than 100 Rupees per cubic meter saved/generated. On-farm agro-technologies/practices like Zero Tillage, Integrated Balanced Fertilizer Use or System of Rice Intensification, not only increase crop yields, but also reduce the overall cost of cultivation. Such interventions help in bridging the water demand – supply gap with no direct cost assigned to water savings (resulting from their implementation) and incremental costs are shown as negative. Some other technologies viz. Improved Irrigation Methods, save water through improved efficiency as well as increased yields (and consequent reduction in irrigated area requirement). Technologies like Improved Germplasm results only in increased yields with no direct water savings. But the potential of these technologies to bridge the demand supply gap is much larger.

For example, 2030 Water Resource Group (2009) estimated that yield- increasing technologies might reduce water demand by 50 bcm as compared to 15 bcm only through agricultural efficiency improvement.

The corresponding savings through efficiency improvement in municipal and industrial sectors would yield only 2.2 and 0.7 bcm respectively.

3.7.5 *Basin Level Water Demand Balance and Suggested Action Programmes*

In view of the fact that a matching gain in water supply to bridge the supply deficit to the extent of 80% could be had by demand management, adoption of this option should be given priority. The balance 20% gap between supply and demand should be addressed through wastewater reuse, cost effective storage development projects and limited regional river water transfers. Desalinization of sea water may be resorted to for augmenting drinking water supplies in coastal cities facing acute shortages. It is emphasized that both the cost estimates as well as the quantity of water that can be saved/ made available, are only indicative. But these highlight the relative importance of various productivity enhancing measures. There are large agro-climatic, hydro-geological and physiographic variations within and across river basins. These determine the crop choices and their productivity and consequently the techno-economic suitability of the technologies. Further, the river basins in the country are at different stages of development and varying levels of water stress. For example, the Luni and the WFR1 group of rivers(west flowing rivers) are facing physical scarcity with little potential left for development. Such areas are not going to benefit from low value water intensive crops. Hence, introduction of high-value crops, mostly aromatic and medicinal plants, and arid horticultural crops with micro-irrigation, would be the right choice. On the other hand, in the Mahanadi basin, soil erosion control and rainwater harvesting in hilly areas would get priority. In the same basin in coastal Orissa, surface drainage and irrigation with shallow wells will be more beneficial. The grain crop-intensive Indus basin would have to reduce area under rice and wheat to curtail its water demands and introduce high tech precision agriculture.

3.7.6 *Bridging Water Availability Gap through Supply Management*

Increasing water availability through supply measures includes abstraction of more water from the rivers and aquifers, rainwater harvesting, inter-basin transfers, wastewater treatment and desalinization etc. Projections show that 45% of the estimated 1.64 billion population in 2050 AD would be living in urban agglomerates requiring 148 bcm of fresh water supply and generating waste water of more than 100 bcm. This water could become either a valuable resource or a source of environmental pollution, depending upon the reuse options and the technology employed. As any major increase in urban water supply would come from diversion from agriculture, and, since agricultural use of wastewater also serves as a means of its use and treatment, it has to be a priority option. It is seen that compared to water saving options, the cost of creation of new supplies is much higher. Even amongst the supply measures, the variation in unit cost is quite large. For example, wastewater reuse and deep aquifer development measures are much lower in cost than desalinization. Completing the surface storage projects as well as rainwater harvesting through watershed management project would be more cost effective.

3.7.7 *Important 2025 Targets for Water Supply Increasing Interventions*

Even though the supply measures face a steep marginal cost curve, with the ceiling price set by expensive technologies (2030 WRG,2009), the task of ensuring water security for food, economic development and maintenance of ecosystem in a healthy state in a dependable manner, would require development of additional water resources. The Water Resource Group (2009) estimated that about 400 bcm of additional water could be developed through various supply enhancing measures. As regards agriculture, reclamation and reuse of domestic wastewater, aquifer recharge during monsoon, creation of new resources by completing the ongoing water development projects, should be the priority. Large scale rehabilitation of irrigation infrastructure could increase the irrigation potential by 5Mha. Completion of last mile irrigation infrastructure could bridge the gap between the potential created and the irrigation realized by 9 Mha. The wastewater, after treatment, is going to be a major source of new water supply. It may added that the consumptive use in domestic and industry sectors is less than 20%. The estimated diversion for these two sectors in 2025 being of the order of 260 bcm, an estimate close to 200 bcm would be a dependable target for committed water supply for reuse. Compared to other sectors, agriculture is better suited for using such waters. Drinking water scarcity in certain locations such as Chennai may justify investment in desalination. The National River Linking Project (NRLP) would get priority in view of the order passed of the Hon’ble Supreme Court of India on 27 February, 2012 and need to be taken up at the earliest. Brief details of the proposed NRLP are discussed separately.

3.7.8 *The Emerging Directions for Development*

A few interesting findings emerge from this analysis of water demand and supply scenarios and the possible options for meeting the 2025-2050 water challenge. It is evident that our water demands would escalate sharply while water supply would not match the growth in demand. Growth in agriculture, energy, industry and environment sectors have significant implications for water budgets in the river basins. It is observed that water demands for the year 2025 and 2050 would not be met by the current and projected water resources development plans in the Business As Usual mode. It is also noted that a major part of the solution, to the extent of 80%, lies in demand management, particularly through the productivity enhancement route in agriculture. Of course, demand management is subject to diffusion of knowledge, skills, and access to capital by millions of small and marginal Indian farmers which by itself is a difficult and complex task.

However, the positive aspect is that a large basket of technologies is available to trigger productivity growth at reasonable cost. Further, the Government seems to have appreciated the significance of water availability for meeting India's food and nutrition security. Based on the premise that solutions to Water- 2050 Challenge are within reach, the immediate objective is to design a pragmatic and implementable combination of programs and align it with the national development goals and plans. It is well known that development of various sectors is inter-linked and no sector can move forward in isolation. An obvious example is the energy and water nexus. Water is needed for energy generation but at the same time, the development process as well as use of water are dependent on energy availability for pumping irrigation water, performing field operations and processing, storing and transporting food. In a growing economy, public policies influence the direction and the extent of development by way of resource allocation, framing laws and rules for facilitating clearances and ensuring good governance. Various issues relating to availability of technology along with prioritization for their adoption, implementation challenges, and the need for aligning public policies and the institutions to meet the water challenge, are briefly discussed below.

3.7.9 *Technology*

Exploiting the Full Potential of Crop Genetics

The three main elements of crop production technology are: seed, nutrients and water. The vast diversity of the plant kingdom and the emergence of new tools to enhance the genetic potential, afford us an opportunity to have high yielding crop varieties which are resistant to biotic and abiotic stresses. Biotechnology also enables us to have the common crops fortified with additional nutrients for achieving the national goal of nutrient security along with food security. The increase in crop productivity through the seed route is not only large, but also the cheapest option, obviating the need for putting additional land under irrigation. Estimates show that improved germplasm in irrigated and rain-fed farming together has the potential of bridging 17% of the water demand–supply gap (2030 WRG, 2009).

3.7.10 *Harnessing Synergy between Green and Blue Water*

The contribution of green and blue waters to agricultural production is in the ratio of 2.5:1, yet green water seldom appears in the water balance equation and the entire planning revolves around blue water. It must be realized that blue water alone is incapable of ushering in the revolution we are hoping for during the next few decades. On the other hand, green water by itself, is also not in a position to ensure the productivity levels for achieving production targets of 2025. If the irrigated land productivity is frozen at current level, about 25 million ha additional land would have to be put under irrigation, with additional blue water, to meet the projected food and feed demands in 2025. The only way out lies in appreciating and realizing the importance of utilizing the synergy between blue and green waters and work towards establishing a smooth and continuous transition from green water dominated rainfed agriculture to partial and intensively irrigated agriculture. Essentially, these calls for harvesting and storing rainwater, not only in-Situ in the soil profile, but also in on-farm reservoirs as well as equipping these small reservoirs with micro-irrigation systems to achieve the desired area coverage.

3.7.11 *Making Use of the Comparative Advantage in Crop Choices*

River basins in the country have varying endowments, not only of water, but also of terrain, soil and climate, enabling them to produce certain crops with higher productivity. The crop choices should be determined by both water endowments and crop water foot prints. The technology and skills for growing crops are transferable from one region to other regions, through water transfers are difficult and costly. It is clear that for water- deficient basins like the Indus, it would not be correct ecologically to put extensive areas under high water-requiring crops for intra-basin grain transfer to water rich areas. Extensive crop diversity gives us an opportunity to shift to crops, which are less water-consuming, and at the same time, more remunerative. It is envisaged that, in future, the Ganga basin would replace the Indus basin for producing surplus food grains for food deficient basins. Concerted efforts in mission mode are required, to achieve this goal.

3.7.12 *Wastewater as Irrigation Resource*

As more than 50% of our population would live urban areas by 2050, wastewater is going to be an expanding and dependable source of water supply for reuse to the extent of 80-100 bcm. But looking at the health hazards that poor sanitation might create, it would be necessary to develop and enforce appropriate guidelines for disposal and use of such water.

3.7.13 *Combating Water Pollution*

In spite of the efforts made during the past few decades, pollution of both rivers and ground water has not declined and the long-term threat of what SIWI terms as 'Hydrocide' looms large (Falkenmark, 2005). The recent report of the Central Water Commission (2011) bears testimony to this state of affairs. It identified hot spots of water pollution which have grown in number and intensity. Such spots are linked largely to industrial hubs and metropolitan areas, though non-point source pollution from agriculture is also growing.' The polluter pays' principle works to some extent, if the polluters can be identified, but this is becoming increasingly difficult in case of water pollution. The "Polluter Pays" principle should be replaced by "Prevention Pays Off" or PPO principle. The PPO would essentially involve investment in treatment technology which comes at a cost.

3.7.14 *Prioritization of Technologies for Implementation*

The cost curve, relative costs and payback periods of various technologies provide the basis for ranking and choosing the technologies for execution. However, not all technologies are equally applicable to all the basins. For example, SRI has little relevance for the Luni basin and Laser Leveling will not be useful in Sikkim or Mizoram. Hence, for each basin, a prioritized list of interventions alongwith the scale of implementation needs to be drawn up. Some technologies like drip irrigation may be implemented across the basins

Implementation Challenges

Implementation of even sound technologies poses several challenges because of institutional barriers, presence of multiple agencies without specific division of responsibilities, lack of capacity and information. The challenges could be financial (lack of access to capital, high initial cost, high transaction cost), organizational (limited organizational capacity and fractured responsibility), social (low priority and 'lack of appreciation for the intended benefits) and political (price distortions due to subsidies or perceived negative impact in the locality). Motivating and enabling the millions of small and marginal farmers, to take advantage of the emerging opportunities, is the biggest challenge. Needless to say, the existing technology diffusion network and the financial commitments will have to be strengthened.

3.7.15 *Incentivizing Technology Adoption*

Availability of new technologies is not sufficient, by itself, to bring about development. Effective institutions and sustained policy support are equally important. Advanced production technologies in irrigated agriculture will get implemented better in a favourable policy environment. The capital cost of the technology is an important demand for technology adoption (Garido, 2005) and advanced technology comes at a cost. In such a situation, if the private sector is to bear the cost of the improvement, the technology would get implemented only if the financial returns from investment are attractive and competitive. Capital intensive technologies get implemented only when increase in variable costs of other inputs makes it attractive or a part of the capital cost is subsidized. Such subsidies should not be considered entirely as a dole to the farmers. It should be regarded as a mechanism to underwrite a certain fraction of the cost of the many social or pubic benefits, accruing from adoption of the technology. Micro irrigation has already come under the Accelerated Irrigation Benefit Programme (AIBP). This programme should be expanded to include other equally effective technologies e.g. laser leveling, subsurface drainage, zero tillage for incentivizing their adoption and it could be renamed as a Programme for Accelerated Benefits to Agriculture (PABA).

3.7.16 *Future : Water Scenario in 2025-2050 / Meeting the Water Challenges, 2025-2050 – Conclusions and Some Policy Options*

(a) Development Vs Management of Water Resources

In 2025, the country's water supply deficit would be more than 500 bcm. Demand management will, no doubt, play a significant role in reducing this supply gap provided the 500 million small and marginal farmers are enabled with technical knowledge and finances to adopt the new technology. But the balance water deficit would remain quite high. Further, the proposed food security programmes would require development of additional water resources. For several decades, the water sector was starved of public funds for financing water development projects. Though the contribution of ground water has been appreciated, water storage schemes have not been given their due. We should appreciate the hydrological reality that much of the groundwater was generated by the canal system feeding on water stored in reservoirs and diversions from rivers. It should be understood that we need both, a Sukhomajri as well as a Bhakra. It is not an either or situation and our policy should be to maximize water storage, be it behind dams, or in groundwater aquifers or in multipurpose local reservoirs.

(b) Strategic Role of Ground Water and Water Banks

In arid basins like the Indus, the Sabarmati, the Mahi etc, development of ground water played a strategic role in minimizing the impact of drought on agriculture and domestic supply. But the massive development is unsustainable as it is based on mining. Lack of planning and inadequate legal framework and still weaker enforcement, has led to a new debate on this issue. Accelerated efforts are required to augment the valuable ground resource through induced recharge as well as for enforcement of safeguards meant for maintaining the aquifers in good health. We often talk of gene banks, seed bank and fodder bank, but seldom talk of water bank which enables the other banks to function. It is time that India starts thinking of water banks in a big way via the groundwater route.

(c) Increased Funding for Water Resources Development and Private Participation

Surface water development, an entirely public funded programme, suffered from lack of funds in the last 2 / 3 decades resulting in languishing of projects, cost over runs and non fulfillment of targets. The need for increased investments in the water sector can hardly be overemphasized. Private participation in surface water development sector has not been possible so far because of the risks involved. However, a number of industrial hubs with huge water demands are now being established. Currently, the State makes the capital investment and the Industries pay the water charges. The time is now ripe to promote the PPP mode in the sector, as has been done in many other sectors.

(d) Strengthening Technology Research, Development and Incubation Hubs

Technology hubs need to be set up for development of new technologies and benchmarking of available technologies to provide a transparent picture of benefits to the private entrepreneurs. These hubs would also provide incubation facilities to inexpensive new technologies for attracting private participation. Hydro-hubs in Singapore and Irrigation Technology hubs in Israel could be the role models.

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3.8 Recommendations

(a) Right to Water

Access to safe and clean drinking water should be regarded as a fundamental human right and the State should ensure a minimum specified quantity of potable water to each individual at an affordable price. There is a pressing need to provide a constitutional amendment on lines similar to “Food Security Bill”

(b) **Reform in the Irrigation Department**

There is need for a major change programme in the public irrigation sector. This may require unbundling of the Irrigation department into into smaller independent management units with operational autonomy and greater accountability . Authors feel that limiting the role of Irrigation Department to that of a bulk supplier and leaving the distribution below the outlet to concerned user groups with or without private participation is the best available option for India. Also a credible information and monitoring system about how public irrigation systems are performing against their original designs, their current objectives, and vis-a-vis each other should be put in place

(c) **Expanding the Area under Conjunctive Management of Surface and Groundwater**

The simplest step that canal irrigation management in India can take to significantly enhance its impact is to maximize areas under conjunctive use of ground and surface water. Presently, this is not happening because India’s irrigation systems irrigate only a fraction of the area they were designed to. A potentially gigantic opportunity for unlocking value out of India’s canal systems is by spreading their waters on much larger areas to expand the areas under conjunctive management of surface and groundwater

(d) **Separation of right to Ground Water from right to Land**

Presently, groundwater belongs to the land owner and there is no limitation on groundwater withdrawal by the land owner . Landless households (or tribes), who may have community rights over land, have no private rights. Ground water should be managed as a community resource and held by the State as a public trust to ensure food security, livelihood, and equitable and sustainable development for all A new legislation should be enacted to control groundwater exploitation, and a constitutional amendment made to separate the right to groundwater from the right to land. . For this, the existing Act should be modified suitably.

(e) **Ground Water recharge to be allocated highest priority**

Apart from reducing over-exploitation, increasing the recharge of groundwater through harvesting of rain and surface flows would prevent the dewatering of aquifers, and also greatly improve equity by making water available in the wells affordable to small and marginal farmers. In this context artificial ground water recharge should be given highest priority.

(f) **Strategic Role of Ground Water and Water Banks**

Accelerated efforts are required to augment the valuable ground resource through induced recharge as well as for enforcement of safeguards meant for maintaining the aquifers in good health. It is time that India starts thinking of water banks in a big way via the groundwater route.

(g) **Encourage Private Sector Participation in Drinking Water Supply**

The need and advantages of private sector participation in the water sector are evident when one looks at the success achieved in terms of improved quality of service to users in other sectors, such as national highways, telecom and power. Unprecedented pace of urbanization has made urban water supply one of the most challenging task which the States will find most difficult to manage on their own. The case study of Manila Water and Sewerage Concessions(Annex 2) can provide valuable lessons for adoption in major urban conglomerates. Even in the rural sector, there is need for a change in the attitude of state governments towards private sector agencies . States need to encourage private consultants, contractors, and operators becoming more active in rural water service delivery, as several examples show that they are often more effective in improving service delivery. This is particularly important for the planning and implementation of multi village schemes. A beginning can be made by entering into service contracts / lease contract thereby retaining public ownership. Private participation in the water sector could achieve objectives of various public-private partnership (PPP) models, viz. improvement of water use efficiency, capital mobilization, , better harnessing of renewable resources, professionalism and access to better technology. Towards this end, steps have to be taken to improve the current legal/regulatory framework to facilitate such private sector involvement. Institutional strengthening is another important aspect that needs to be taken care of so as to make it amenable for establishing PPPs in the sector

(h) Empowering Panchayati Raj Institutions (PRIs)

There is a need for greater efforts at cost recovery and the allocation of more funds for the maintenance of schemes so that their useful life can be extended. The ownership of single village schemes should be handed over to the Panchayati Raj Institutions (PRIs) and/or user committees, after proper rehabilitation, and their O&M costs should be recovered from user charges. Similarly, multi village schemes and regional schemes may be unbundled into smaller schemes at the village level and the responsibility handed over to the Gram Panchayat/village community with contractual agreements and performance improvement targets between user groups and the bulk water providers. The desirable state to achieve is one in which the O&M cost needs to be properly assessed and fully recovered through user charges. State-wise, uniform cost sharing principles need to be worked out, irrespective of types of programs or sources of financing. For high cost schemes, it is not necessary, nor desirable, to recover fully the O&M cost through user charges. Rather, a transparent criteria needs to be developed to determine 'affordable' contributions, **including a criteria for socially disadvantaged groups.**

(i) Increasing Productivity through Irrigation Efficiency Route

India has so far been investing heavily on supply side management with much less emphasis on demand side management. The change in BAU irrigation demand (with surface irrigation efficiency at 50, 55 and 60%) and groundwater irrigation efficiencies (70, 75 and 80% by 2050) can bring in significant changes in water demands A mere 5% increase in both canal irrigation efficiency (CE) and ground water efficiency (GE) would **reduce** irrigation demands by 60 bcm (**8%).** If efficiencies are raised by 10%, in case of canals and ground water, irrigation demands would come **down** by **18%** (129.5bcm). There is urgent need to concentrate on improving the water use efficiency..

(j) Encouraging Technology adoption

Effective technologies like laser leveling, subsurface drainage, zero tillage etc. should be encouraged and for incentivizing their adoption they could be made a part of the Programme for Accelerated Benefits to Agriculture (PABA).

(k) River linking project to be given higher priority

It is evident that India will require considerable additional water to meet the demand in the coming decades since a number of river basins,(particularly in southern/ peninsular region), would become severely water stressed. Transfer of water from the Himalayan rivers in the north to the deficit peninsular/southern region has been suggested since the last forty years through a number of options/plans/projects. A comprehensive one, the National Perspective Plan would (contentious issues apart) give additional benefits of 25 million hectares of irrigation from surface waters, 10 million hectares by increased use of ground water, totalling 35million hectares and 34,000 MW of hydro-power generation, amongst others. In view of the importance and urgency, it is recommended that the project be taken up, in phases, at the earliest, and on top priority.

(l) Rational pricing of Water

Normally, efficient use of scarce resources requires appropriate pricing, but pricing of water is a sensitive issue. This problem can be solved by providing 'lifeline' water supplies for drinking and cooking at very low prices, while charging appropriately for additional water use by domestic consumers. There is a stronger case for rational pricing reflecting the scarcity of water for commercial and industrial use. There is also a strong case for rational pricing of water for agricultural purposes. The proportion of water recycled in urban areas, and by Indian industry needs to be significantly increased. This will happen if supply for commercial purposes is appropriately priced. A rational pricing must be accompanied by regulatory measures to ration water to different agricultural users, and stronger measures to discourage pollution

(m) Change in mindset

For bringing about these changes there is an imperative and urgent need to ensure a change in the thought process of all the stakeholders , the citizens, civil society, Govts., both State and Central. Only then can any appreciable change can be brought about.

Acknowledgements: This Chapter(3) has been prepared based on the information available in the public domain viz. Studies, Reports **(incl. INAE Reports),** on-line information etc. and is not an *ab initio* study. Mention/acknowledgements have been indicated (to the extent feasible) in the text, or at the end of the sections. Authors are grateful to Dr Bharat Sharma (IWMI), Dr Prem Pangotra (IIM/Ahmedabad) and officials of NWDA for their valuable advice and inputs in finalizing this Report.

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Annex 1

National Water Policy (2012)

Preamble

A scarce natural resource, water is fundamental to life, livelihood, food security and sustainable development. India has more than 18 % of the world's population, but has only 4% of world's renewable water resources and 2.4% of world's land area. There are further limits on utilizable quantities of water owing to uneven distribution over time and space. In addition, there are challenges of frequent floods and droughts in one or the other part of the country. With a growing population and rising needs of a fast developing nation as well as the given indications of the impact of climate change, availability of utilizable water will be under further strain in future with the possibility of deepening water conflicts among different user groups. Low consciousness about the scarcity of water and its life sustaining and economic value results in its mismanagement, wastage, and inefficient use, as also pollution and reduction of flows below minimum ecological needs. In addition, there are inequities in distribution and lack of a unified perspective in planning, management and use of water resources. The objective of the National Water Policy is to take cognizance of the existing situation, to propose a framework for creation of a system of laws and institutions and for a plan of action with a unified national perspective.

The present scenario of water resources and their management in India has given rise to several concerns, important amongst them are;

(i) Large parts of India have already become water stressed. Rapid growth in demand for water due to population growth, urbanization and changing lifestyle pose serious challenges to water security.

(ii) Issues related to water governance have not been addressed adequately. Mismanagement of water resources has led to a critical situation in many parts of the country.

(iii) There is wide temporal and spatial variation in availability of water, which may increase substantially due to a combination of climate change, causing deepening of water crisis and incidences of water related disasters, i.e., floods, increased erosion and increased frequency of droughts, etc.

(iv) Climate change may also increase the sea levels. This may lead to salinity intrusion in ground water aquifers / surface waters and increased coastal inundation in coastal regions, adversely impacting habitations, agriculture and industry in such regions.

(v) Access to safe water for drinking and other domestic needs still continues to be a problem in many areas. Skewed availability of water between different regions and different people in the same region and also the intermittent and unreliable water supply system has the potential of causing social unrest.

(vi) Groundwater, though part of hydrological cycle and a community resource, is still perceived as an individual property and is exploited inequitably and without any consideration to its sustainability, leading to its over-exploitation in several areas.

(vii) Water resources projects, though multi-disciplinary with multiple stakeholders, are being planned and implemented in a fragmented manner without giving due consideration to optimum utilization, environment sustainability and holistic benefit to the people.

(viii) Inter-regional, inter-State, intra-State, as also inter-sectoral disputes in sharing of water, strain relationships and hamper the optimal utilization of water through scientific planning on basin/sub-basin basis.

(ix) Grossly inadequate maintenance of existing irrigation infrastructure has resulted in wastage and under-utilization of available resources. There is a widening gap between irrigation potential created and utilized.

(x) Natural water bodies and drainage channels are being encroached upon, and diverted for other purposes. Groundwater recharge zones are often blocked.

(xi) Growing pollution of water sources, especially through industrial effluents, is affecting the availability of safe water besides causing environmental and health hazards. In many parts of the country, large stretches of rivers are both heavily polluted and devoid of flows to support aquatic ecology, cultural needs and aesthetics.

(xii) Access to water for sanitation and hygiene is an even more serious problem. Inadequate sanitation and lack of sewage treatment are polluting the water sources.

(xiii) Low consciousness about the overall scarcity and economic value of water results in its wastage and inefficient use.

(xiv) The lack of adequate trained personnel for scientific planning, utilizing modern techniques and analytical capabilities incorporating information technology constrains good water management.

Water Framework Law

There is a need to evolve a National Framework Law as an umbrella statement of general principles governing the exercise of legislative and/or executive (or devolved) powers by the Centre, the States and the local governing bodies. This should lead the way for essential legislation on water governance in every State of the Union and devolution of necessary authority to the lower tiers of government to deal with the local water situation.

Such a framework law must recognize water not only as a scarce resource but also as a sustainer of life and ecology. Therefore, water, particularly, groundwater, needs to be managed as a community resource held, by the state, under public trust doctrine to achieve food security, livelihood, and equitable and sustainable development for all. Existing Acts may have to be modified accordingly.

There is a need for comprehensive legislation for optimum development of inter- State rivers and river valleys to facilitate inter-State coordination ensuring scientific planning of land and water resources taking basin/sub-basin as unit with unified perspectives of water in all its forms (including precipitation, soil moisture, ground and surface water) and ensuring holistic and balanced development of both the catchment and the command areas. Such legislation needs, inter alia, to deal with and enable establishment of basin authorities, comprising party States, with appropriate powers to plan, manage and regulate utilization of water resource in the basins.

Uses of Water

Water is required for domestic, agricultural, hydro-power, thermal power, navigation, recreation, etc. Utilisation in all these diverse uses of water should be optimized and an awareness of water as a scarce resource should be fostered. The Centre, the States and the local bodies (governance institutions) must ensure access to a minimum quantity of potable water for essential health and hygiene to all its citizens, available within easy reach of the household.

Ecological needs of the river should be determined, through scientific study, recognizing that the natural river flows are characterized by low or no flows, small floods (freshets), large floods, etc., and should accommodate developmental needs. A portion of river flows should be kept aside to meet ecological needs ensuring that the low and high flow releases are proportional to the natural flow regime, including base flow contribution in the low flow season through regulated ground water use.

Rivers and other water bodies should be considered for development for navigation as far as possible and all multipurpose projects over water bodies should keep navigation in mind right from the planning stage.

In the water rich eastern and north eastern regions of India, the water use infrastructure is weak and needs to be strengthened in the interest of food security.

Community should be sensitized and encouraged to adapt first to utilization of water as per local availability of waters, before providing water through long distance transfer. Community based water management should be institutionalized and strengthened.

Adaptation to Climate Change

Climate change is likely to increase the variability of water resources affecting human health and livelihoods. Therefore, special impetus should be given towards mitigation at micro level by enhancing the capabilities of community to adopt climate resilient technological options.

The anticipated increase in variability in availability of water because of climate change should be dealt with by increasing water storage in its various forms, namely, soil moisture, ponds, ground water, small and large reservoirs and their combination. States should be incentivized to increase water storage capacity, which inter-alia should include revival of traditional water harvesting structures and water bodies.

The adaptation strategies could also include better demand management, particularly, through adoption of compatible agricultural strategies and cropping patterns and improved water application methods, such as land leveling and/or drip / sprinkler irrigation as they enhance the water use efficiency, as also, the capability for dealing with increased variability because of climate change. Similarly, industrial processes should be made more water efficient.

Stakeholder participation in land-soil-water management with scientific inputs from local research and academic institutions for evolving different agricultural strategies, reducing soil erosion and improving soil fertility should be promoted. The specific problems of hilly areas like sudden run off, weak water holding capacity of soil, erosion and sediment transport and recharging of hill slope aquifers should be adequately addressed.

Planning and management of water resources structures, such as, dams, flood embankments, tidal embankments, etc., should incorporate coping strategies for possible climate changes. The acceptability criteria in regard to new water resources projects need to be re-worked in view of the likely climate changes

Enhancing Water Available for Use

The availability of water resources and its use by various sectors in various basin and States in the country need to be assessed scientifically and reviewed at periodic intervals, say, every five years. The trends in water availability due to various factors including climate change must be assessed and accounted for during water resources planning.

The availability of water is limited but the demand of water is increasing rapidly due to growing population, rapid urbanization, rapid industrialization and economic development. Therefore, availability of water for utilization needs to be augmented to meet increasing demands of water. Direct use of rainfall, desalination and avoidance f inadvertent evapo-transpiration are the new additional strategies for augmenting utilizable water resources.

There is a need to map the aquifers to know the quantum and quality of ground water resources (replenishable as well as non-replenishable) in the country. This process should be fully participatory involving local communities. This may be periodically updated.

Declining ground water levels in over-exploited areas need to be arrested by introducing improved technologies of water use, incentivizing efficient water use and encouraging community based management of aquifers. In addition, where necessary, artificial recharging projects should be undertaken so that extraction is less than the recharge. This would allow the aquifers to provide base flows to the surface system, and maintain ecology.

Inter-basin transfers are not merely for increasing production but also for meeting basic human need and achieving equity and social justice. Inter-basin transfers of water should be considered on the basis of merits of each case after evaluating the environmental, economic and social impacts of such transfers.

Integrated Watershed development activities with groundwater perspectives need to be taken in a comprehensive manner to increase soil moisture, reduce sediment yield and increase overall land and water productivity. To the extent possible, existing programs like MGNREGA may be used by farmers to harvest rain water using farm ponds and other soil and water conservation measures.

Demand Management and Water Use Efficiency

A system to evolve benchmarks for water uses for different purposes, i.e., water footprints, and water auditing should be developed to promote and incentivize efficient use of water. The 'project' and the 'basin' water use efficiencies need to be improved through continuous water balance and water accounting studies. An institutional arrangement for promotion, regulation and evolving mechanisms for efficient use of water at basin/sub-basin level will be established for this purpose at the national level.

The project appraisal and environment impact assessment for water uses, particularly for industrial projects, should, inter-alia, include the analysis of the water footprints for the use.

Recycle and reuse of water, including return flows, should be the general norm. 6.4 Project financing should be structured to incentivize efficient & economic use of water and facilitate early completion of ongoing projects.

Water saving in irrigation use is of paramount importance. Methods like aligning cropping pattern with natural resource endowments, micro irrigation (drip, sprinkler, etc.), automated irrigation operation, evaporation-transpiration reduction, etc., should be encouraged and incentivized. Recycling of canal seepage water through conjunctive ground water use may also be considered.

Use of very small local level irrigation through small bunds, field ponds, agricultural and engineering methods and practices for watershed development, etc, need to be encouraged. However, their externalities, both positive and negative, like reduction of sediments and reduction of water availability, downstream, may be kept in view.

There should be concurrent mechanism involving users for monitoring if the water use pattern is causing problems like unacceptable depletion or building up of ground waters, salinity, alkalinity or similar quality problems, etc., with a view to planning appropriate interventions.

Water Pricing

Pricing of water should ensure its efficient use and reward conservation. Equitable access to water for all and its fair pricing, for drinking and other uses such as sanitation, agricultural and industrial, should be arrived at through independent statutory Water Regulatory Authority, set up by each State, after wide ranging consultation with all stakeholders.

In order to meet equity, efficiency and economic principles, the water charges should preferably / as a rule be determined on volumetric basis. Such charges should be reviewed periodically. 7.3 Recycle and reuse of water, after treatment to specified standards, should also be incentivized through a properly planned tariff system.

The principle of differential pricing may be retained for the pre-emptive uses of water for drinking and sanitation; and high priority allocation for ensuring food security and supporting livelihood for the poor. Available water, after meeting the above needs, should increasingly be subjected to allocation and pricing on economic principles so that water is not wasted in unnecessary uses and could be utilized more gainfully.

Water Users Associations (WUAs) should be given statutory powers to collect and retain a portion of water charges, manage the volumetric quantum of water allotted to them and maintain the distribution system in their jurisdiction. WUAs should be given the freedom to fix rates subject to floor rates determined by WRAs.

The over-drawal of groundwater should be minimized by regulating the use of electricity for its extraction. Separate electric feeders for pumping ground water for agricultural use should be considered.

Conservation of River Corridors, Water Bodies and Infrastructure

Conservation of rivers, river corridors, water bodies and infrastructure should be undertaken in a scientifically planned manner through community participation. The storage capacities of water bodies and water courses and/or associated wetlands, the flood plains, ecological buffer and areas required for specific aesthetic recreational and/or social needs may be managed to the extent possible in an integrated manner to balance the flooding, environment and social issues as per prevalent laws through planned development of urban areas, in particular.

Encroachments and diversion of water bodies (like rivers, lakes, tanks, ponds, etc.) and drainage channels (irrigated area as well as urban area drainage) must not be allowed, and wherever it has taken place, it should be restored to the extent feasible and maintained properly.

Urban settlements, encroachments and any developmental activities in the protected upstream areas of reservoirs/water bodies, key aquifer recharge areas that pose a potential threat of contamination, pollution, reduced recharge and those endanger wild and human life should be strictly regulated.

Environmental needs of Himalayan regions, aquatic eco-system, wet lands and embanked flood plains need to be recognized and taken into consideration while planning.

Sources of water and water bodies should not be allowed to get polluted. Systemof third party periodic inspection should be evolved and stringent punitive actions be taken against the persons responsible for pollution.

Quality conservation and improvements are even more important for groundwaters, since cleaning up is very difficult. It needs to be ensured that industrial effluents, local cess pools, residues of fertilizers and chemicals, etc., do not reach the ground water.

The water resources infrastructure should be maintained properly to continue to get the intended benefits. A suitable percentage of the costs of infrastructure development may be set aside along with collected water charges, for repair and maintenance. Contract for construction of projects should have inbuilt provision for longer periods of proper maintenance and handing over back the infrastructure in good condition.

Legally empowered dam safety services need to be ensured in the States as well as at the Centre. Appropriate safety measures, including downstream flood management, for each dam should be undertaken on top priority.

Project Planning and Implementation

Considering the existing water stress conditions in India and the likelihood of further worsening situation due to climate change and other factors, water resources projects should be planned as per the efficiency benchmarks to be prescribed for various situations.

Being inter-disciplinary in nature, water resources projects should be planned considering social and environmental aspects also in addition to techno-economic considerations in consultation with project affected and beneficiary families. The integrated water resources management with emphasis on finding reasonable and generally acceptable solutions for most of the stakeholders should be followed for planning and management of water resources projects.

Considering the heavy economic loss due to delay in implementation of projects, all clearances, including environmental and investment clearances, be made time bound.

Concurrent monitoring at project, State and the Central level should be undertaken for timely interventions to avoid time and cost over-runs.

All components of water resources projects should be planned and executed in a pari-passu manner so that intended benefits start accruing immediately and there is no gap between potential created and potential utilized.

Local governing bodies like Panchayats, Municipalities, Corporations, etc., and Water Users Associations, wherever applicable, should be involved in planning of the projects. The unique needs and aspirations of the Scheduled caste and Scheduled Tribes, women and other weaker sections of the society should be given due consideration.

All water resources projects, including hydro power projects, should be planned to the extent feasible as multi-purpose projects with provision of storage to derive maximum benefit from available topology and water resources.

Management of Flood & Drought

While every effort should be made to avert water related disasters like floods and droughts, through structural and non-structural measures, emphasis should be on preparedness for flood / drought with coping mechanisms as an option. Greater emphasis should be placed on rehabilitation of natural drainage system. Land, soil, energy and water management with scientific inputs from local, research and scientific institutions should be used to evolve different agricultural strategies and improve soil and water productivity to manage droughts. Integrated farming systems and non-agricultural developments may also be considered for livelihood support and poverty alleviation.

In order to prevent loss of land eroded by the river, which causes permanent loss, revetments, spurs, embankments, etc., should be planned, executed, monitored and maintained on the basis of morphological studies. This will become increasingly more important, since climate change is likely to increase the rainfall intensity, and hence, soil erosion.

Flood forecasting is very important for flood preparedness and should be expanded extensively across the country and modernized using real time data acquisition system and linked to forecasting models. Efforts should be towards developing physical models for various basin sections, which should be linked to each other and to medium range weather forecasts to enhance lead time.

Operating procedures for reservoirs should be evolved and implemented in such a manner to have flood cushion and to reduce trapping of sediment during flood season. These procedures should be based on sound decision support system.

Protecting all areas prone to floods and droughts may not be practicable; hence, methods for coping with floods and droughts have to be encouraged. Frequency based flood inundation maps should be prepared to evolve coping strategies, including preparedness to supply safe water during and immediately after flood events. Communities need to be involved in preparing an action plan for dealing with the flood/ drought situations.

To increase preparedness for sudden and unexpected flood related disasters, dam/embankment break studies, as also preparation and periodic updating of emergency action plans / disaster management plans should be evolved after involving affected communities. In hilly reaches, glacial lake outburst flood and landslide dam break floods studies with periodic monitoring along with instrumentation, etc., should be carried out.

Water Supply and Sanitation

There is a need to remove the large disparity between stipulations for water supply in urban areas and in rural areas. Efforts should be made to provide improved water supply in rural areas with proper sewerage facilities. Least water intensive sanitation and sewerage systems with decentralized sewage treatment plants should be incentivized.

Urban and rural domestic water supply should preferably be from surface water in conjunction with groundwater and rainwater. Where alternate supplies are available, a source with better reliability and quality needs to be assigned to domestic water supply. Exchange of sources between uses, giving preference to domestic water supply should be possible. Also, reuse of urban water effluents from kitchens and bathrooms, after primary treatment, in flush toilets should be encouraged, ensuring no human contact.

Urban domestic water systems need to collect and publish water accounts and water audit reports indicating leakages and pilferages, which should be reduced taking into due consideration social issues.

In urban and industrial areas, rainwater harvesting and de-salinization, wherever techno-economically feasible, should be encouraged to increase availability of utilizable water. Implementation of rainwater harvesting should include scientific monitoring of parameters like hydrogeology, groundwater contamination, pollution and spring discharges.

Urban water supply and sewage treatment schemes should be integrated and executed simultaneously. Water supply bills should include sewerage charges. 11.6 Industries in water short regions may be allowed to either withdraw only the make up water or should have an obligation to return treated effluent to a specified standard back to the hydrologic system. Tendencies to unnecessarily use more water within the plant to avoid treatment or to pollute ground water need to be prevented.

Subsidies and incentives should be implemented to encourage recovery of industrial pollutants and recycling / reuse, which are otherwise capital intensive.

Institutional Arrangements

There should be a forum at the national level to deliberate upon issues relating to water and evolve consensus, co-operation and reconciliation amongst party States. A similar mechanism should be established within each State to amicably resolve differences in competing demands for water amongst different users of water, as also between different parts of the State. A permanent Water Disputes Tribunal at the Centre should be established to resolve the disputes expeditiously in an equitable manner. Apart from using the good offices‟ of the Union or the State Governments, as the case may be, the paths of arbitration and mediation may also to be tried in dispute resolution.

Water resources projects and services should be managed with community participation. For improved service delivery on sustainable basis, the State Governments / urban local bodies may associate private sector in public private partnership mode with penalties for failure, under regulatory control on prices charged and service standards with full accountability to democratically elected local bodies.

Integrated Water Resources Management (IWRM) taking river basin / sub-basin as a unit should be the main principle for planning, development and management of water resources. The departments / organizations at Centre / State Governments levels should be restructured and made multi-disciplinary accordingly.

Appropriate institutional arrangements for each river basin should be developed to collect and collate all data on regular basis with regard to rainfall, river flows, area irrigated by crops and by source, utilizations for various uses by both surface and ground water and to publish water accounts on ten daily basis every year for each river basin with appropriate water budgets and water accounts based on the hydrologic balances. In addition, water budgeting and water accounting should be carried out for each aquifers.

Appropriate institutional arrangements for each river basin should also be developed for monitoring water quality in both surface and ground waters. States should be encouraged and incentivized to undertake reforms and progressive measures for innovations, conservation and efficient utilization of water resources.

Trans-Boundary Rivers

Even while accepting the principle of basin as a unit of development, on the basis of practicability and easy implementability, efforts should be made to enter into international agreements with neighbouring countries on bilateral basis for exchange of hydrological data of international rivers on near real time basis.

Negotiations about sharing and management of water of international rivers should be done on bilateral basis in consultative association with riparian States keeping paramount the national interest. Adequate institutional arrangements at the Center should be set up to implement international agreements.

Database & Information System

All hydrological data, other than those classified on national security consideration, should be in public domain. However, a periodic review for further declassification of data may be carried out. A National Water Informatics Center should be established to collect, collate and process hydrologic data regularly from all over the country, conduct the preliminary processing, and maintain in open and transparent manner on a GIS platform.

In view of the likely climate change, much more data about snow and glaciers, evaporation, tidal hydrology and hydraulics, river geometry changes, erosion, sedimentation, etc. needs to be collected. A programme of such data collection needs to be developed and implemented.

All water related data, like rainfall, snowfall, geo-morphological, climatic, geological, surface water, ground water, water quality, ecological, water extraction and use, irrigated area, glaciers, etc., should be integrated with well defined procedures and formats to ensure online updation and transfer of data to facilitate development of database for informed decision making in the management of water.

Research & Training Needs

Continuing research and advancement in technology shall be promoted to address issues in the water sector in a scientific manner. Innovations in water resources sector should be encouraged, recognized and awarded. It is necessary to give adequate grants to the States to update technology, design practices, planning and management practices, preparation of annual water balances and accounts for the site and basin, preparation of hydrologic balances for water systems, benchmarking and performance evaluation.

It needs to be recognized that the field practices in the water sector in advanced countries have been revolutionized by advances in information technology and analytical capabilities. A re-training and quality improvement programme for water planners and managers at all levels in India, both in private and public sectors, needs to be undertaken.

An autonomous center for research in water policy should also be established to evaluate impacts of policy decisions and to evolve policy directives for changing scenario of water resources.

To meet the need of the skilled manpower in the water sector, regular training and academic courses in water management should be promoted. These training and academic institutions should be regularly updated by developing infrastructure and promoting applied research, which would help to improve the current procedures of analysis and informed decision making in the line departments and by the community. A national campaign for water literacy needs to be started for capacity building of different stakeholders in the water sector.

Implementation of National Water Policy

National Water Board should prepare a plan of action based on the National Water Policy, as approved by the National Water Resources Council, and to regularly monitor its implementation.

The State Water Policies may need to be drafted/revised in accordance with this policy keeping in mind the basic concerns and principles as also a unified national perspective.

Annex 2

Case Study
MANILA WATER AND SEWERAGE CONCESSIONS

Water Supply and Sewerage

CASE OVERVIEW

Country: Philippines

ULB: Metro Manila (Region) – comprising 12 cities and 5 municipalities

Sector: Urban Basic Services Sub-Sector: Water Supply and Sewerage

Award Date: August 1997 (including financial closure)

Type and Period of concession: Operations and Maintenance (O&M) concession (two separate agreements) for 25 years

Stakeholders:

Contracting Authority

Public Utility for Metro Manila: Metropolitan Water Works and Sewerage System (MWSS)

Concessionaire

The city was divided into two service areas. West zone was awarded to Maynilad Water Services Inc. (Maynilad), and the East Zone to Manila Water Company Inc. (Manila Water).

Oversight Arrangement

Special body constituted for the project period - MWSS Regulatory Office (MWSS-RO)

Present Status of Project: Manila Water continues to be the Concessionaire for the East Zone and Maynilad for the West Zone. Maynilad went through a change of ownership in 2007.

PROJECT TIMELINE:

1994 : Advisory Technical Assistance (TA) by ADB and creation of the MWSS Privatization Committee, mandated to guide the privatization process

1995 : Enactment of the Water Crisis Act (WCA), empowering the President to privatize water utilities in the country

1996 : Increase in water tariff and reduction in staff of public utility prior to the bidding process

1997 : Award of the concession to two separate Concessionaires for the East and West service areas through an international competitive bid Asian Financial Crisis – Heavy Forex losses to Concessionaires

2001 : Contractual amendment introducing mechanisms for facilitating recovery of losses incurred by Concessionaires

2002 : Filing of termination suit by West Zone Concessionaire to the International Arbitration Panel (IAP), asserting MWSS failure to meet its obligations

2003 : Counter petition by MWSS IAP ruling - forbidding termination of the contract

2005 : Listing of the East Zone Concessionaire (Manila Water) on the Philippines Stock Exchange

2007 : Reconstitution of the West Zone Concessionaire (Maynilad) through a public bid

1. PPP CONTEXT

1.1 ENABLING ENVIRONMENT

In order to forestall economic bankruptcy and address the international debt burden, several initiatives were undertaken in the Philippines in the 1990s, for reducing public expenditure and monopoly and encouraging private investments in infrastructure. Chief amongst these (and which set the background for the Manila Water concessions) were:

1. Constitution of a Committee on Privatization (COP) mandated to privatize State owned enterprises
2. Enactment of the Foreign Investments Act of 1991
3. Enactment of the Build-Operate-Transfer Law of 1993
4. Creation of an MWSS Privatization Committee (1994) for guiding the privatization process
5. Enactment of the Water Crisis Act (WCA) of 1995, empowering the President to privatize water utilities in the country

1.2 SECTORAL CONTEXT

1. As of 1997, the coverage of water supply networks in the Metro Manila region (approximately 11 million population) was about 59% and that of sewerage as low as 8%.
2. The prevalent system suffered from rampant leakages, faulty and inadequate metering, and illegal connections leading to as much as 58% of Non-Revenue Water (NRW). Revenue loss was further compounded due to inefficient billing and collection, despite relatively high personnel to connections ratio of 9.8/1000.
3. The sector also lacked adequate investments, and the MWSS was heavily indebted on account of decades of inefficiency and provision of price subsidy to consumers.

2. PROJECT DEVELOPMENT

2.1 Project Conceptualization

Engagement with the private sector was expected to plug existing gaps in investments, and quality/coverage of services within a specific time frame and without overburdening consumers with high user charges by bringing in requisite efficiency in revenue collection and minimizing losses. An Area concession model (O&M concession) was chosen, transferring all operational and investment responsibilities to the Concessionaire without transferring ownership of assets.

2.2 Project Development

President Ramos was the key political driving force behind the MWSS privatization (empowered by the WCA), overseeing proceedings up till the financial closure in August 1997.

1. Advisory Technical Assistance (TA) provided by the Asian Development Bank (ADB) in 1994 formed the background for the privatization process and led to the constitution of the MWSS Privatization Committee.
2. The committee conducted background research and proposed a model based on study visits of England, France and Argentina for reviewing their water privatization models. International Finance Corporation (IFC) was appointed as the Transaction Advisor and advised the Government on policy/legal matters, sectoral requirements and contractual structure. The structure was approved at various levels including the COP, a Special Advisory Committee to the President (created for the duration of project development) and finally the President himself.
3. In order to encourage bidders the existing water tariff was increased by 38% (award was based on lowest tariff proposed) and MWSS labour force was reduced by 30%, since it was binding on the Concessionaires to absorb the existing staff as part of the contract.

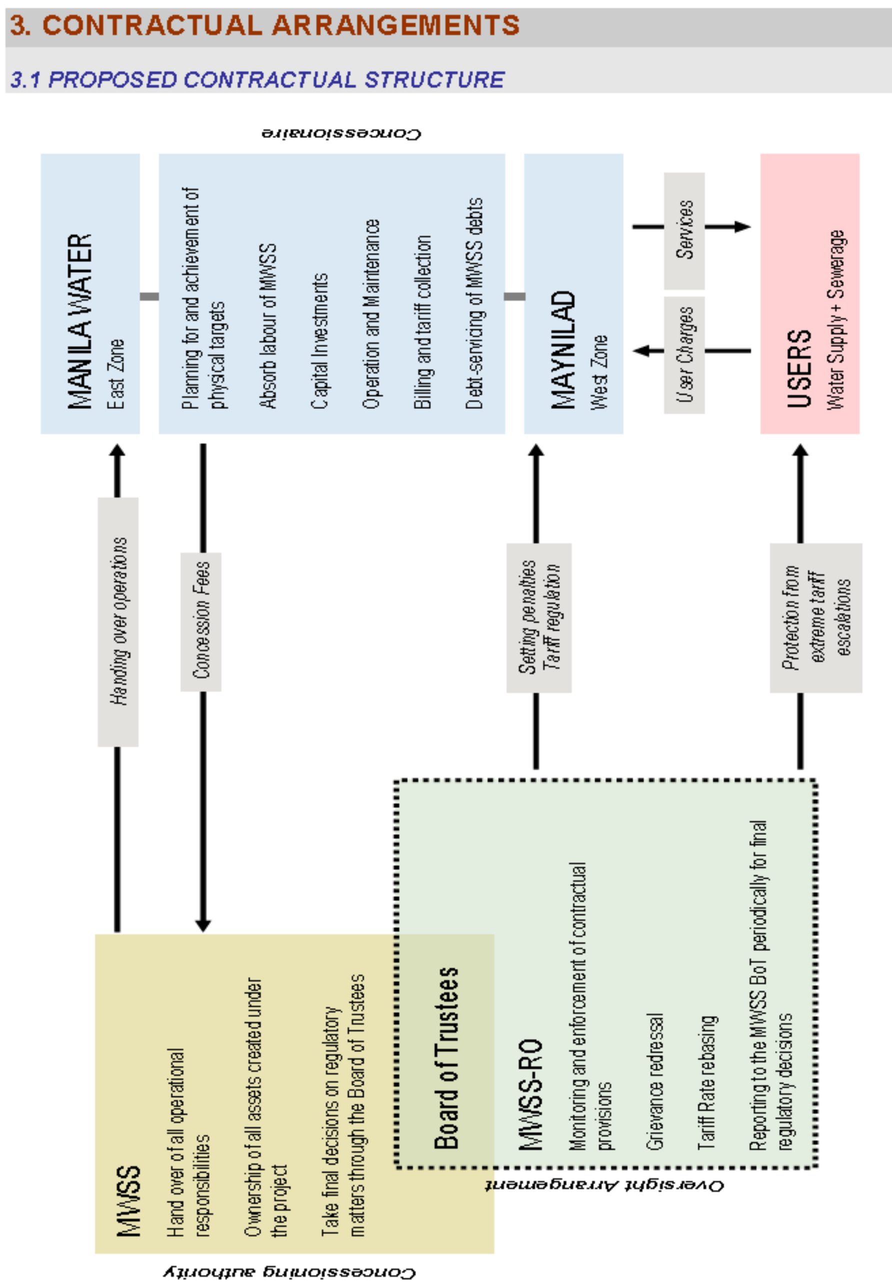
2.3 Procurement Procedure

The service area was divided into two zones – the Eastern and Western regions – each of which was to be allotted in the form of 25 year O&M concessions to separate bidders. It should be noted that base conditions for the two concessions were different:

(i) The MWSS debt liability was split in a 9:1 ratio (refer 3.5 for details) between the West and East Zones making the West Zone Concessionaire responsible for a major proportion of the debt.

(ii) The West zone contained infrastructure in a much worse state, and a large un-connected and low-income population. In comparison, the Manila Water zone had a much more viable situation.

The concessions were awarded through an international competitive bid, based on the lowest quotes for tariffs (bid parameter). The West zone was awarded to Maynilad Water Services Inc. (Maynilad), a consortium between Benpres (Philippines) and the Lyonnaise des Eaux (France), who committed a 74% reduction in prevalent tariffs for the East Zone. The East Zone was awarded to Manila Water Company Inc. (Manila Water), a consortium between Ayala (Philippines) and International Water (U.K./U.S.), who committed a 44% reduction in prevalent tariffs for the West Zone.



3. CONTRACTUAL ARRANGEMENTS

3.1 Proposed Contractual Structure

Concessioning authority Hand over of all operational responsibilities Ownership of all assets created under the project Take final decisions on regulatory matters through the Board of Trustees MWSSMWSS-RO Board of Trustees Oversight Arrangement Monitoring and enforcement of contractual provisions Grievance redressal Tariff Rate rebasing Reporting to the MWSS BoT periodically for final regulatory decisions Planning for and achievement of physical targets Absorb labour of MWSS Capital Investments Operation and Maintenance Billing and tariff collection Debt-servicing of MWSS debts MANILA WATER East Zone MAYNILAD West Zone Concessionaire USERS Water Supply + Sewerage Concession Fees Setting penalties Tariff regulation Services User Charges Protection from extreme tariff escalations Handing over operations

3.2 Operator Output Obligations

The Concessionaire was responsible for all operations and creation of new infrastructure to meet output specifications provided in the contract. The contract specified targets for coverage, water pressure, reliability and quality, reduction in NRW, renewal and expansion of the sewerage system and customer service. Key outputs included:

1. Increasing water supply coverage from the then current - 67% (for both service areas) to 96% by 2006
2. Increasing supply reliability to 24 hours and achieving water pressure of 16 psi
3. Improving sewerage coverage in the East Zone from 13% to 55% and in the West Zone from 7% to 66%.

3.3 Obligations of the Concessioning Authority

Obligations of the Concessioning Authority included peaceful and timely transfer of all operations, assets and human resource to the Operator.

3.4 Regulatory and Monitoring Arrangements

A separate regulatory body was created within MWSS, called MWSS Regulatory Office (MWSS-RO). The body was responsible for enforcing the provisions of the contract, setting appropriate penalties for non-compliance, implementing rate revisions, and dealing with complaints.

3.5 Project Financials

1. The contractual commitments of the Concessionaires were output based and not investment based. The Concessionaire was responsible for all capital/operational investments required to meet these targets.
2. The Concessionaires were to reimburse the Government for the transaction cost and pay concession fees to the MWSS. The concession fee included components for servicing the existing debts of MWSS and meeting a part of the operational costs of the MWSS (its BoT and remaining staff) and the MWSS-RO. Debt servicing liability was split in a 9:1 ratio between Maynilad and Manila Water.
3. All investments were to be recovered through user charges (tariffs), which accrued entirely to the Concessionaires. The tariff included all operating and capital costs, cost of borrowing, foreign exchange variations, and concession fee payments. Procedures for periodic tariff revision (to be carried out by the MWSS-RO) were also stipulated within the concession agreement.
4. The Concessionaire was granted an income tax holiday (6 years), preferential tariffs on import of capital equipment, tax benefits on locally produced equipment and exemptions from local and franchise taxes.

3.6 Project Risks and Allocation

Investment Risk

Associated with forecasting demand for services (since revenue was tariff based), was borne by the operator and the contract did not provide any guarantees to that effect. The tariff was also regulated by the MWSS-RO.

Performance

Borne by the operator through mechanisms for penalties for non-compliance with risk contractual commitments and through annually renewable performance bonds.

Currency risk

Currency risk was a crucial component of the contract, since the MWSS debt (borne by the Concessionaire) was US$ denominated. The Forex risk was split between the Concessionaires and consumers, introducing tariff adjustment mechanisms to reflect Forex fluctuations thereby passing the risk to consumers, while shielding consumers from extreme escalations by spreading collections over the 25 year span of the project.

Force Majeure

The MWSS was obliged to compensate the Concessionaire for investments made up till the date of termination, in case of early termination due to changes in policy.

3.7 Disputes Resolution Mechanism

An appeals panel was set up for minor disputes; with the regulator, the Concessionaire and the appeal chairman each appointing one member on the panel. In the event of major disputes, the matter could be referred to the Internal Arbitration Panel (IAP).

4. Partnership in Practice

Two unforeseen events occurring at the outset, threatened the success of the privatization initiative. First, water availability reduced by 30% due to an unprecedented draught and second, the Philippine Peso devalued during the Asian Financial Crisis (1997); almost doubling the MWSS's dollar denominated debt-burden and increasing the Concessionaires' liabilities twofold. Despite measures by the Government to keep the concessions afloat, the two Concessionaires followed completely different trajectories – while Maynilad filed for bankruptcy in 2003, was handed over to MWSS in the interim and went through a change of ownership in 2007; Manila Water was financially successful and is a listed company on the Philippines Stock Exchange. Immediately upon reconstitution Maynilad repaid its outstanding debts (January 2008) and initiated several steps to improve its service coverage and reliability, and reduce NRW - targeting major outcomes by 2012.

4.1 Project Outcomes

Service Outputs

1. The serviced population increased from 7.5 to 9.5 million and supply network (length of pipelines) improved from 4500 to 6300 km for both concessions in the first four years of the contract

2. The percentage of consumers with 24 hour service reliability in the East zone increased from 26 to 98% by 2006. This factor improved in the West zone after re-organization of Maynilad, with 60% of consumers availing the facility by 2008.

3. Sewerage networks have improved in both service areas, through rehabilitation of existing facilities and construction of new facilities for treatment of waste water.

Operations

4. Operational efficiency in terms of worker productivity improved for both concessions, and NRW in the successful East zone concession reduced from 39% to 24% by 2007.

Urban Poor

5. Both the Concessionaires launched separate programmes for bringing hard-to-reach urban poor localities within the service network. About 1.5 million poor households have been brought under the service network through Manila Water schemes and about 0.5 million through Maynilad schemes.

4.2 Project Shortcomings

1. Despite increases in coverage and other aspects of service delivery indicated in the previous section, output targets up till 2009 for water supply and sewerage in both service areas remain unachieved.

2. Since the awards were based on lowest quote for tariffs, the project was expected to significantly reduce the cost burden on consumers. However, as indicated in the following table Manila Water rates increased by 540% and Maynilad rates by 325% by 2006.

Year	Average Base Tariff (PHP per cubic metre)	
	Manila Water	Maynilad
Pre-Privatization	8.56	8.56
Post-Privatization		
1997/98	2.32	4.96
2000	2.76	6.13
2002	4.51	11.39
2003	10.06	11.39
2004	10.40	11.39
2006	14.94	21.12

3. Maynilad failed to pay concession fees (towards MWSS debt-service) to the MWSS between 2001 and 2007. This increased the debt burden of MWSS since it had to borrow on several occasions in order to address its maturing debt liabilities.

4. In the course of implementation it was realised that the pre-bid data provided by the Concessioning Authority was incorrect leading to anomalies in the investment forecasts of the Concessionaires. On the other hand tariff quotes of the Concessionaires (bid parameter) were later criticized as being too low and unrealistic, resulting in a series of tariff hikes during the course of implementation.

4.3 Legal/Contractual Issues

1. A contractual amendment was enacted in 2001 to address the unforeseen increase in the MWSS debt-servicing liabilities of the Concessionaires during the financial crisis. The Original contract, while loading such losses on the consumers, shielded them from extreme escalations in the short term by spreading such collections over the project duration. This provision was amended, enabling the Concessionaires to recover losses within 15 months instead of 22 years, passing the Forex risk entirely to the consumers.

2. The amendment reduced several output commitments so as to enable the Concessionaires to meet targets.

3. The amendment also reduced the autonomy of the MWSS-RO, and deemed that the RO would report to the MWSS Board of Trustees, who in turn took final decisions on all regulatory matters. The regulatory body was thus subservient to the decisions and interests of the contracting party. This was further compounded through repeated political intervention throughout the implementation period (in several cases overruling the decisions of the MWSS-RO).

4. Despite the contractual amendment and substantial increases in tariffs, Maynilad filed for termination of contract to the IAP in December 2002, blaming the government for the firm's inability to sustain operations in the West Zone, followed by a counter petition by MWSS in 2003. The IAP ruled in 2003 that neither party could terminate the contract and directed Maynilad to compensate MWSS for unpaid concession fees (refer 4.2). Maynilad formally declared bankruptcy in November 2003 and Benpres (lead consortium member) relinquished its shares in Maynilad to MWSS in lieu of the unpaid compensation fees in 2005. This led to the eventual change of ownership of Maynilad through a public bid in 2007.

4.4 Difference in Performance: Manila Water and Maynilad

As mentioned in 2.3 there were differences in the two contracts in the sharing of the debt liability as well as in the nature of the concession areas leading to differences in the initial conditions of the two Concessionaires. Some of the key reasons that may have led to the differential performance of the two Concessionaires are as follows:

	Manila Water (East Zone)	Maynilad (West Zone)
a	**Sharing of debt liability:** Debt service liability of MWSS debt was shared in a 9:1 ratio between Maynilad and Manila Water	
	Manila Water carried only 10% of the debt liability	Maynilad carried 90% liability and hence experienced a large hike in its debt liabilities (debt being dollar denominated) during the Asian Financial Crisis
b	**Third-party sub-contracting:** The concession did not enforce the use of competitive bidding processes for sub-contracting works to third parties.	
	However, with the exception of a single contract, all procurement (third party) was through open competitive bids significantly lowering the price of services obtained through third parties.	In the case of Maynilad most sub contracts were related-party contracts awarded to associates of the International firm involved in the consortium, leading to higher procurement costs and heavy Forex losses.
c	**Internal financial management (during the financial crisis)**	
	Manila Water focussed on domestic lenders for capital expenditure, obtaining small loans from multiple banks. While this affected capital investments in the initial years leading to restricted performance, the company was able to protect itself from immediate financial risk and subsequently take aggressive steps to achieve its targets. The company also focussed on crucial targets such as reduction of NRW which were central to improving company revenues.	Maynilad on the other hand opted for large loans from international lending agencies. While this helped the company to make large capital investments, it also increased the Forex burden during the financial crisis. Investments were also not directed properly (for instance towards plugging revenue losses due to NRW) with the result that the NRW increased from 64% to 69% between 1997 and 2003, reducing the potential revenue for the company.

5. Lessons Learnt

1. Need for robust sectoral needs and investment analysis prior to the bidding process, so as to allow all parties in a PPP structure to make informed assumptions and set accurate output forecasts. In this case lack of accurate information from the Concessioning Authority and unrealistic bids from the Concessionaires led to tariff escalations during implementation – hampering the initial objective of the project.

2. Need for proper risk allocation even during contractual amendments as this could seriously impact the expected outcomes of projects. In the Manila Case, the amendment resulted in transferring the Currency risk, initially allocated on a long term shared basis, entirely from the Concessionaires to the public.

3. Need for ensuring transparency in third party contracting, so as to avoid unearned gains for operators and unwarranted escalation of project costs. In this case the eventual financial failure of Maynilad could be attributed, at least in part, to the lack of such transparency

4. Need for ensuring autonomy of regulatory bodies/arrangements in order to eliminate regulatory bias and protect project interests. In the Manila case though the original contract envisaged a neutral regulatory arrangement, subsequent amendments did not uphold the strategic importance of such an arrangement, leading to eventual disputes and compromising project outcomes.

5. On the positive side the experience also highlights the possibility of bringing hitherto excluded urban poor communities within the service network through PPP arrangements, on account of issues of efficiency and economic returns involved within the process

6. Despite its shortcomings the project also highlights the substantial efficiency gains that can be achieved through PPP arrangements. For instance, coverage for the two service areas increased by 30% in the first five years, a significant improvement considering that MWSS would have achieved this in 30 years based on their historical performance.

Annex 3

List of Abbreviations Used

AIBP	**Accelerated Irrigation Benefits Programme**
ARWSP	**Accelerated Rural Water Supply Programme**
ASHAs	**Accredited Social Health Activists**
BaU	**Business as Usual**
bcm/BCM	**Billion Cubic Metres**
BL/MC/EC	**Base Line / Mid Century / End Century**
BPL	**Below Poverty Line**
BRC	**Block Resource Centre**
CE	**Canal-irrigation Efficiency**
CGWB	**Central Ground Water Board**
CPCB	**Central Pollution Control Board**
CPWF	**Challenge Program on Water and Food**
CSR	**Corporate Social Responsibility**
CSSRI	**Central Soil Salinity Research Institute**
CWC	**Central Water Commission**
CWP	**Consumptive Water Productivity**
DAC	**Development Assistance Committee**
DDWS	**Department of Drinking Water Supply / Department of Drinking Water & Sanitation**
DPR	**Detailed Project Report**
FAO	**Food and Agriculture Organisation (UN)**
GE	**Ground-water Efficiency**
GOI	**Government of India**
HPEC	**High Powered Expert Committee (on Urban Infrastructure)**
IAP	**Integrated Action Plan**
ICAR	**Indian Council of Agricultural Research**
ICPRI	**International Food Policy Research Institute**

ID	**Irrigation Department**
IDFC	**Infrastructure Development Finance Company**
IFPRI	**International Food Policy Research Institute**
IGP	**Indo Gangetic Plain**
IIM	**Indian Institute of Management**
INAE	**Indian National Academy of Engineering**
IPCC	**Intergovernmental Panel on Climate Change**
IWMI	**International Water Management Institute**
IWRM	**Integrated Water Resource Management**
IWRDP	**Integrated Water Resources Development Plan**
JE/AES	**Japanese Encephalitis / Acute Encephalitis Syndrome**
JNNURM	**Jawaharlal Nehru National Urban Renewal Mission**
KT	**Kohlapur Type (Weir)**
lpcd	**litres per capita per day**
MDGs	**Millennium Development Goals**
MDI	**Management Development Index**
MGNREGA	**Mahatma Gandhi National Rural Employment Guarantee Act**
Mha	**Million Hectares**
MoWR	**Ministry of Water Resources**
NCEF	**National Clean Energy Fund**
NCIWRD	**National Commission for Integrated Water Resource Development**
NGO	**Non Government Organisation**
NPP	**National Perspective Plan**
NRAA	**National Rainfed Area Authority**
NRDWP	**National Rural Drinking Water Programme**
NRLP	**National River Linking Project**
NSSO	**National Sample Survey Organisation**
NWDA	**National Water Development Agency**
NWP	**National Water Policy (2002 / 2012)**

NWRC	**National Water Resources Council**
OECD	**Organisation for Economic Co-operation and Development**
O&M	**Operation & Maintenance**
PABA	**Programme for Accelerated Benefits to Agriculture**
PIM	**Participatory Irrigation Management**
PPP	**Public Private Partnership**
PRECIS	**Providing REgional Climates for Impact Studies**
PRI	**Panchayati Raj Institution**
PUWR	**Potentially Utilisable Water Resource**
RCM	**Regional Climate Model**
R&M	**Renovation & Modernisation**
RWS	**Rural Water Supply**
SC/ST	**Scheduled Castes / Scheduled Tribes**
SIWI	**Stockholm International Water Institute**
SRES	**Special Report on Emission Scenarios**
SRI	**System of Rice Intensification**
TMC	**Thousand Million Cubic Feet**
ULBs	**Urban Local Bodies**
UNICEF	**United Nation's International Children's Emergency Fund**
UWSS	**Urban Water Supply Sector**
VWSC	**Village Water & Sanitation Committee**
WB	**World Bank**
WP	**Water Productivity**
WRG	**Water Resources Group**
WUA	**Water User's Association**
WWDR	**World Water Development Report**
ZTL	**Zero-Till Farming**

Chapter 3(S)

Water - Meeting the Future Challenges

Brief Synopsis and Recommendations

Index

Chapter 3(S)

Water – Meeting the Future Challenges

Brief Synopsis and Suggested Plan for Action

S.3.1 Introduction

Water is one of the most important basic necessity for mankind. Unfortunately, water scarcity already affects almost every continent and impacts more than 40 percent of world's population. By 2025, an estimated 1.8 billion people will be living in countries or regions with very severe water scarcity, and two-thirds of the world's population could be living under water stressed conditions (FAO, 2012). With business as usual scenario, India will be one such over stressed country. The World Bank, in their report in 2005, mentioned that India is almost certainly heading towards a severe water problem. This paper covers two main drivers of water demand namely Irrigation and drinking water. The Paper also examines the need for inter basin water transfer, impact of climate change and water security in the near term (2025) and in the long run (2050).

S.3.2 Water Resource Development in India

Earth's Water Resources

Over 70% of Earth's surface is covered by water. Although water is apparently abundant, the real issue is the availability of fresh water. Less than 1% of the world's fresh water is accessible for direct human use, and humans are over-consuming natural resources at an unsustainable pace.

Indian Overview

India is lucky to have plenty of rainfall, nearly 4000 bcm, annually. However approximately half of it gets used up in evaporation, transpiration, penetration to deep strata and sub surface flow to oceans , leaving an estimated balance of 1953 bcm in the form of surface water and ground water. Extreme temporal and spatial variations reduce the available amount further and utilizable water, from both surface and ground sources is estimated to be 1086 bcm, 25% of the annual rainfall. About 830 bcm of surface water and 36 bcm of ground water remains unutilized due to inherent inadequacy and inefficiency (See Fig. 1)

Resources and Demand

India has 16% of the world's population; but only 4% of the total available fresh water. India has 20 river basins of which 14 basins are water-stressed and there is considerable disparity amongst the basins. The Brahmaputra-Barak basin has a total water availability of 11,782 m3 per person. On the other hand in river basins, such as Sabarmati and east flowing rivers (Pennar and Kanyakumari), the availability of water is as low as 260 m3 per person per year . (India Infra Report). The country's fragile resources are stressed and also depleting fast, both in quality and quantity. Preserving the quality of water and managing multiple demands on it requires an integrated water management strategy. Further, climate change is expected to aggravate the problem by causing erratic and unpredictable weather, which could substantially reduce the supply of water coming from rainfall and glaciers.

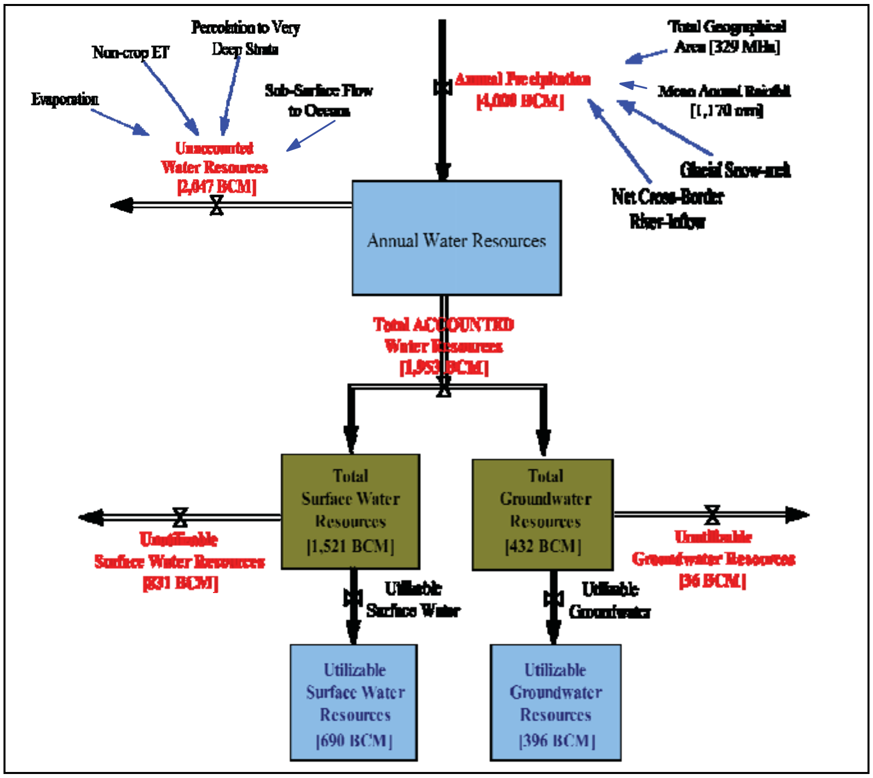


Fig. 1 : India's Water Resources

Demand and Usage

Assuming that irrigation efficiency will increase to 60% from current levels of 35-40%, water demand in bcm by different sectors has been estimated by the National Commission for Integrated Water Resource Development as follows- (Table 4) :

Table 4 : Water Demand (in bcm) by Different Sectoral Users in India

Sector	2010	2025*	2050*
Irrigation	557	611	807 (68)
Drinking	43	62	111 (9.5)
Industry	37	67	81 (7)
Energy	19	33	70 (6)

*Projections.

Source : Planning Commission - Report of the Steering Committee on Water Resources for XIth Plan. The figures are based on projections made by NCIWRD (National Commission of Integrated Water Resources Development) While projecting the above figures NCIWRD has assumed that by 2050 irrigation efficiency will increase to 60% from the current levels of 35-40%. NCIWRD has also projected a lower total demand of 973 bcm in case the population in 2050 is lower at 1346 m instead of 1581m

The availability of utilisable water at 1086 bcm appears to be just about adequate to cater for total projected water demand in 2050 of 973/1180 bcm. NCIWRD in their demand projection for 2050 have assumed a very nominal quantity of 20 bcm of water required towards maintaining the ecosystem. However, Amarasinghe and others (IWMI Research Report 123) have assessed that there will be an additional demand of at least 353 bcm for maintaining the ecosystem to category D,. Water Resource Group has estimated a supply- demand gap of 756 bcm by 2030 (paras 3.7.1 & 3.7.2). (This estimate appears to be on the higher side). Due to unequal distribution of the available water across geographies, many basins will remain water stressed. Situation at sub- basin level may be worse.

It is seen that Agriculture sector is the most dominant sector for water consumption. In 2050 it is projected to consume 68% of the total water requirement, followed by 9.5% for drinking water, 7% for industry and 6% for energy. Balance 9.5% will be required for other use (Table 4).

The two most important drivers of water demand namely the Agriculture and drinking water are discussed in the following paras. Also included is an analysis of climate change impact, Inter –basin water transfer project and the future challenges India faces in ensuring water security.

S.3.3 Agriculture Water Demand

S.3.3.1 Canal Irrigation

Overview

Public irrigation systems are losing their dominant position with more and more farmers switching over to groundwater irrigation. Further, with deceleration in canal irrigated areas, the Government of India had instituted the Accelerated Irrigation Benefits Programme to reverse the trend and step up investment in last-mile projects. Also, more recent thinking on improving the performance of surface systems has prompted rehabilitation of irrigation schemes combined with institutional reforms relying on the participation of farmers and local bodies through participatory irrigation management (PIM). Many states have instituted laws empowering farmers' participation in the management of irrigation systems through the creation of water users' associations (WUAs). However the efforts have remained largely unsuccessful.

Future Options

The key lies in improving the management of the main systems. This may require reorganizing the the Irrigation department into smaller independent management units with operational autonomy and greater accountability .

A potentially gigantic opportunity for unlocking value out of India's canal systems lies in spreading their waters on much larger areas to expand the areas under conjunctive management of surface and groundwater. Presently, this is not happening because India's irrigation systems irrigate only a fraction of the area they were designed to.

Another proposal could be to evolve a public-private partnership between farmers and irrigation departments for efficient utilization of canal water. (A good example of the kind of partnership between the ID and irrigation cooperatives is the Radhanagari project that serves 91 villages in Kolhapur district of Maharashtra (para 3.3.1.2 -C)

Canal Irrigation – Conclusions

The Authors recommend unbundling of the Irrigation department into smaller independent units and also limiting the role of the Irrigation department to that of a bulk supplier and leaving the distribution below the outlet to concerned user groups, with or without private participation. Conjuctive management of Surface and ground water is recommended for expanding the role of irrigation and improving its impact.

S.3.3.2 Ground Water Irrigation

Introduction

Groundwater irrigation has expanded rapidly in India since 1970s and now accounts for about 60 percent of the total area irrigated. About 85% of the rural drinking water supply is also met from ground water sources. Growing demands of ground water have brought problems of over-exploitation of the resource, continuously declining water levels, sea water ingress in coastal areas & ground water pollution in different parts of the country. The falling ground water levels in various parts of the country have threatened the sustainability of ground water resource, as water levels in several blocks have gone down beyond the economic lifts of pumping. (CGWB)

As the reliance of groundwater, especially for irrigation, increases further, many basins will have severe groundwater depletion. According to IWMI research, in case of BaU (business as usual) scenario, many basins will have groundwater abstraction more than 75 % of their utilizable groundwater resources by 2050. (The States of Haryana, Punjab and Rajasthan have already reached a stage of over exploitation exceeding more than 100 % of the annual replenishment -Gandhi 2009). On the supply side several basins will reach physical water-scarce condition by 2050. (Gandhi)

Growth of Ground water irrigation and its impact

The principal source for Water resources is precipitation. With erratic precipitation groundwater has become a major source. Electricity supply (subsidized / free) has made pumping of groundwater easy and economical and consequently groundwater irrigation developed very rapidly. Studies also show that pump irrigated farms perform better than those irrigated by any other source. Groundwater can therefore be a key resource for poverty alleviation and economic development.

Future Options

The estimated total replenishable groundwater resource in India is 433 bcm per year. According to CGWB another 36 bcm could be added with rain water harvesting and artificial recharge taking the total figure to approx 470 bcm . Utilizable groundwater resource will be some what lower than that . In face of this,the projected abstraction 396 bcm may not appear so alarming. However, this number does not reveal the true picture of geographic variation, which is rather extreme. Out of the total replenishable groundwater resource of 433 bcm, the Ganga basin alone accounts for nearly 40 per cent. Thus, the resource is highly concentrated and none of the other basins even cross 10 %. Over exploitation in different river basins could be a serious constraint for sustaining groundwater expansion in the future. Demand side management assumes the greatest importance specially with regards to water use efficiency. A legislation is required to control groundwater exploitation which will require an enabling constitutional amendment separating the right to groundwater from the right to land.

The Role of Land Tenure, Water Rights, and Groundwater Markets in Influencing Equity and Efficiency

As per the law, groundwater is under private regime in India and the rights to groundwater belong to the owner of the land. The right to groundwater is transferred to anyone to whom the land is transferred and there is no groundwater drawing limitation.

And since there is no charge on groundwater there is minimal incentive for efficient and sustainable groundwater utilization leading to groundwater stress.

The Efficacy of Water Institutions (Laws and Policies) in Managing Groundwater Challenges

Draft National Water Policy 2012 (NWP) has several provisions to control and regulate use of ground water (though less development has been made), as under the Constitution, states have the authority to frame suitable policies, laws, and regulations on water. There is an urgent need for overarching national legal framework of general principles on water that can be used by states to draft their own legislation on water governance.

Ground Water Irrigation – Conclusions

Groundwater occupies a dominant place in India's agriculture, food security and water supply but is facing a crisis and needs urgent attention. Groundwater management would need to be different in different areas. Measurement of groundwater level on a monthly or quarterly basis extensively across blocks/villages is required. Controlling the availability of subsidized / free electricity would reduce over-exploitation. Restricting the number of tube-wells through licensing (or through imposing institutional credit restrictions) could be considered. New legislation is required to control groundwater exploitation, and a constitutional amendment separating the right to groundwater from the right to land.

S.3.4 Drinking Water

S.3.4.1 Urban Water supply

Global View

The United Nations has assessed that presently almost fifty percent of the global population lives in the cities and towns and in twenty years this will become 60 per cent. This exponential growth of urban population is creating serious challenges in providing water (and sanitation).

Issues and options for India

Urban water supply in India is facing shortages in investment and faces challenges of inadequate coverage, intermittent supply, inequitable water access etc. These are largely due to insufficient capacities of urban local bodies (ULBs), apart from political issues of tariff. There is thus need for policy changes in the urban water sector. Recently, there has been some progress by way of institutional reforms. (JNNURM had mandated that states and utilities undertake a set of reforms before they can access their project grants).

Manila Water and Sewerage Concessions – A Case Study

In this connection, the Case Study "Manila Water and Sewerage Concessions" is relevant. Some similar attempts have been made in India too, especially at Karnataka, Tamil Nadu and Latur, amongst others. The experience gained will be useful for subsequent similar projects.

Urban Water Supply – Conclusions

In urban areas, urban local bodies (ULBs) are responsible for providing drinking water to households, industrial, and commercial establishments. Drinking water supply and irrigation, both are provided by state or local government entities which are largely in the public sector, and usually, are vertically integrated regional monopolies There is need for private sector participation in the water sector . For this, steps have to be taken to improve the legal/regulatory framework to facilitate such private sector involvement.

S.3.4.2 Rural Water Supply

Background

Historically, drinking water supply in the rural areas in India has been outside the government's sphere of influence. Effective role in this sector started in early seventies.

In 1999-2000, **Third generation programme** with **Sector Reform Projects** evolved to include community in planning, implementation and management of drinking water related schemes, which were later scaled up as **Swajaldhara** in 2002. In July 2011 the **Ministry of Drinking Water and Sanitation** was created

The subject of 'Rural drinking water supply' is in the State list. It is also included in the Eleventh Schedule of the Constitution among the subjects that may be entrusted to Panchayats by the States. Empowerment of the PRI (Panchayati Raj Institutions) in rural drinking water supply is one the most important areas of focus in the sector)

National Rural Drinking Water Programme. NRDWP, is a Centrally sponsored scheme aimed at providing adequate quantity of safe drinking water to the rural population of the country.

Status of Coverage of Habitations with Drinking Water Supply

The current status of provision of drinking water in rural areas (percentage of habitations where the population is fully covered with adequate (40lpcd) and safe drinking water), is about 72% of total rural habitations.

Strategic Plan – Rural Drinking Water Supply

The Strategic Plan has the following goals-

By 2017,

- Ensure that at least 55% of rural households are provided with piped water supply; at least 35% of rural households have piped water supply with a household connection; less than 20% use public taps and less than 45% use hand-pumps or other safe and adequate private water sources.
- Ensure that all households, schools and anganwadis in rural India have access to and use adequate quantity of safe drinking water.
- Provide enabling support and environment for Panchayati Raj Institutions and local communities to manage at least 60% of rural drinking water sources and systems.

By 2022,

- Ensure that at least 90% of rural households are provided with piped water supply; at least 80% of rural households have piped water supply with a household connection; less than 10% use public taps and less than 10% use hand-pumps or other safe and adequate private water sources.
- Provide enabling support and environment for all Panchayati Raj Institutions and local communities to manage 100% of rural drinking water sources and systems.

The vision for rural domestic water supply in the Strategic Plan of the Ministry is to cover all rural households with safe piped drinking water supply @ 70 lpcd.

Rural Water Supply – Conclusions

(1) Efforts have been made by the government to provide water security across the whole country. Enhanced funds were earmarked under the Five Year Plans and limited success was obtained at the operational level. Special attention on the part of the State government with strong political will is required to get the programmes implemented effectively by devolution of requisite powers to the PRIs.

(2) Consider bringing a legislation for water security to guarantee a minimum quantity of clean water to every person at an affordable price. Drinking water should also be accorded top most priority in sectoral distribution and its demand should be met first ahead of agriculture and industrial demand.

(3) Conjunctive use of ground and surface water would go a long way in moving over increasingly to demand-driven programs. Restructuring of the Irrigation department and limiting its role to bulk supply leaving the distribution to PRIs /WUAs will go a long way in sustainability of the water resource .

(4) All multi-village schemes should be made in consultation with the user associations.

(5) Need for a change in the attitude towards private sector agencies in the context of rural water supply.

(6) There is need for greater efforts at cost recovery and allocation of more funds for the maintenance of schemes.

S.3.5 Water and Climate Change

Impact of Climate Change

Climate change is one of the biggest challenges facing mankind and is impacting almost every aspect of human activity. Its effect on Water – the ultimate resource, is engaging the anxious attention of the world.

On Water Availability in Various Basins

The consequences of climate change may alter the reliability of current water management systems and water-related infrastructure. (Climate Change and Water- IPCC Technical Paper VI)

The spatio-temporal availability of water in the various river basins (for three scenarios namely Base Line (BL), Mid-Century (MC) and End-Century (EC) was studied and the impact of Climate change on blue and green water for these three scenarios was analysed. **The trends indicate that blue water, and green water availability increases with time in all except Brahmaputra, Cauvery and Ganga basins**. The green water storage decreases in the mid-century scenario and then increases to the baseline scenario by the end of the century. All basins except Brahmaputra, Ganga, Cauvery and Pennar show improvement in average flows by mid-century. Brahmaputra, Ganga, Cauvery and Pennar also show increase in water availability by End of the Century in comparison to present availability.

On Glaciers in India

Glaciers 'mother' several rivers and streams with their melt run-off. A significant portion of the low flow contribution of Himalayan Rivers during the dry season is from snow and glaciers melt in the Himalayan region. The status of glaciers in the Indus, the Ganga and the Brahmaputra and their contribution to flows are given in Table 9 (Status of the Glacier Inventory of Indus Basin).

Summarising

India receives 1083 mm of average rainfall over a geographical area of 329 million hectares (mha). However, rainfall distribution varies widely across the land, both spatially and temporarily. The runoff generated in various sub-basins of India varies from 25 to 35 percent of rainfall except in the Luni, the Pennar and the east flowing rivers south of the Pennar.

Climate Change is not likely to decrease the average water availability in most basins. The frequency of extreme events could result in increased flooding and perhaps longer droughts. Climate Change is also going to result in melting of glaciers. The impact could be much more in the North western basins (such as the Indus) as compared to that in the eastern basins. (INAE Report-Water Resources Management,Apr. 2012).

Climate Change and Agricultural Water Demand

Climate change may become an important driver of agricultural water demand. The two important parameters of climate change are, global temperature rise and carbon dioxide levels.

Agriculture will be adversely affected not only by an increase or decrease in the overall amounts of rainfall, but also by shifts in rainfall timings. The effects of climate change on water demands in agriculture are summarized below. (Agrawal, P.K., Ed.2009):

Briefly

- Increase in CO2 to 550 ppm increases yields of rice, wheat, legumes and oilseeds by 10-20%.
- A 1deg.C increase in temperature may reduce yields of wheat, soyabean, mustard, groundnut, and potato by 3--7%. There are much higher losses at higher temperatures.
- Productivity of most crops would decrease only marginally by 2020, though by 2100 this decrease could be between 10-40%.
- There could be some improvement in yields of rabi maize, millets and sorghum and coconut in west coast.

(INAE Report-Water Resources Management, 2012).

Climate Change Adaptation For Agriculture and Agro Eco-systems

It is said that climate change mitigation is about gases and that adaptation is about water.

In a world where 70 percent of water withdrawals are used for agriculture, it is important that we develop adaptation strategies to manage the impacts of climate change on water availability, agriculture, and the environment.

Water and Climate Change – Conclusions

To adapt to climate change, we will need to :

(a) Improve basin management and water allocation processes; and

(b) Think creatively about water storage systems, including groundwater storage and reuse;

(c) Develop drought response strategies, including early drought warning systems, crop insurance, changing land use and cropping patterns, and increasing water productivity.

S.3.6 Inter-Basin Water Transfer / National River Linking Project

Backdrop

The idea of having a National Water Grid for transferring surplus water available in some regions to water deficit areas dates back to early seventies when the then Minister for Irrigation late Dr. K.L. Rao proposed a 2640 km. long river linking grid with Ganga - Cauvery link as its main component. It was found to be economically unviable.

Another subsequent proposal (from Capt D J Dastur) envisaged construction of two canals – the first 4200 km. Himalayan Canal at the foot of Himalayan slopes; and the second 9300 km Garland Canal covering the central and southern parts, with both the canals integrated with numerous lakes and interconnected with pipelines. It was found technically infeasible and having an adverse cost-benefit ratio.

The idea of the water transfer led to formulation of a National Perspective Plan (NPP) in 1980 to minimize the regional imbalances and optimally utilize the available water resources.

It was decided in 1982 to set up a National Water Development Agency (NWDA) to carry out detailed studies as a follow-up of the National Perspective.

The National Perspective as well as the NWDA studies have two components :

(c) Himalayan component and,

(d) Peninsular component.

The two do get linked on the Mahanadi. When completed, the project would consist of 30 river links and 3,000 storage structures to transfer 174 bcm of water through a canal network of about 14,900 km.

Project Benefits

According to NWDA , The National Perspective Plan would give additional benefits of 25 million hectares of irrigation from surface waters, 10 million hectares by increased use of ground water, totaling 35million hectares and 34,000 MW of hydro-power generation.It is estimated that when completed, NRLP will increase India's utilizable water resources by 25 percent,

Project Costs

The NRLP is estimated to cost more than USD 120 billion (at 2000 prices), of which

- the Himalayan component costs USD 22 billion;
- the Peninsular component costs USD 40 billion; and
- the hydro-power component costs USD 58 billion.

Some Contentious Issues

The NRLP concept has been contentious from the very beginning with several environmentalists and social activist opposing the idea due to concerns about environment , massive displacement of people , socio economic costs etc. Scientists and technical experts opposed the ideas on the ground of hydrological and technical feasibility issues.

IWMI studied the three major contentious issues, namely -

(1) Water surpluses of donor river basins; 2) Key drivers of justification; and 3) Potential of alternative water management options .

Issue 1 – Water Surpluses of Donor River Basins

The issue of surplus surface water in the donor basins is a leading cause of disagreement. An extreme view is that no river basin is water surplus. Some argue, "…from a holistic perspective there is no surplus water in a river basin, because every drop performs some ecological service all the time… there is no free surplus water in a basin that one can take away without a price." A moderate view is that a river basin can have surplus water if there is excess river flow after meeting the potential demand of agricultural, domestic and industrial sectors and an adequate allocation for the environment (IWMI).

Issue 2 – Key drivers of justification

Self-sufficiency

The contentious issues are the estimates of food and water demand emanating out of different concerns.

Food grain demand

The likely projections of food grains demand *and consequently the demand on water* are disputed.

Rural Livelihood Needs

Rural employment was a key driver of irrigation development in the past.

Migration from full time agriculture to nonfarm rural and urban livelihood will increase.

Costs and Benefits of Irrigation Water Transfers

Another issue is benefits and costs. The NRLP water transfers envisage benefiting irrigation the most. It plans to add 35 million ha of new irrigated croplands (25 mha through surface and 10 mha through groundwater). The financial and social benefits, both direct (crop production) and indirect (backward and forward linkages), of irrigation are major components of the benefits. However, achieving this would require committing a huge outlay.

Issue 3 – Potential of Alternative Water Management Options

There is a feeling that inadequate attention is being given to alternative water management strategies like increasing water productivity, improving rainfed agriculture in managing the water demand and artificial groundwater recharge in managing the supply.

Inter-Basin Water Transfer / National River Linking Project – Conclusions

There are indications that India will require substantial additional water supply to cater to increasing demand in the coming decades. Population and economic growth, increasing world trade, changes in lifestyles etc. will be the primary drivers for increased demand. Climate change will become an influencing factor in the long-term with higher intensity of floods and drought cycles. Ground water has been the major source for meeting increasing demand in all sectors. It is highly likely that this trend will continue. Many river basins , particularly in peninsular India, will have severe water stress conditions. With increasing reliance on groundwater, particularly for irrigation, many river basins will have severe groundwater overexploitation-related problems. Meeting India's short to medium term water demand itself will be a challenging task.

However, many options are available to meet this challenge. Recharging groundwater to increase the groundwater stocks; harvesting rainwater for providing the life-saving supplemental irrigation; promoting water saving technologies for increasing water use efficiency; formal or informal water markets and providing reliable separate rural feeders for reducing uncontrolled groundwater pumping; increasing research and extension for enhancing agriculture water productivity; and carefully crafted virtual water trade between basins are important policy options for meeting the increasing demand. With increasing disposable income, people's affordability and willingness to pay for a reliable domestic and industrial water supply will increase. This, along with a reliable water supply for diversifying high value cropping patterns, may require large surface water transfers. The inter basin water transfers, besides generating clean energy , could increase the recharge groundwater in much of the over-exploited area. While artificial groundwater recharge, rainwater harvesting, and inter basin water transfers are a solution for meeting the water demand in the near-term, they are also solutions for increasing the potential utilizable water supply in many water scarce river basins. They will indeed have major benefits when full influence of the climate change starts to impact the utilizable supply in many water scarce river basins.

S.3.7 Future : Water Scenario in 2025-2050 / Meeting the Water Challenges, 2025-2050

Introduction

The projected water demand for 2050, with 10 % improvement in irrigation efficiency and 46.5% increase in crop productivity, is assessed at 735 bcm. In addition, there would be requirements of industrial, domestic and other sectors (373 bcm). The water demand would thus be 1108 bcm; the total utilizable quantity would be about 1123 bcm. The environmental demands for (moderate modification in the ecosystem (that would not seriously modify biodiversity and habitat), are assessed at 501 bcm (33 % of total renewable water resources) while for (largely modified ecosystem), it is 353 bcm (Amarasinghe et al, 2007). The current water situation is thus heavily imbalanced. The Basin-wise water supply and demand balance projections for 2025 and 2050 show that basins like the Indus are currently physically water-deficient and are surviving on groundwater overdraft, which is unsustainable. It is therefore imperative that we take serious note of the available water demand and supply management options.

Demand and Supply Measures to Meet the 2050 Water Challenge

Conceptually, three broad sets of options are available for meeting the growing water demand challenges:

One is demand management, the other is supply management and the third is a mix of both these options. Agriculture sector is the dominant user of water and its current level of low productivity and irrigation system inefficiencies provides greater scope for minimizing water demand as compared to other sectors. The 2030 Water Resource Group (2009) reported in their study that, of the estimated supply-demand gap in 2030, nearly 80% could be bridged through improvements in agriculture.

Bridging the Water Availability through Demand Management in Agriculture

Demand management can be done through:

(iv) biological interventions (like introduction of improved germplasm),

(v) improved plant nutrient management and

(vi) improved water management technology.

Agricultural Productivity – BAU and other Scenarios

Apart from water, two other important inputs which contribute to agricultural productivity are seeds and fertilizers.

Crop Yield Growth Rates

The BAU scenario assumes an annual growth rate of 1.4% during 2010-2025 and 1.1% during 2025-2050, providing an average grain yield of 2.4 tons/ha in 2025 and 3.2 tons/ha in 2050.

Increasing Productivity through Irrigation Efficiency Route

The changes in BAU irrigation demand with various surface irrigation efficiencies and groundwater irrigation efficiencies by 2050 bring in significant changes in water demands.

Ways to Improve Irrigation System Efficiencies

Laser leveling has the potential for making positive contributions to increasing the productivity and incomes of farmers.

Micro Irrigation

Micro irrigation provides triple benefits: reduction in irrigation requirements, fertilizer saving and increased crop yields. The return on investment on micro irrigation would be high.

Some Other Resource Conserving and Yield Enhancing Technologies

Zero-Till Farming (ZTL), System of rice intensification (SRI) not only increase productivity per unit area, but also reduce costs of cultivation, besides savings of water.

Basin Level Water Demand Balance and Suggested Action Programmes

In view of the fact that a matching gain in water supply to bridge the supply deficit to the extent of 80% could be had by demand management, adoption of this option should be given priority. The balance 20% gap between supply and demand should be addressed through wastewater reuse, cost effective storage development projects and limited regional river water transfers. Desalinisation of sea water may be resorted to for augmenting drinking water supplies in coastal cities facing acute shortages.

Bridging Water Availability Gap through Supply Management

Increasing water availability through supply measures includes abstraction of more water from the rivers and aquifers, rainwater harvesting, inter-basin transfers, wastewater treatment and desalinisation etc.

Important 2025 Targets for Water Supply Increasing Interventions

The task of ensuring water security for food, economic development and maintenance of ecosystem in a healthy state in a dependable manner, would require development of additional water resources. The Water Resource Group (2009) estimated that about 400 bcm of additional water could be developed through various supply enhancing measures.

Further, wastewater, after treatment, is going to be a major source of new water supply.

The Emerging Directions for Development

Some interesting findings emerge from this analysis of water demand and supply scenarios and the possible options for meeting the 2025-2050 water challenge. It is evident that our water demands would escalate sharply while water supply would not match the growth in demand. Growth in agriculture, energy, industry and environment sectors have significant implications for water budgets in the river basins. It is also observed that water demands for the year 2025 and 2050 would not be met by the current and projected water resources development plans in the Business As Usual mode. It is noted that the solution largely lies in demand management, particularly through the productivity enhancement route in agriculture. However, the positive aspect is that a large basket of technologies is available to trigger productivity growth at reasonable cost.

Technology

Exploiting the Full Potential of Crop Genetics.

Harnessing Synergy between Green and Blue Water

Making Use of the Comparative Advantage in Crop Choices

Extensive crop diversity gives us an opportunity to shift to crops, which are less water-consuming, and at the same time, more remunerative. It is envisaged that, in future, the Ganga basin would replace the Indus basin for producing surplus food grains for food deficient basins.

Wastewater as Irrigation Resource

As more than 50% of our population would live urban areas by 2050, wastewater is going to be an expanding and dependable source of water supply for reuse.

Incentivizing Technology Adoption

Micro irrigation has already come under the Accelerated Irrigation Benefit Programme (AIBP). This programme should be expanded to include other equally effective technologies e.g. laser levelling, subsurface drainage, zero tillage for incentivizing their adoption.

Some Policy Choices

(a) Development Vs Management of Water Resources

Our policy should be to maximize water storage, be it behind dams, or in groundwater aquifers or in multipurpose local reservoirs.

(b) Strategic Role of Ground Water and Water Banks

Accelerated efforts are required to augment the valuable ground resource through induced recharge as well as for enforcement of safeguards meant for maintaining the aquifers in good health. Perhaps, one should start thinking of water banks in a big way via the groundwater route.

(c) Increased Funding for Water Resources Development and Private Participation

Promote the PPP mode in the sector, as has been done in many other sectors.

(d) Strengthening Technology Research, Development and Incubation Hubs

Technology hubs need to be set up for development of new technologies and benchmarking of available technologies. These hubs would also provide incubation facilities to inexpensive new technologies for attracting private participation.

S.3.8 Recommendations

(a) Right to Water

Access to safe and clean drinking water should be regarded as a fundamental human right and the State should ensure a minimum specified quantity of potable water to each individual at an affordable price. There is a pressing need to provide a constitutional amendment on lines similar to "Food Security Bill"

(b) Reform in the Irrigation Department

There is need for a major change programme in the public irrigation sector. This may require unbundling of the Irrigation department into into smaller independent management units with operational autonomy and greater accountability. Authors feel that limiting the role of Irrigation Department to that of a bulk supplier and leaving the distribution below the outlet to concerned user groups with or without private participation is the best available option for India. Also a credible information and monitoring system about how public irrigation systems are performing against their original designs, their current objectives, and vis-a-vis each other should be put in place

(c) Expanding the Area under Conjunctive Management of Surface and Groundwater

The simplest step that canal irrigation management in India can take to significantly enhance its impact is to maximize areas under conjunctive use of ground and surface water. Presently, this is not happening because India's irrigation systems irrigate only a fraction of the area they were designed to. A potentially gigantic opportunity for unlocking value out of India's canal systems is by spreading their waters on much larger areas to expand the areas under conjunctive management of surface and groundwater

(d) Seperation of right to Ground Water from right to Land

Presently, groundwater belongs to the land owner and there is no limitation on groundwater withdrawal by the land owner . Landless households (or tribes), who may have community rights over land, have no private rights. Ground water should be managed as a community resource and held by the State as a public trust to ensure food security, livelihood, and equitable and sustainable development for all A new legislation should be enacted to control groundwater exploitation, and a constitutional amendment made to separate the right to groundwater from the right to land. . For this, the existing Act should be modified suitably.

(e) Ground Water recharge to be allocated highest priority

Apart from reducing over-exploitation, increasing the recharge of groundwater through harvesting of rain and surface flows would prevent the dewatering of aquifers, and also greatly improve equity by making water available in the wells affordable to small and marginal farmers. In this context artificial ground water recharge should be given highest priority.

(f) Strategic Role of Ground Water and Water Banks

Accelerated efforts are required to augment the valuable ground resource through induced recharge as well as for enforcement of safeguards meant for maintaining the aquifers in good health. It is time that India starts thinking of water banks in a big way via the groundwater route.

(g) Encourage Private Sector Participation in Drinking Water Supply

The need and advantages of private sector participation in the water sector are evident when one looks at the success achieved in terms of improved quality of service to users in other sectors , such as national highways, telecom and power. Unprecedented pace of urbanization has made urban water supply one of the most challenging task which the States will find most difficult to manage on their own. The case study of Manila Water and Sewerage Concessions (Annex 2) can provide valuable lessons for adoption in major urban conglomerates. Even in the rural sector, there is need for a change in the attitude of state governments towards private sector agencies . States need to encourage private consultants, contractors, and operators becoming more active in rural water service delivery, as several examples show that they are often more effective in improving service delivery. This is particularly important for the planning and implementation of multi village schemes. A beginning can be made by entering into service contracts / lease contract thereby retaining public ownership. Private participation in the water sector could achieve objectives of various public-private partnership (PPP) models,viz. improvement of water use efficiency, capital mobilization, , better harnessing of renewable resources, professionalism and access to better technology. Towards this end, steps have to be taken to improve the current legal/regulatory framework to facilitate such private sector involvement. Institutional strengthening is another important aspect that needs to be taken care of so as to make it amenable for establishing PPPs in the sector

(h) Empowering Panchayati Raj Institutions (PRIs)

There is a need for greater efforts at cost recovery and the allocation of more funds for the maintenance of schemes so that their useful life can be extended. The ownership of single village schemes should be handed over to the Panchayati Raj Institutions (PRIs) and/or user committees, after proper rehabilitation, and their O&M costs should be recovered from user charges. Similarly, multi village schemes and regional schemes may be unbundled into smaller schemes at the village level and the responsibility handed over to the Gram Panchayat/village community with contractual agreements and performance improvement targets between user groups and the bulk water providers. The desirable state to achieve is one in which the O&M cost needs to be properly assessed and fully recovered through user charges. State-wise, uniform cost sharing principles need to be worked out, irrespective of types of programs or sources of financing. For high cost schemes, it is not necessary, nor desirable, to recover fully the O&M cost through user charges. Rather, a transparent criteria needs to be developed to determine ‘affordable’ contributions, **including a criteria for socially disadvantaged groups.**

(i) Increasing Productivity through Irrigation Efficiency Route

India has so far been investing heavily on supply side management with much less emphasis on demand side management. The change in BAU irrigation demand (with surface irrigation efficiency at 50, 55 and 60%) and groundwater irrigation efficiencies (70, 75 and 80% by 2050) can bring in significant changes in water demands A mere 5% increase in both canal irrigation efficiency (CE) and ground water efficiency (GE) would **reduce** irrigation demands by 60 bcm (**8%). I**f efficiencies are raised by 10%, in case of canals and ground water, irrigation demands would come **down** by **18%** (129.5bcm). There is urgent need to concentrate on improving the water use efficiency..

(j) Encouraging Technology adoption

Effective technologies like laser leveling, subsurface drainage, zero tillage etc. should be encouraged and for incentivizing their adoption they could be made a part of the Programme for Accelerated Benefits to Agriculture (PABA).

(k) River linking project to be given higher priority

It is evident that India will require considerable additional water to meet the demand in the coming decades since a number of river basins,(particularly in southern/ peninsular region), would become severely water stressed. Transfer of water from the Himalayan rivers in the north to the deficit peninsular/southern region has been suggested since the last forty years through a number of options/plans/projects. A comprehensive one, the National Perspective Plan would (contentious issues apart) give additional benefits of 25 million hectares of irrigation from surface waters, 10 million hectares by increased use of ground water, totalling 35million hectares and 34,000 MW of hydro-power generation, amongst others.In view of the importance and urgency, it is recommended that the project be taken up, in phases, at the earliest, and on top priority.

(l) Rational pricing of Water

Normally, efficient use of scarce resources requires appropriate pricing, but pricing of water is a sensitive issue. This problem can be solved by providing 'lifeline' water supplies for drinking and cooking at very low prices, while charging appropriately for additional water use by domestic consumers. There is a stronger case for rational pricing reflecting the scarcity of water for commercial and industrial use. There is also a strong case for rational pricing of water for agricultural purposes. The proportion of water recycled in urban areas, and by Indian industry needs to be significantly increased. This will happen if supply for commercial purposes is appropriately priced. A rational pricing must be accompanied by regulatory measures to ration water to different agricultural users, and stronger measures to discourage pollution

(m) Change in mindset

For bringing about these changes there is an imperative and urgent need to ensure a change in the thought process of all the stakeholders , the citizens, civil society, Govts., both State and Central. Only then can any appreciable change can be brought about.

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Chapter 4

Transport – Making it Greener

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Chapter 4

Transport – Making it Greener

4.1 Introduction

4.1.1 The mechanized modes of transport comprise Railways, Highways/Roads, Coastal Shipping, Airlines, Pipelines, and Inland Water Transport. No centralised monitoring authority/institution for regulating coordinated operation and integrated growth of different modes of transport exists in the country. To give an example, while Railways are centrally administered as a department of the government, for the highways, infrastructure is provided by the Central and State governments, and the operation of vehicles is by private sector/owners. Some States also have State Transport Undertakings for the passenger transport.

4.1.2 The data regarding 'Originating Inter Regional Freight Traffic Growth and Changing Modal Split in India' can be seen in Table No.1. This data has been taken from the White Paper on Indian Railways, December 2009 and is based on a recent Study done by RITES for the Planning Commission. It will be seen from it that currently in our country about 91% of the Inter Regional Freight Traffic is carried by Rail (30%) and Road (61%), and the balance by Coastal Shipping (2.3%), Pipelines (4.5%) and Inland Water Transport (2.2%), the share of Airlines being very small (0.3 million tonne). **The share of Rail in freight traffic has come down from 89% to 30% since 1950-51 and for the passenger traffic it has reduced from 69% to 15%. (Ref. : Agarwal – 2004 & Indian Railway's White Paper – 2009)**

Table 1 : Freight Traffic Growth and Changing Modal Split in India

		Mode-wise Traffic in Million Tonnes with Percentage Share					
Year	**Total Originating Inter Regional Traffic (Million Tonnes)**	**Railways**	**Highways**	**Coastal Shipping**	**Airlines**	**Pipelines**	**Inland Water Transport**
1950-51	82.2	73.2 (89%)	9.0 (11%)	NA	NA	NA	NA
1978-79	283.4	184.7 (65%)	95.6 (34%)	3.1 (1%)	NA	NA	NA
1986-87	484.9	255.4 (53%)	224.0 (46%)	5.5 (1%)	NA	NA	NA
2007-08	2555.4	768.7 (30%)	1558.9 (61%)	59.1(2.3%)	0.3	113.5(4.5%)	54.9(2.2%)

Source : White Paper on Indian Railways, December, 2009 / Planning Commission – Total Transport System Study 2009.

4.1.3 It will be interesting to examine the pattern of **intra-regional** freight traffic carried by the Road. The inter-regional freight traffic mentioned in para 1.2 basically takes a 'District' as a 'Region' for evaluating the traffic while for the **intra-regional** traffic the movements within the Region/District are considered. The pattern of traffic for the year 2007-08 as per the Planning Commission Study referred to in para 4.1.2 is as under :

	Volume	Average Lead
Inter-regional freight traffic	1558 Mt	453 km
Intra-regional freight traffic	4640 Mt	15 km
	(x3)	(x1/30)

It will be seen that the volume of **Intra-Regional freight traffic is three times the inter-regional traffic but in terms of ton-km it is only about 10%.**

4.1.4 Demand for transport is directly connected to GDP growth. For a developing economy like ours, the elasticity of transport to GDP can be taken as about 1.25. GDP growth of 9% would, therefore, translate into increase in demand for transport to the tune of 11%. The traffic is very likely to double in next 7-10 years.

4.1.5 Our existing transport infrastructure is already under severe strain with congestions visible everywhere. Paucity of necessary resources came in the way of infrastructure development and the lower GDP growth in the earlier periods also made us complacent towards the need for such a development. However, booming economy now necessitates that the transport infrastructure develops at an accelerated pace and that too in a coordinated and integrated manner. Development of necessary transport infrastructure is a pre-requisite to sustain the current levels of GDP growth and if timely action is not taken growth may get stifled.

4.1.6 To compound the problem of accelerated growth of transport infrastructure, the issue of environment has assumed paramount importance in the recent years, needing cuts in emissions of greenhouse gases (GHGs). **Growth of transport infrastructure has to consciously keep in view the need for using a mode which is least polluting and hence more environment-friendly in addition to planned efforts to reduce transport demand to the extent possible. Further, besides fuel and system efficiency measures, integrated and optimal use of various transport modes is essential.**

4.1.7 A European Study gives details of carbon dioxide (CO_2) emissions from various transport modes, both for the passenger and the freight traffic (see Table No. 2). Such emissions may even be higher for Indian conditions with less stringent fuel quality and vehicle maintenance norms. It will be seen from it that Rail is more environment-friendly with lower CO_2 emissions. On the other hand Table No.1 indicates that while the volume of freight traffic is increasing, the proportionate volume of traffic carried by Rail, which is **Greener** and so more environment-friendly, is declining.

Table 2 : Carbon-Dioxide (CO_2) Emissions

CO_2 Emissions from Freight Transport (gms/tonne-km)

Road	158
Water Transport	31
Rail	29

CO_2 Emissions from Passenger Transport (gms/passenger-km)

Air	229
Road (Car)	175
Rail	75

Source : Soft Mobility Paper – Europe – July 2006.

4.1.8 **Transport accounts for approximately 25% of global carbon dioxide (CO_2) emissions**, and is the sector with the highest growth in emissions, and the second largest contributor overall (after electricity and heat supply sector). Railways and their energy efficiency are crucial to reducing greenhouse gas emissions. Incidentally, a shift of 3% from road to rail transport corresponds to 10% decrease in GHG emissions (Sharma - 2009).

In 2005, India's transport sector consumed about 17% of the commercial energy supply, and 78% of this was used by Road Transport, 11% by Aviation, 10% by Rail Transport and 1% by Inland Water Transport. Of the total energy consumed in the transport sector 98.5% is met through petroleum products and the rest by electric power. Transport sector consumed 27% of the total oil and oil products in India during 2006-07 (Singh - 2009).

4.1.9 **Transport pricing does not tell the environmental truths because social costs are not factored in.** The social costs of transport operation chiefly encompass costs arising from accidents, atmospheric pollution, damage to the climate and to public health, noise, impairment of natural resources and the landscape, and damage to buildings. In the absence of any such authentic data for our country the data from a European Study (Soft Mobility Paper – 2006) can be taken as a broad guide (see Table No. 3) which indicates that Rail has the lowest social costs.

Table 3 : Social Costs of Various Transport Modes

(A) Average Social Costs – Freight Transport (2000)
(Euros per 1000 tonne-km)

Air	271.3
Road (Light Lorries)	250.2
Road (Heavy Vehicles)	71.2
IWT	22.5
Rail	17.9

(B) Average Social Costs – Passenger Transport (2000)
(Euros per 1000 passenger-km)

Road (Car)	76.0
Air	52.5
Road (Bus)	37.7
Rail	22.9

Source : Soft Mobility Paper – Europe – July 2006.

4.1.10 The concern of the Government of India for addressing climate mitigation and adaptation is clearly reflected in the National Action Plan on Climate Change (NAPCC) which was released by the Prime Minister of India in June 2008. As detailed in Chapter 1 Para 1.4.9 it has identified eight core Missions**. While many fuel and technology efficiency parameters are included in these Missions but the benefits which could be achieved by modal shifts to more environment-friendly modes of transport have not been explicitly covered. These can make a marked change in the environment scene and will need pointed attention.**

4.1.11 The approaches that need to be adopted to reduce green-house gas (GHG) emissions in the transport sector can be classified into the following groups :

- Reducing transport demand by suitable relocation of production and consumption activities; use of Information and Communication Technology (ICT) including the use of geographic information systems (GIS) and the global positioning systems (GPS) to reduce movements or to make them more efficient;
- Behavioural changes by moving towards an optimum utilization of seating space and load factor;
- **Planned Shift to Non-motorised Transport (NMT)** e.g., for low lead intra-regional freight traffic (see Para 4.1.3) and for passenger traffic in busy metropolitan areas;
- **Encouraging a shift of commuters from use of road to rail and from personalized vehicles to public mass transport;**
- **Modal shift of freight traffic towards more environment friendly modes like Rail and Inland Water Transport (IWT);**
- Fuel efficiency improvements – A European Study indicated that upto 25% of fuel consumption could be saved through the use of efficient driving methods (Ecodriving);
- System efficiency improvements through traffic engineering and management measures; and
- Technological and fuel changes through upgrading automobile technology and fuel quality and promoting alternative fuels.

4.1.12 In this Technology Foresight Exercise while the various measures to make the Transport Greener have been outlined **but the emphasis is basically on improving the share of Rail in the overall Transport scenario**. About 91% of the traffic in our country is carried by Road and Rail,

Rail is 4-6 times environment-friendly vis-à-vis Road and uses much less space (land use) for carrying the same volume of traffic. A 3% shift from Road to Rail transport will reduce GHG emissions by 10% and thus the potential is enormous. Planning Commission has also been endorsing modal shift to Rail (Para 4.9). An independent analysis by Balance Research Institute, Melbourne (Para 4.8), also points towards much greater role for Rail in future World Transport scenario. Fast growing network and role of Railways in China, the fastest growing economy of the world, also justifies this line of action. It will not be out of place to mention that about a decade back the Chinese Railway network was smaller than that of Indian Railways (IR) but has since overtaken it. **The proposed action plan in broad terms is as under** :

- All transport modes must function in an integrated manner to get optimal output. There is urgent need for a centralized monitoring authority / institution for regulating coordinated operation and integrated growth of various transport modes.

- Directed efforts have to be made to reduce transport demand, choose environmentally efficient modes and make the operations and fuel systems of all transport modes more effective / efficient.

- While all transport modes be tackled in this manner but for Rail incremental efforts will not be enough. Rail needs special inputs on fast track to improve its market share besides other system improvements.

4.2 Indian Railways (Ref.: Indian Railways Year Book 2011-12)

- Indian Railways (IR) is one of the world's largest rail networks with 64,600 Route Kms of route lengths. The size of the network – gauge-wise as on March. 2012 is as follows :

Gauge	Route Kms	Running track kms	Total track kms
Broad Gauge (1676 mm)	55,956	80,779	104,693
Metre Gauge (1000 mm)	6,347	6,725	7,801
Narrow Gauge (762 mm and 610 mm)	2,297	2,297	2,568
Total	**64,600**	**89,801**	**115,062**

- With its more than 150 year old history, IR is a state-owned public utility of the Government of India under the Ministry of Railways.

- Indian Railways carried during the year 2011-12, 8224 million passengers **(about 2.25 crore passengers per day)** and 969 million tonnes of freight traffic **(about 2.65 million tonnes per day)**.

- The Golden Quadrilateral (connecting four metro cities of Delhi, Kolkata, Chennai and Mumbai) and its two diagonals, **which constitutes about 16% of Route Kms or 25% of Running Track Kms carries more than 55% of the traffic of the Indian Railways (IR)**.

- Some salient data about IR is as under :

➢ Bridges	Important	725
	Major	10,833
	Minor	1,22,315
	Total	**1,33,873**

- Level Crossings Manned 18,316

  Unmanned 13,530

  Total **31,846**
- Locomotives Steam 43

  Diesel 5,197

  Electric 4,309

  Total **9,549**
- Conventional Coaches 46,722
- EMU Coaches 7,793
- Wagons 2,39,321
- Number of Passenger Trains run daily 12,335
- Total Staff 13.05 Lakh

- Indian Railways, functioning as Ministry of Railways, is headed by the Minister of Railways. The apex body entrusted with the management of this mega enterprise is led by the Chairman Railway Board (CRB). Members of the Railway Board include Financial Commissioner, Member Traffic, Member Engineering, Member Mechanical, Member Electrical and Member Staff who represent their respective functional domains. For administrative purposes, Indian Railways is divided into 17 Zones, each headed by a General Manager. Zonal Railways are further divided into smaller operating units called Divisions. There are 68 operating Divisions in Indian Railways at present, each under a Divisional Railway Manager. In addition, there are a number of Production Units, Training Establishments, Public Sector Enterprises and other Offices working under the control of Railway Board.

4.3 Road Sector

- In our country, Roads carry around 85% of the passenger and 61% of the freight traffic.
- The category-wise break-up of road network (Total length about 4.2 million km) is as under. (Ref.: Indian Infrastructure 2012)

National Highways	71,772 km
State Highways	154,522 km
Major & other District Roads	2,577,396 km
Rural Roads	1,433,577 km
Total	4,237,267 km

- Central Government is responsible for development and maintenance of National Highways. The National Highway system which comprises only 1.7% of the total Road network carries 40% of the traffic and is overloaded at several points. Further, only 24% of the National Highways have four or more lanes, rest having Single lane (24%) or Double lane (52%). Generally, a lane has a width of 3.75 m in case of Single lane and 2.5m per lane in case of multi-lane National Highways. (Ref.: India – 2013)

- Several initiatives in the last decade have helped to improve the road network. Schemes such as the National Highways Development Programme (NHDP) for developing the national highway network, the Pradhan Mantri Gram Sadak Yojna (PMGSY) for developing rural road infrastructure, and Special Accelerated Road Development Programme for North-Eastern region (SARDP-NE) for improving road infrastructure in the north-eastern region have also been launched.

- The road sector receives funding from various sources. These include budgetary allocations by the Central and State Governments, assistance from multilateral agencies, the Central Road Fund (CRF) (Rs. 2 cess on diesel and petrol) and public-private partnerships (PPPs). The PPPs, especially on toll format, are increasingly being used to develop road projects. Some of the schemes are fully funded by governments, like PMGSY. The NHAI also provides support upto 40% in the form of viability gap (VG) fund for its projects. On an overall basis, budgetary resources account for 50% of the total funding in the road sector.

4.4 Inland Water Transport

4.4.1 Inland waterways have played an important role in the Indian Transport System since ancient times. However, in decades after independence, the importance of this mode of transport has declined considerably with the expansion of road and rail transport. Nevertheless, there is a growing realization that Inland Water Transport has to be an integral component of the overall transport system since it is a transport mode having least impact on environment, the lowest cost for domestic and international transport, enormous capacity reserves, and the least energy consumption.

4.4.2 India has over 1,45,000 km of navigable Waterways. These include five National Waterways covering 4329 km and other waterways controlled by respective State Governments.

4.4.3 Inland Waterways Authority of India (IWAI) was set up in 1986 for regulation and development of inland waterways for the purpose of shipping and navigation. IWAI is primarily responsible for development, maintenance and regulation of National Waterways. Following five waterways have been declared as National Waterways : (Ref.: India 2013)

- Allahabad-Haldia stretch (1620 km) of Ganga-Bhagirathi-Hooghly river system (NW-1) in 1986.
- Sadiya-Dhubri stretch (891 km) of Brahmaputra river (NW-2) in 1998.
- Kottapuram-Kollam stretch of West Coast Canal along with Champakara Canal and Udyogmandal Canal (205 km) (NW-3) in 1993.
- Kakinada-Puducherry stretch of Canal and Kalurelly Tank, stretches of river Godavari and Krishna (1028 km) in 2008.
- Talcher-Dhamra stretch of river Brahmani, Geonkhali Charbatia stretch of East Coast Canal, Charbatia-Dhamra stretch of Matai river along with Mahanadi delta river system (585 km) in 2008.

In addition, declaration of Barak River from Lakhpur to Bhanga (121 km) as sixth National Waterway is under consideration of the Government.

4.5 Civil Aviation (Ref.: Indian Infrastructure – 2012)

4.5.1 The civil aviation sector has been facing major challenges over the past two years. Though traffic volumes have increased, policy bottlenecks, land acquisition issues and high fuel prices have impacted its financial viability. The viability of public private partnership (PPP) projects has been affected due to a large dependence on non-aeronautical revenues and differences in opinion between the Airports Economic Regulatory Authority (AERA) and the Industry on tariff structures.

4.5.2 The six metro airports (Delhi, Mumbai, Bengaluru, Hyderabad, Kolkata, Chennai) and 35 non-metro airports carried during the year 2011-12 a total of 162.3 million passengers and 2.28 million tonnes of freight traffic. During the period 2007-12, the passenger and freight traffic at airports witnessed a compound annual growth rate of 8.56% and 7.85%, respectively.

4.5.3 It may be interesting to compare the volume of passenger traffic handled by Air with that of Rail as they are seen as competitors in this area. During 2011-12 Indian Railways carried 8224 million passengers (about 2.25 crore passenger/day) and thus the Air passenger traffic is about 1.97% of the Rail passenger traffic. On the other hand, Rail carries about 15% of the total passenger traffic (the balance 85% being carried by Road) and so the Air passenger traffic will be about 0.29% of the total passenger traffic in the country.

4.6 Urban Transport

4.6.1 India's urban population increased from 286 million in 2001 to 377 million in 2011, accounting for about 32 per cent of total population. However, the growth in urban infrastructure services has not matched the rate of urbanization.

4.6.2 The government has brought in various reforms and policy initiatives to streamline the urban infrastructure. The biggest reform initiative was the launch of the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) under which the Union Government incentivises urban local bodies (ULBs) to undertake mandatory reforms like full cost recovery, accrual-based accounting, e-governance, etc., in return for grants to improve service levels in a financially sustainable manner. The JNNURM covers water supply and sanitation, sewerage and solid waste management, **urban transport,** etc.

4.6.3 For the urban transport, the National Urban Transport Policy was introduced in April 2006 by the Planning Commission with the objective of providing a unified policy framework. The policy lays emphasis on the need to increase the efficiency of the use of road space by giving preference to public transport, by using traffic management instruments and by restraining the growth of private vehicular traffic. **It also proposes the integration of land use and transport planning, and the setting up of urban metropolitan transport authorities as a means to integrate the sector.**

4.6.4 The exponential growth of urban transport, growing visible traffic congestions, and the need to reduce green house gas emissions necessitate coordinated and integrated planning, and massive system inputs. The systems should support/encourage shift from (a) Personalised vehicles to Public transport and (b) from Road to Rail modes. In this regard mention could be made of the following :

(i) **Bus Rapid Transit (BRT) System** : Of all the mass transport modes, BRT offers the highest return on investment and the shortest implementation time. **It provides equal road space to all types of commuters and offers safely to cyclists and pedestrians.**

(ii) **Rail Transport** : Rail based urban transport is more reliable, comfortable and safer than road based systems and reduces journey time by 50-75 per cent. **One train carries the same amount of traffic as nine bus lanes or 33 private car lanes.** Further, it does not occupy any road space, if underground, and only about 2 m width of the road, if elevated.

4.6.5 A typical Bus Rapid Transit (BRT) system, with single lane each way, may provide a carrying capacity of 10,000 passengers per peak hour per direction (pphpd). On the other hand a Monorail or Elevated Light Rail Transit (ELRT) system will be able to cater to 10,000 to 30,000 pphpd and a Heavy Metro Rail System 70,000 pphpd or more.

4.6.6 The Rail systems mostly use steel rail to steel wheel contact (some systems also use rubber tyred wheels for lesser noise) which provides a system with low friction and so a lower fuel consumption. Further, use of electric power makes such systems more environment friendly because of better energy efficiency (in generation and in the use of electric power) as also in avoiding polluting emissions in busy city areas where such rail systems operate. In cities having comparatively lesser traffic resurgence of 'Trams' is now seen on these very considerations.

4.6.7 While setting up of **urban metropolitan transport authorities has been/is being done** there is also a need to give a boost to more environment-friendly rail mode which, inter alia, can also carry much larger volumes of traffic faster and with greater safety. Growth of metro rail systems in our country has been extremely slow but the success of Delhi Metro Rail Project clearly points towards the need for having many more such systems especially in the major cities. **About 40% support by the Government of India (GOI) by way of viability gap cum accelerated development cum environment mitigation fund for metro rail projects and establishment of a "Centralised Metro Rail Transport Authority" are suggested.**

4.6.8 National Capital Region (NCR) is an unique example of inter-state regional development planning for a region with National Capital at its core. The NCR Planning Board has prepared a Regional Plan with the perspective for year 2021 for promoting growth and balanced development of the National Capital Region. As a part of this effort a **Regional Rapid Transit System (RRTS)** is also being developed and the Integrated Transport Plan 2032 has identified eight RRTS corridors for the purpose :

1. Delhi-Gurgaon-Rewari-Alwar (DGRA)
2. Delhi-Ghaziabad-Meerut
3. Delhi-Sonepat-Panipat
4. Delhi-Faridabad-Ballabhgarh-Palwal
5. Delhi-Bahadurgarh-Rohtak
6. Delhi-Shahadara-Baraut
7. Ghaziabad-Khurja
8. Ghaziabad-Hapur

4.6.9 The Delhi Integrated Multi Modal Transit Systems (DIMTS) have prepared a Detailed Project Report (DPR) for the Delhi-Gurgaon-Rewari-Alwar (DGRA) corridor and the salient features of DGRA-RRTS System are mentioned below to give a feel of what is in store for future. This is definitely a laudable effort and will greatly contain congestion/pollution.

- Total length of DGRA-RRTS is 180 km (39 km Underground + 141 km Elevated) – Fully grade separated – Generally follows the road alignment – Uses minimum space (land).
- It will have 19 Stations (8 Underground + 11 Elevated)
- Track Gauge will be Broad Gauge (BG) i.e. 1676 km.
- Trains will operate at a maximum of 160 kmph (100 kmph in Underground Section) with an average speed of 90 kmph.
- Distance of 180 km will be covered in 2 hours.

4.7 How to Measure Traffic Congestion : A Thumb Rule

4.7.1 While sophisticated models and other systems like Long Range Decision Support Systems(LRDSS) are used for the purpose, the Thumb Rule described below gives a better physical feel about the extent of traffic congestion.

4.7.2 If we consider two points 30 km away (say between Gurgaon and Delhi) on a road stretch where maximum permissible speed is 60 kmph, the bare running time will be 30 minutes. To this, we can add another 10 minutes (one third of the bare running time) to take into account the road signals, bad road patches, zebra crossings, speed breakers, etc., and the normal running time will work out to 40 minutes giving an average point to point speed of 45 kmph. **If the average speed is 75% of the maximum permissible speed there is no congestion on the road**. However, if due to traffic congestion, unscheduled delays start occurring which finally reach a value of around 50% of the normal running time (i.e. 20 minutes in this case), the total time required to reach the destination will be 60 minutes giving an average point to point speed of 30 kmph. **The road is congested if the average speed is half of the maximum permissible speed.**

4.7.3 If the unscheduled delays further exceed the normal running time (say 50 minutes of delay against a normal running time of 40 minutes) then the total time required to reach the destination will be 90 minutes giving an average point to point speed of 20 Kmph. **The road is having very severe congestion if the average speed is one third of the maximum permissible speed.** Actual position on several roads, especially during peak periods, is even worse with speeds falling to 5-10 kmph resulting in traffic jams with consequent time loss, **fuel loss (environmental pollution)** and gross uncertainties in journey plans.

4.7.4 **On the same pattern, if we examine the movements on the Indian Railways (IR), the average Goods Train speeds are about 25 kmph while the maximum permissible Goods Train speed is 75 kmph (some Goods Trains also run at 100 kmph) indicating very severe congestion to traffic movements.** Even for Mail/Express Passenger Trains having a maximum permissible speed of 110 kmph, there are very few trains which average more than 55 kmph and fall in the category of Super Fast Trains. **Here too traffic congestion is clearly indicated.**

4.8 World Transport – Changing Relativities between Road and Rail (1999)

4.8.1 With the relentless growth of the world economy it is quite probable that **in next 100 years the total transport would be about four times today's levels according to the studies made at the Balance Research Institute, Melbourne**. These estimates appear rather conservative and traffic growth may be faster especially for economies like India and China. However, future is difficult to predict on such a long time horizon; and changes in the patterns of production and consumption, more intense use of IT, improved logistics, etc., may contain the growth of transport.

4.8.2 The Study further mentions that the growth of road traffic by four times will not be a practical reality with congestions already visible with the existing levels of traffic, cost of road service growing faster than the cost of rail especially because of sharply rising fuel costs, concerns for environment (road being much more polluting than rail), etc. The governments with the support of industry will have to find ways to keep highways available for tasks that rail cannot perform. The governments will be led to reinforce this with deliberate policies leading to more and better rail services. For the transport and logistics industry, this will mean opportunities to offer better services at lower costs than they otherwise would, with continuation of present policies.

4.8.3 **The Balance Research Institute Study highlights the following** :

- Governments will always need to subsidise transport in some way, but the investments they make will have to support the mode which uses less resources. If this is the policy direction, highways will increase greatly in quality and safety but not so much in capacity. The rail will absorb the transport needs with innovations in technology and management, much of which will be undertaken by the private sector responding to signals from governments.

- **Including all known costs and revenues perhaps rail freight is 80% commercial at present, whereas road freight is perhaps 50%. If they both had to pay 100% of the economical and societal costs then the modal split would change towards rail.**

- With rising energy costs rail will have an advantage vis-a-vis road as it consumes less fuel per unit of task. Further, rail can use electrical energy also, unlike road vehicles which basically use petroleum fuels.

- In the medium to long distance corridors, rail may run freight services at 100/160 kmph and passenger services upto 200 kmph (excluding high speed passenger trains).

- For rail traffic from a major terminal, port or depot an automated central transfer or sorting facility for containers would eventually be developed in each metropolis. Trains would unload their containers automatically (self strip) on to a conveyor system. Each container would then be directed automatically to its destined train which would then self-load.

- In metropolitan areas where several freight stations have been closed for many years, changes will even be greater. If container technology had come to local transport a couple of decades earlier, the freight service would have become more efficient and some of these stations would have remained.
- A new kind of intermodal service may evolve wherein direct freight services will feed small intermodal stations which will have short road legs typically upto five km.
- **Economically sound ways will be found for rail to play a vital role in limiting road traffic growth. To achieve a 'four times traffic growth' the rail will have to grow not four times, but to eight, ten or twenty times its present level of passenger and freight traffic.**

4.9 Planning Commission endorses Modal Shift towards Rail

Modal shift in favour of rail will not only reduce emissions (due to reduced diesel consumption) but will also save considerable amount of foreign exchange (about 80% of crude is imported) and has also been endorsed by the Planning Commission as detailed below :

(a) Integrated Transport Policy - Planning Commission - Oct 2001

- Para 11.9

"…, the Railways may attempt to increase its share in total traffic from the present level of 40% to 50% by 2010, leading to a saving in diesel, which at the present level of traffic would amount to around Rs. 2500 crore of foreign exchange per annum. …"

(b) Integrated Energy Policy – Planning Commission – Aug. 2006

(i) Para 4.3.1(c)

"… . The share of railways in total tonne kilometer (t-km) of goods traffic has come down from 70% in 1970-71 to 39% in 2003-04. If the railway carried 70% of the goods traffic today, it would carry 300 Bt-km of additional traffic. Assuming that all of this goods traffic would have been carried by Railways using diesel, the diesel saved in the year 2003-04 would have been around 5 Mt out of a total consumption of 40 Mt. …"

(ii) Chapter VI – page 86

"… . Carrying 3000 billion tonne kilometers (Bt-km) of freight (half of projected freight traffic in 2031) by rail instead of trucks can save approximately 50 Mt of diesel per year. …"

4.10 Passenger Fares & Freight Rates on the Indian Railways – Tariff Ratio

4.10.1 Tariff ratio is defined as the ratio between the average passenger fare per km to the average freight rate per tonne km. The financially desirable value for the Tariff ratio is around 1.0 while the Chinese Railways have adopted a value which is greater than 1.0. The values of Tariff ratio for some selected countries are given below :

Korea	1.4
France	1.3
China	1.2
Austria	1.1
Indonesia	0.9
Greece	0.4
India	0.3
Bangladesh	0.2

Source : White Paper on Indian Railways, December, 2009.

4.10.2 On the Indian Railways (IR) passenger fares were deliberately kept low (Agarwal – 2004) as will be evident from the following (Court of Directors – East India Company – 1845) :

"According to the experience of this country (Great Britain) by far the largest returns are procured from passengers; the least from the traffic of goods. The condition of India is in this respect directly the reverse of that of England. Instead of a dense and wealthy population, the people of India are poor and in many parts thinly scattered over extensive tracts of the country. But, on the other hand, India abounds in valuable produce of nature which are in a great measure deprived of a profitable market by want of cheap and expeditious means of transport. It may, therefore, be assured that remuneration for rail-roads in India, must for the present, be drawn chiefly from the conveyance of merchandise, and not from passengers."

4.10.3 In the year 1950-51 the value of Tariff Ratio on the IR was around 0.5 which has since come down to 0.3. The IR's passenger earnings for the year 2008-09 were about Rs. 21,000 crore and the loss on passenger segment about Rs. 14,000 crore. (IR – White Paper – 2009). If the Tariff Ratio was maintained at 0.5 then at least this loss in passenger segment would have been wiped out making the passenger segment break even

4.10.4 For a system already having a policy of keeping passenger fares low (Tariff ratio as 0.5 earlier) this further lowering of passenger fares (Tariff ratio 0.3 at present) is resulting in a loss of Rs. 14 thousand crore in the passenger segment. This is partly responsible for the higher freight rates on the IR (see Table No.4) as also for the paucity of adequate funds for maintenance, modernization, and growth. The problem got further compounded due to the non-availability of level playing field to Rail vis-à-vis Road, the two primary transport modes carrying about 91% of the traffic. **The solution lies in having a Policy which ensures a level playing field to Rail vis-à-vis Road; and the Rail correcting its Tariff ratio to 0.5 (from the existing value of 0.3) so that the Passenger traffic does not remain a loss-making segment.**

Table 4 : Average Freight Revenue : World Scenario

Country	**Average Freight Revenue per ton-km**
Germany	751
India	395
South Africa	281
France	218
Japan	207
China	185
Russia	122
USA	100

Source : White Paper on Indian Railways, December, 2009 / World Bank.

4.11 Indian Railways : An Efficient System but with Severe Capacity Constraints

4.11.1 Indian Railways (IR) is an efficient organization and has well-tuned systems. The "Input vs Output" (Table No.5) indices indicate that with very little inputs (e.g., only 21% increase in Route Kms since 1950-51) about fourteen times more traffic is being carried currently. The "Select Data – Indian Railways" (Table No.6) shows how in the last eighteen years 'Wagon Turnround' and 'Number of Accidents' have reduced. However, lack of timely investments in maintenance and capacity building and heavy burden of Social Service Obligations have adversely affected the system.

Table 5 : Input vs Output : Indian Railways

	1950-1951	2011-2012
Input Indices		
• Route Kms	100	121
• Running Track Kms	100	151
• Wagon capacity	100	311
• Coaches - Passengers	100	356
Output Indices		
• Freight Traffic – NT Kms (Rev. + Non Rev.)	100	1516
• Passenger Traffic – Pass Kms (Non-Sub)	100	1505

Source : Indian Railways Year Book 2011-12.

Table 6 : Select Data – Indian Railways

Year	Track Renewals (Kms)	Number of Accidents	Wagon Turnround (days)	Operating Ratio (Percent)
1994-95	2,763	501	9.5	82.6
1995-96	2,893	398	9.1	82.5
1996-97	2,795	381	8.5	86.2
1997-98	2,950	396	8.1	90.9
1998-99	2,967	397	8.2	93.3
1999-00	3,006	463	7.7	93.3
2000-01	3,250	473	7.5	98.3
2001-02	3,620	415	7.2	96.0
2002-03	4,776	351	7.0	92.3
2003-04	4,986	325	6.7	92.1
2004-05	5,566	234	6.4	91.0
2005-06	4,725	234	6.1	83.8
2006-07	4,686	195	5.5	78.7
2007-08	4,002	194	5.23	75.9
2008-09	3,841	177	5.19	90.5
2009-10	3,840	165	4.98	95.3
2010-11	3,465	139	4.97	94.6
2011-12	3,300	131	5.08	94.8

Source : Indian Railways Year Book 2011-12 & Indian Railways Annual Report and Account 2011-12.

4.11.2 The argument, that capacity constraints and adequate inputs are not the IR's problem but it is basically the inefficient operation and lack of focus, does not cut much ice. Following may elucidate the point further :

- In early 1980s, problem of lack of capacity was solved in an adhoc manner by permitting running of only "rake loads" of traffic thereby making movements faster but in the process loosing high rated piecemeal traffic. Planned inputs for 'capacity generation' and 'containerisation' in time could have avoided such a situation.

- Asset rehabilitation arrears had to be wiped out through a Special Railway Safety Fund of Rs. 17,000 crore (year 2001-02 onwards) indicating inadequate investments in maintenance and upkeep of the system.

- Recently also, the capacity constraints had largely been overcome by an adhoc increase in axle loads from 20.3 tonne to 22.9 tonne. This can be broadly translated into an annual traffic increase of 90 Mt and a corresponding extra yearly income of Rs. 6,000 cr. (Sudhir Kumar & Shagun Mehrotra – 2009).

4.11.3 There is severe congestion on the Golden Quadrilateral (connecting four metro cities of Delhi, Kolkata, Chennai and Mumbai) and its two diagonals which constitute about 16% of Route Kms but carry more than 55% of the IR's traffic. Large number of sections falling on these routes are having line capacity utilization exceeding 100% (see Table No.7).

Table 7 : Line Capacity Utilisation on Golden Quadrilateral and its two Diagonals (2007-08)

Routes	**No. of Sections**	**Sections having Line Capacity Utilisation**			**Critical Sections$ (%)**
		More than 80%	More than 100%	More than 120%	
Delhi-Howrah	41	11	12	17	**70%**
Mumbai-Howrah	42	10	17	13	**71%**
Delhi-Mumbai	28	5	5	15	**71%**
Delhi-Chennai via Jhansi, Nagpur-Ballarshah	24	2	5	16	**88%**
Howrah-Chennai	17	5	6	5	**65%**
Mumbai-Chennai	25	6	5	10	**60%**
Total	**177**	**39**	**50**	**76**	**71%**

Source : White Paper on Indian Railways – Dec.2009.

Notes :
1. Sections having line capacity utilization of 100% or more have been assumed to be critical sections.
2. More than 55% of IR's traffic moves on the Golden Quadrilateral and its two diagonals.
3. About two-third of the sections are showing a line capacity utilisation exceeding 100%.
4. In next 7-10 years traffic will double. Immediate action for capacity enhancement is called for.

4.11.4 Capacity of a transport system can basically be seen in two ways. Firstly, whether the required levels of traffic can be carried by it, and secondly, whether the system provides for a free flow to traffic wherein unscheduled delays do not occur. Unscheduled delays to movements deter the users as the movements not only take more time but there is also a large amount of uncertainty involved. Studies carried out on sections like Vadodara-Surat, a busy double line section, using the Long Range Decision Support System (LRDSS), have indicated that beyond 61 trains in each direction, the unscheduled delays exceed 50% of the bare running time. **On the IR many mainline sections are congested with some of them running 90-100 trains in each direction.**

4.12 Need for Accelerated Development of Rail Capacity

4.12.1 For efficient and effective performance of a transport system, on a sustainable basis, following three areas need proper attention and inputs :

(i) Maintenance of existing assets – Fixed, Moving, and Others.

(ii) Expansion of the Network – As for example, New lines and additional parallel lines (Doubling; Three Lines; Quadrupling) on a Railway System, along with necessary support facilities.

(iii) Modernisation.

On the Indian Railways (IR), all the three areas have suffered primarily due to paucity of resources and policy of advantage Road vis-à-vis Rail. However, extreme concerns for Rail safety, voiced by media and public, have resulted in investments in Maintenance and Modernisation to a large extent but the Expansion of Network had lagged far behind.

4.12.2 Planners have to consciously realize that booming economy will necessitate doubling of traffic in next 7 to 10 years and both the Rail and the Road, which carry about 91% of the traffic, will have to be given suitable inputs for capacity augmentation. Both the modes will have to complement/supplement each other to take on this galloping transport demand.

4.12.3 The congestions on roads already visible with the existing levels of traffic, cost of road service growing faster than the cost of rail especially because of sharply rising fuel costs, concerns for environment (road being much more polluting than rail – see also Box No.1) etc., will necessitate that rail not only carries the traffic on the existing pattern but improves it further. **This clearly highlights the need for accelerated capacity generation on the IR both on the existing routes (Doubling/Third Line/Quadrupling) and in the new growth areas (New Line Construction).**

4.12.4 Financing of various Projects/Schemes through Public Private Partnership (PPP) or other means could be considered for the IR. However, basic features of Rail/Road infrastructures needing Government support still remain and the Government of India (GOI) will need to support the accelerated pace of building of fixed infrastructure on the IR on the same pattern as is being done for Roads. Once such inputs are given to improve the capacity of the fixed infrastructure, the IR should be able to garner adequate resources for the ‘moving assets’ and ‘other facilities’.

Box No. 1

Savings in Fuel : Rail vs Road

- Planning Commission's Integrated Energy Policy (August 2006) mentions that carriage of 3000 BTKM of freight traffic by Rail instead of by Trucks (in the year 2030) will save 50 million tonne of diesel oil. **Thus saving in the cost of diesel oil for each net ton-km (NTKM) of freight carried by rail vis-à-vis road works out to Rs. 0.60** (one ton of diesel = 1.2 kilolitres; cost of diesel Rs. 30 per litre based on 2006 prices)..

- A **Study by Deutsche Bank (7th April 2006)** indicates that cost of carriage of freight by Road per NTKM is Rs. 1.10 out of which 58% is fuel cost. On the other hand the cost of carriage by Rail is Rs. 0.50 per NTKM out of which fuel cost is 14%. This translates into the following :

  (a) Fuel cost Per NTKM-Road = Rs. 0.58x1.1 = Rs. 0.638
  (b) Fuel cost Per NTKM-Rail = Rs. 0.14x0.5 = Rs. 0.070
  (c) **Difference in Fuel costs Per NTKM = Rs. 0.568**

  This also brings out that the road transport consumes nine times more fuel in carrying one NTKM of freight vis-à-vis Rail.

- This cost data (fuel cost per NTKM for Road Rs. 0.638; cost of carriage by Rail per NTKM Rs. 0.50) further indicates **that carriage of trucks on rail wagons (similar to RO-RO service in operation on the Konkan Railway)** will not only be a financially viable option for the truckers but will also benefit the national economy by reducing the fuel consumption. **However, this can be a practical reality only when adequate rail capacity to allow free flow of traffic exists, to ensure fast movements in guaranteed time, by the Railways.**

4.13 Roll-on Roll-off (RoRo) Service on the Konkan Railway

4.13.1 RoRo service operates on the Konkan Railway, where the road trucks are carried on rail wagons, rail freight more or less equals the fuel cost which the truck would have otherwise incurred in its road journey, and the time of travel by rail is roughly half of what it would have been by road. It is a win-win situation for the rail, truckers, and the environment. However, such a service has not picked up on other IR sections primarily because of capacity and congestion factors. Once Dedicated Freight Corridors (DFCs) are constructed, many more such services should be a practical reality.

4.13.2 The cost data given in Box No.1 broadly indicates that while fuel cost for each net ton-km of freight carried by Road truck is Rs. 0.638, the cost of carriage by Rail is Rs. 0.50 (Based on a Study by Deutsche Bank – April 2006). If the Road truck is carried on Rail (Ro-Ro Service) it has not to spend extra money (Fuel cost = Rail Freight), wear and tear of truck is saved, door to door delivery is still possible, several road barriers enroute are avoided, etc. However, the Ro-Ro Scheme will be attractive only when overall journey time (Loading + Rail Journey + Unloading) is also less than the time of travel by road. With the completion of the Dedicated Freight Corridor (DFC) project, free flow of freight traffic will become a practical reality and Ro-Ro trains could be planned according to fixed time schedules.

4.13.3 The Ro-Ro service will have the following advantages :

(i) Win-Win situation for the Truckers and the Rail.

(ii) Saving in fuel hence environment friendly. On Swiss Railway System, road trucks are carried on rail wagons to reduce environmental pollution.

(iii) Will provide speed and reliability of Rail and flexibility of Road (at loading and unloading legs) for the freight traffic.

(iv) Will reduce congestion on existing roads.

4.14 Dedicated Freight Corridors on the Indian Railways

4.14.1 The Golden Quadrilateral (connecting four metro cities of Delhi, Kolkata, Chennai and Mumbai) and its two diagonals, which constitutes about 16% of Route Kms or 25% of Running Track Kms carries more than 55% of the traffic of the Indian Railways (IR).

4.14.2 Dedicated Freight Corridors (DFCs) are planned for the entire Golden Quadrilateral and its two diagonals by laying two new parallel double lines exclusively for freight traffic thereby making the existing system a passenger corridor. The approximate length of six DFCs (Four sides of the quadrilateral plus two diagonals) will be 11,500 km of double line (23,000 km of rail track). The DFCs will mostly run parallel to the existing system but in busy areas and yards detours will be necessary. Currently, work on Eastern and Western DFCs is already in progress.

4.14.3 Existing network is mostly a double line section (except for some stretches where 3rd or 4th lines exist) and the construction of DFCs will virtually mean quadrupling (Two Passenger lines + Two Freight lines) of the sections. **With four lines, increasing traffic, and improving average speeds of trains (due to enhanced mobility) the operation of existing level crossing (surface crossings of road and rail) will not be practically possible and so grade separation becomes an essential prerequisite, needing provision of Road Over Bridges (ROBs) or Road Under Bridges (RUBs) in lieu of existing level crossings.**

4.14.4 The existing axle load on the IR system is 20.3t which has recently been enhanced on some selected routes to 22.9t. The DFCs are being designed to take axle loads of 32.5t and for the present 25.0 t axle load wagons are proposed to be run for which Feeder Routes (about 4,500 km; axle load 22.9t) are also being upgraded to enable carriage of 25.0t axle load wagons.

4.14.5 Container traffic will be growing faster than the normal traffic. Accordingly, running of double stack container trains is contemplated on the DFCs and overhead clearances of structures like Road Over Bridges (ROBs), Foot Over Bridges (FOBs), Tunnels etc. are being planed accordingly, also keeping in mind the aspects of electrification of the lines now or in future. For heavier traffic, electrification of routes proves to be a more economical proposition in addition to an overall reduction in the consumption of energy vis-à-vis use of fossil fuels.

4.14.6 Construction of DFCs will greatly enhance capacity and mobility, mainly due to the following :

(a) Slow moving goods trains (75 kmph/100 kmph) will not come in the way of passenger trains (100 kmph/140kmph) nor the slow moving freight trains will have to wait for giving precedence to faster moving passenger trains. This will reduce congestion and improve average speeds of both the passenger and the freight trains. The sectional capacity will also markedly improve.

(b) Higher axle load wagons plying on DFCs will carry more load per train.

(c) Existing corridors (passenger corridors) will be relieved of heavier freight trains thus giving relief in maintenance especially to old existing bridges.

(d) Since level crossings will not be existing (complete grade separation), the existing passenger corridors could run normal trains at 160 kmph speeds as also tilt body passenger trains upto speeds of 200 kmph (similar to Swedish X2000) by suitably fencing the existing tracks and providing cab signalling. This will also enhance safety of travel.

(e) The Rajdhanis' which currently run at a maximum speed of 130/140 kmph and take about 16 hours for journeys between New Delhi and Mumbai and about 28 hours between New Delhi and Chennai may be able to cover these distances in about 11 and 18 hours respectively.

4.14.7 Completion of DFC project, in a period of about ten years is essential to meet the growing traffic demands (traffic is likely to double in next 7-10 years). However, it will be a difficult and challenging task involving construction of about 2300 km of rail lines every year.

4.14.8 Completion of all the six DFC lines (Quadrilateral and two diagonals) in about ten years will not be possible unless adequate funds are assured. In this regard, **Government of India should consider**

providing 40% of the Project Cost as a Grant in the form of Viability Gap cum Accelerated Development cum Environment Mitigation Fund.

4.14.9 It will be desirable to execute the DFC Project as a National Project in view of its importance to the country's economy. A special purpose vehicle (SPV) viz., Dedicated Freight Corridor Corporation of India Limited (DFCCIL) of the Indian Railways is already in place and work on the Eastern and Western DFC corridors is currently in progress.

4.15 Construction of New Railway Lines

4.15.1 New Railway Lines are being constructed at a very slow pace, primarily because of fund constraints and their financial non viability. Since 1950-51, only 21% addition has been done to the Route Kms which indicates that the pace of New Line construction has been about one third of what it was in the 100 year period prior to Independence (1947).

4.15.2 New lines open the system to traffic from new markets and are also needed to develop rural areas including the vulnerable 'border' areas. **In addition to generation of employment during construction and subsequently for the maintenance and operation, such lines generate considerable amount of employment in the related non-railway sectors.** Environmental consideration also necessitate improved transport share for Rail clearly pointing towards the need for expeditious growth of the Rail network.

4.15.3 Some may argue that such lines are not necessary for the Indian Railways (IR) but more than 11,000 km New Line projects already sanctioned (IR Vision 2020 – Dec. 2009) and waiting to be executed tell a different story. The progress of New Line construction in the pre-Independence era was more than 500 km/yr which reduced to about one third (about 180 km/yr.) after Independence (1947). The five years (2004-05 to 2008-09) have seen a construction rate of about 230 km/yr. (IR White Paper - 2009). The need for a major thrust towards this vital area of Network Expansion has been recognized and the IR's Vision 2020 document suggests a growth rate of 2500 km/yr for the New Lines which has been scaled down to 1000 km/yr in the Rail Budget (24th Feb. 2010). The target of 1000 km/yr appears more pragmatic but even for it funds will be a major constraint. **It is suggested that construction of New Railway Lines should be considered in the same light as the Pradhan Mantri Gram Sadak Yojna (PMGSY) and the Government of India (GOI) should consider a support for this vital need in the form of viability gap cum accelerated development cum environment mitigation fund.** Other inputs like the rolling stock, operation and maintenance costs, and the allied losses for such lines could be borne by the IR.

4.16 High Speed Trains on Existing Rail Tracks : Common Man's High Speed Trains

4.16.1 According to UIC (International Union of Railways) an existing upgraded line equipped to carry speeds of 200 kmph is termed as a High Speed Line. On the other hand, for specially built new lines the speeds have to 250 kmph or more for being qualified as High Speed Lines.

4.16.2 Today, High Speed trains are already in operation in 14 countries (8 countries in Europe plus Japan, China, USA, South Korea, Taiwan and Turkey) and as on 1st July 2012 there were 17,574 km of High Speed Rail (HSR) tracks in operation. In addition, construction of 9289 km and planning for 15,476 km HSR tracks were in progress in various countries (Ref.: Singh, K. P. – 2013).

4.16.3 On the Indian Railways (IR) currently maximum train speeds are 130-140 kmph. Train speeds above 140-150 kmph need grade separation (No level crossings), fencing of tracks (To avoid trespassers) and Cab-signaling (Driver to get the aspect of Signal in the locomotive itself) coupled with Automatic braking should the 'Signal' be at danger (Red aspect of Signal). These features are essential from considerations of passenger safety. At higher speeds even a collision with a cattle can derail the train. Cab-signalling coupled with Automatic braking precludes any possibility of overshooting or passing the Signal at danger by the train Driver.

4.16.4 Indian Railways are planning Dedicated Freight Corridors (DFCs) on the entire Golden Quadrilateral (connecting four metro cities of Delhi, Kolkata, Chennai and Mumbai) and its two Diagonals and currently work on Eastern and Western DFCs is already in progress. For the purpose two new parallel lines (Double lines) are being constructed exclusively for freight traffic thereby making the existing system a passenger corridor. All level crossings are also being eliminated as an essential pre-requisite. (Ref. Para 4.14.3)

4.16.5 Several Committees have emphasized the need for adopting measures like Cab-signalling and Automatic braking for enhancing passenger safety in the past. There exists a good opportunity to take advantage of DFC project and usher in HSR travel (200 kmph) on the IR. This will also enhance safety of travel for all other trains which may be running at lower speeds (say 160 kmph). The High Speed Trains (200 kmph) can adopt 'tilt body' coaches to negotiate existing curves.

4.16.6 The HSR project can be suitably integrated with the DFC project on the Indian Railways. Inputs required will be minimal as the level crossings have already been eliminated. What will be needed is suitable fencing of tracks, provision of Cab-signalling for some selected trains and better inputs to track maintenance in addition to Special Coaches. **In this manner a HSR (200 kmph on existing lines) network on the entire Golden Quadrilateral and its two diagonals (About 11,500 km double line) can be a practical reality in a short period of time. This will improve the speed and safety of passenger travel with only small inputs and may even capture some of the Air passenger traffic. These can rightly be called Common Man's High Speed Trains in view of lower fares (vis-à-vis conventional H.S. Trains) due to lower investment and maintenance costs. A suitable HSR Blue Print has to be made and executed in a phased manner with speed.**

4.17 Financing of Projects

4.17.1 Methods of funding the Projects are closely interlinked with the philosophy and ideology of development (see Box No.2).

4.17.2 Indian Railways in the Pre-independence era (1845-1947) experimented with several financing methods as briefly outlined in Box No.3 and with aggregate rate of construction of new lines about 3 times faster vis-à-vis that after the Independence, one can argue that these methods could provide much better financing towards the development of IR network.

4.17.3 Poulose (2009) while discussing the various methods of project funding like Build Operate Transfer (BOT), Public Private Partnership (PPP), Foreign Direct Investment (FDI), Foreign Aid, Loans, etc. observes that to meet the massive resource requirements for bridging the infrastructure investment gaps, and the inability of any sector by itself to raise the resources, there is no escape from joint efforts by all the sectors. In this background, no method of funding can be rejected out of hand. All the methods would need to be adopted, by the Public and Private sectors together, for implementing projects, for the benefit of society.

4.17.4 Historically, governments in developing regions have themselves funded about 70 percent of infrastructure needs, with 22 percent funded by the private sector and 8 percent by official development assistance (Ref.: Poulose - 2009).

4.17.5 Funding of transport infrastructure projects has to keep in mind the following features :

(a) Governments will always need to subsidise transport in some way, the extent and need of support varying with the mode type and the location. For example, rural roads in our country are being executed through government funds and even the national highway projects are being provided **viability gap (VG) funding** to the extent of 40% of the project cost.

(b) Indian economy which was earlier growing at a slow pace is now growing at a much faster rate. With a GDP growth of about 9%, the demand for transport is likely to grow by about 11% and the traffic is very likely to double in next 7-10 years. Adequate transport infrastructure is a necessary pre-requisite to sustain this growth rate. **Accelerated development of transport infrastructure becomes inescapable, needing inputs in the form of accelerated development funds.**

(c) Further, the current environmental concerns the world over need that emissions be minimized in the interest of our very survival and so transport modes which are environment friendly have to be preferred. The economic and social costs have to be considered to decide upon the most suitable transport mode. **For super-accelerated growth of such transport modes, additional inputs by way of environment mitigation funds have to be provided**.

4.17.6 Fund generation for accelerated/super-accelerated growth of transport sector will need special and directed efforts on all fronts (Public Private People Partnership) and may, inter alia, include divestment of transport and allied PSUs, cess on diesel/petrol, cess on passengers/freight, service tax on related transport services, government support, FDI, Foreign Aid, loans, etc., in addition to government grants.

Box No. 2

Funding Methods vs Philosophy/Ideology of Development
(Ref. : Poulose - 2009)

Funding methods have closely followed the changes that have taken place in the philosophy and ideology of development from time to time. And the organisation structure and funding arrangements have also varied in tandem.

From laissez-faire in the 18^{th} century with minimal direct role of the State in economic activities, the philosophy shifted to greater State intervention late in the 19^{th} and 20^{th} centuries. The State intervention was viewed as a major contributor not only for economic development but also for the social and political stability.

In the early 1940s and 1950s, the accepted wisdom in economic policy asserted the need to put the State in command. This emerged out of the experience of 'market failure' in the thirties and of the war and reconstruction policies of the forties and fifties.

India opted for central planning and dominance of the public sector and this philosophy was embodied in the Industrial Policy Resolution of 1956. The massive investments made in this sector, over more than four decades, enabled India to attain a comfortably high rank in industrialization among the developing countries.

Even though from early days itself, disillusionment with public sector had started but by the 1980s, the excesses of too much government intervention were evident, and leaders like Ronald Reagan and Margaret Thatcher caused the pendulum to swing back to free markets.

Perennial scarcity of resources, especially for the infrastructure sectors, made it necessary for the State to step in, and this led to ownership, management and control of such undertakings being vested in the State. Recognizing that governments will continue to be a major source of funds for infrastructure, *The World Development Report 1994* emphasised how critical it was to improve the effectiveness of public sector enterprises through commercialization of their operations.

The Report of the Nobel Laureate Michael Spence, who headed Spence Commission on Growth and Development set up by the World Bank, issued at the end of May 2008, adopts an approach that recognizes the limits of what we know, emphasizes pragmatism and gradualism, and encourages governments to be experimental. It reflects a broader intellectual shift within the development profession, a shift that encompass not just growth strategies but also health, education and other social policies.

Box No. 3

Financing of Railway Projects in the Pre-Independence Era
(1845-1947) (Ref.: Agarwal - 2004)

(a) Guaranteed Returns

In this system, the Government of India guaranteed to provide the owner (a Joint Stock Company) a minimum rate of return on the capital deployed. The rate of interest to be guaranteed was generally in the range of 4% to 5%; period of lease was 25 or 50 years or 99 years; the land was given free; the Government prescribed standards for construction and supervised the working and had the flexibility to purchase the line after 25 or 50 years. In case of surplus profits, half of them were to go to the Government and the other half to the share holders. In this system, the tendency on the part of the companies was to inflate the cost of construction as it provided more interest payments. An official report submitted to the House of Commons in 1872-73 indicated as under :

"There are now open in India 5872 miles of railway which should cost about (pounds) 97 million, giving an average expenditure of 16,536 (pounds) per mile. The exorbitance of the expenditure becomes evident when it is realised that in Australia, the cost per mile for railway construction was 12,000 (pounds) and in Canada only 8,500 (Pounds)."

(b) Provision of 'subsidy'

In this case, payments were made to secure the construction of railways in India on comparatively more favourable terms and instead of guaranteed return, a subsidy per kilometer was to be given. The system however failed to attract capital and was given up.

(c) Government Funding

In view of high cost of construction obtained in the system of 'guaranteed returns' and failure of the 'subsidy' approach, the system of Government funding was suggested from 1869 onwards. This funding was provided by classifying the works into three categories as under :

- Productive works

  These were the works which could give adequate returns after meeting of liabilities and so could be financed with borrowed money.

- Protective works

  These were not remunerative but provided a safeguard against future outlay in the relief of population and were to be financed with revenue surplus and not with borrowed money.

- Provincial works

  These were to be undertaken as per the requirements and the Local Governments were to guarantee interest on the capital raised.

  In this way from 1880 onwards, the construction of Government lines as also the Company lines started side by side.

4.18 Need for Three Policy Directions

(1) Level Playing Field to Rail vis-à-vis Road

In our country 91% of the traffic is carried by Rail (31%) and Road (60%). For carriage of freight traffic, Rail is nine times fuel efficient vis-à-vis road but is loosing its market share (from 89% in 1950-51 to 30% as of now) resulting in enhanced pollution for the transport sector as a whole. Earlier efforts to contain this decline in Rail's market share have not succeeded but the environmental concerns now necessitate urgent action to rectify the situation. As has been discussed earlier, the main reason for the Rail to loose vis-à-vis Road is that 'social costs' are not suitably factored in. While authentic data in this regard is not available for our conditions, a recourse to other international studies clearly highlights that its impact is substantial. Table No. 3 gives data from a European Study with regard to social costs. The findings of the Balance Research Institute, Melbourne (1999) mentioned in Para 5.8.3 earlier (reproduced below) amply testify this fact :

"Including all known costs and revenues perhaps rail freight is 80% commercial at present, whereas road freight is perhaps 50%. If they both had to pay 100% of the economical and societal costs then the modal split would change towards rail."

This also highlights the need for a detailed Study and evaluation of the Social Costs for our conditions and till this is done to provide inputs to Rail on the same pattern as being done for the Road very much like the National Highways Development Programme (NHDP) and the Pradahan Mantri Gram Sadak Yojana (PMGSY). As a matter of fact Rail should be given some further inputs so that the skew already created could be rectified with speed.

(2) Rail to correct its Tariff Ratio

Once a level playing field is provided to Rail vis-à-vis Road, the Rail tariffs can be fixed in a more rational and pragmatic manner. In such a situation, the Indian Railways can plan to correct the Tariff ratio (Ratio between the average passenger fare per km to the average freight rate per tonne km) from a value of around 0.3 to a value of about 0.5, as was existing in the year 1950-51. (see also Para 5.10.4) Cross subsidising passenger traffic at the cost of freight traffic, is not desirable. This correction could be accomplished by suitably enhancing the passenger fares and/or reducing the freight rates and will generate some extra revenue for the IR which could be gainfully utilized in the development of facilities for the passengers.

(3) Formation of a Centralised Metro Rail Transport Authority

Metro Rail projects are not only essential to carry heavy urban traffic but also considerably reduce environmental pollution. The Integrated Energy Policy of the Planning Commission, August 2006 lays special emphasis towards development of rail-based urban transport systems in major cities to conserve fuel/energy. Construction of metro rail projects in our country has far lagged behind. Even though urban transport is a State subject but the Metro Rail projects need highly specialized knowledge and inputs. To give a boost and direction to this activity constitution of 'Centralised Metro Rail Transport Authority' appears necessary (see also Para 4.6.7). This will ensure faster and effective coordination between the Ministry of Urban Development, Ministry of Railways, concerned State Governments, Urban Local Bodies (ULBs) and other Stake holders.

4.19 Some Points to Ponder

4.19.1 Primary contribution to the 'Transport Greening' exercise will be through the modal shift of Freight/Passenger/Suburban traffic to Rail. For the purpose expeditious expansion of rail network (construction of New Railway Lines @ 1,000 km/year), removing traffic congestion on the existing busy Golden Quadrilateral and its two Diagonals (construction of six Dedicated Freight Corridors (DFCs) in next 10 years or so) and Metro Rail projects in major cities have been suggested. Rapid Rail Transit Systems (RRTS) on some selected routes are also planned for the National Capital Region (NCR).

4.19.2 Further, High Speed (HS) Trains on the existing tracks (200 kmph) on the entire Golden Quadrilateral and its two Diagonals are also suggested as all Freight traffic will now shift to the DFCs. Such HS trains will improve the speed and safety of travel, will result in enhancement of passenger traffic and may even capture some of the air traffic.

4.19.3 Rail will have to intensify and accelerate its maintenance/modernization/capacity generation plans. At this juncture it may be pertinent to point out that on any rail system and more so on a major system like the Indian Railways (IR) any technology input/improvement takes time to fructify fully. To give example, heavy axle load wagons (having greater carrying capacity) planned for the new DFC routes may not be optimally used unless the feeder routes to originating/destination stations are also suitably strengthened to take higher loads.

4.19.4 Investments will have to be prioritized in important areas viz. Dedicated Freight Corridors, high capacity rolling stock, last mile linkages and port connectivity. Development of logistics parks would also need to be taken up on priority basis to create matching terminal and handling capacity and facilitate integration of Rail with other modes of transportation.

4.19.5 In freight operations, improving axle loads of wagons, expansion of long haul, use of GPS and RFID technology for tracking purposes and technological innovations to improve the efficiency of operations will be needed. Containerization will be a major strategy to gain share of freight market.

4.19.6 Expanding the electrified rail network and making greater use of electric traction will help in saving precious diesel oil. This will also result in conserving foreign exchange (as most of the crude petroleum is imported) and will also enhance energy security. How far this shift from diesel traction to electric traction will impact the 'environment scene' still remains a debatable issue as most of the electricity generation in our country is Coal based (high CO2 emissions) and the situation is not likely to materially change in the near future. If the coal based electricity generation could be made 'cleaner' by developing suitable and cost effective **carbon sequestration and carbon capture** methods, it can be a win-win situation for the 'environment' and the IR. It may be mentioned that currently more than 40% of IRs freight traffic is Coal based and the continuation of this traffic is in IR's business interests. It will be prudent on the part of IR to support the R&D efforts in the **carbon sequestration and carbon capture** areas not only to help the 'environment' but also to protect its major bulk traffic viz. Coal.

4.20 Summary and the Proposed Action Plan

4.20.1 In this Technology Foresight Exercise an attempt has been made to examine the mechanised transport modes of our country holistically, keeping in view the need for accelerated growth of the transport infrastructure commensurate with the fast growth of the economy, and the need for the super-accelerated growth of those transport modes which are environment friendly.

4.20.2 **The broad approaches that need to be adopted to reduce green house gas (GHG) emissions in the transport sector have been outlined in Para 4.1.11.**

4.20.3 Since Rail and Road modes carry about 91% of the traffic in our country these have been discussed in greater detail. The modes for which carbon-dioxide emissions are the least is the Rail Transport with Water Transport as a close second. With regards to Social Costs too, the Rail scores over other modes. Why has the Rail, if it is fuel efficient and has the least social costs, lost market share so sharply (In freight traffic from 89% to 30% & in passenger traffic from 69% to 15%, since 1950-51)? Is it because of its inefficiency to carry traffic or there are others factors responsible for it? It can be argued that in the initial years after the Independence (1947), the war ravaged and partitioned rail network apportioned its limited resources towards consolidation/rehabilitation but why the investments in railways did not keep pace with the growing traffic demands thereafter? The issues have relevance not only for the Indian Railways (IR) but have a direct bearing on the national economy and the national/international environmental scene.

4.20.4 Data from IR convincingly proves that it is an efficient organisation. However, inadequate inputs to Rail infrastructure; policy of advantage Road vis-à-vis Rail; non-availability of level playing field to Rail in the absence of adequate analysis and compensation towards social costs; low passenger fares on the IR; inadequate recognition that Rail mode is best suited mode for crowded metropolitan cities, etc., emerge as the major issues which need attention/correction.

4.20.5 While adequate data is not available, some studies made at the Balance Research Institute, Melbourne have indicated that perhaps rail freight is 80% commercial at present, whereas the road freight is perhaps 50% (see Para 4.8.3). If they both had to pay 100% of the economical and social costs then the modal split would change towards rail. Till the time such region and mode specific data with regard to social costs is available, funding of transport sector projects has to be supported by suitable provision of **viability gap cum accelerated development cum environment mitigation funding**.

4.20.6 **Two Rail Projects as National Projects**

Expeditious development of Rail transport capacity on busy routes and development of rail network in the country are being suggested. The IR is taking action in this regard and have also developed a Vision 2020 document and an Action plan. **However, to ensure timely availability of adequate rail infrastructure it will be desirable to undertake the following two rail projects as National Projects by the Government of India.**

I. Dedicated Freight Corridors (DFCs) – See Para 4.14

II. Construction of 10,000 Km of New Railway Lines @ 1,000 Km/yr. (See Para 4.15)

4.20.7 **Need for a National Transport Authority**

There is no centralized monitoring authority/institution for regulating coordinated operation and integrated growth of different transport modes in our country. Authentic relevant data is also not available for our conditions. The current environmental scene necessitates much greater weightage towards 'social costs' and it has to be duly reflected in the optimization process in addition to the usual 'economic costs'. **There is an urgent need to have a National Transport Authority for the purpose and also for taking further action on the Three Policy Directions elaborated in Para 4.18.**

It is heartening to note that a 'National Transport Development Policy Committee' has been constituted by the Government of India (GOI) under the chairmanship of Dr. Rakesh Mohan, former Deputy Governor, Reserve Bank of India, and a renowned Infrastructure Expert (Feb. 11, 2010). The Committee includes several other experts as also the Secretaries in the ministries of coal, petroleum & natural gas, civil aviation, road transport & highways, finance, urban development, and power, besides the Chairman of the Railway Board. The Committee is to assess the investment needs of the transport sector and identify the role of state and the private sector in meeting these. It will also compare the cost advantages of various modes of transport while addressing the issues of rural connectivity and the problems of remote and difficult areas on the one hand and of the urban and metropolitan areas on the other.

At the time of finalisation of this Chapter (Chapter 4 : Transport – Making it Greener), the Report of the National Transport Development Policy Committee (NTDPC) had just been submitted to Government of India. The Committee has assessed the Transport requirement of the economy for the next two decades. It has been observed that despite Railways being more reliable and energy efficient transport mode, they have been loosing out to Roads for want of capacity augmentation on various fronts. The NTDPC has proposed that the market share of Rail for Freight traffic should be increased to 50%. The Committee has also proposed an increase in the investment on Railways from about 0.4% of GDP in the last two decades to around 0.8% in the 12th Plan (2012-2017) and then rising to around 1.1 to 1.2% of GDP in the following three Plans (2017-2032).

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<u>**Chapter 4 (S)**</u>

Transport – Making it Greener

Brief Synopsis and Suggested Plan for Action

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Chapter 4 (S)

Transport – Making it Greener

Brief Synopsis and Suggested Plan for Action

S.4.1 Brief Synopsis

S.4.1.1 The mechanized modes of transport comprise Railways, Highways/Roads, Coastal Shipping, Airlines, Pipelines, and Inland Water Transport. No centralised monitoring authority/institution for regulating coordinated operation and integrated growth of different modes of transport exists in the country. To give an example, while Railways are centrally administered as a department of the government, for the highways, infrastructure is provided by the Central and State governments, and the operation of vehicles is by private sector/owners. Some States also have State Transport Undertakings for the passenger transport.

S.4.1.2 The data regarding 'Originating Inter Regional Freight Traffic Growth and Changing Modal Split in India' can be seen in Table No.1. This data has been taken from the White Paper on Indian Railways, December 2009 and is based on a recent Study done by RITES for the Planning Commission. It will be seen from it that currently in our country about 91% of the Inter Regional Freight Traffic is carried by Rail (30%) and Road (61%), and the balance by Coastal Shipping (2.3%), Pipelines (4.5%) and Inland Water Transport (2.2%), the share of Airlines being very small (0.3 million tonne). **The share of Rail in freight traffic has come down from 89% to 30% since 1950-51 and for the passenger traffic it has reduced from 69% to 15%.**

Table 1 : Freight Traffic Growth and Changing Modal Split in India

		Mode-wise Traffic in Million Tonnes with Percentage Share					
Year	**Total Originating Inter Regional Traffic (Million Tonnes)**	**Railways**	**Highways**	**Coastal Shipping**	**Airlines**	**Pipelines**	**Inland Water Transport**
1950-51	82.2	73.2 (89%)	9.0 (11%)	NA	NA	NA	NA
1978-79	283.4	184.7 (65%)	95.6 (34%)	3.1 (1%)	NA	NA	NA
1986-87	484.9	255.4 (53%)	224.0 (46%)	5.5 (1%)	NA	NA	NA
2007-08	2555.4	768.7 (30%)	1558.9 (61%)	59.1 (2.3%)	0.3	113.5 (4.5%)	54.9 (2.2%)

Source : White Paper on Indian Railways, December, 2009 / Planning Commission – Total Transport System Study 2009.

S.4.1.3 Demand for transport is directly connected to GDP growth. For a developing economy like ours, the elasticity of transport to GDP can be taken as about 1.25. GDP growth of 9% would, therefore, translate into increase in demand for transport to the tune of 11%. The traffic is very likely to double in next 7-10 years.

S.4.1.4 Our existing transport infrastructure is already under severe strain with congestions visible everywhere. Paucity of necessary resources came in the way of infrastructure development and the lower GDP growth in the earlier periods also made us complacent towards the need for such a development. However, booming economy now necessitates that the transport infrastructure develops at an accelerated pace and that too in a coordinated and integrated manner. Development of necessary transport infrastructure is a pre-requisite to sustain the current levels of GDP growth and if timely action is not taken growth may get stifled.

S.4.1.5 To compound the problem of accelerated growth of transport infrastructure, the issue of environment has assumed paramount importance in the recent years, needing cuts in emissions of greenhouse gases (GHGs). **Growth of transport infrastructure has to consciously keep in view the need for using a mode which is least polluting and hence more environment-friendly in addition to planned efforts to reduce transport demand to the extent possible. Further, besides fuel and system efficiency measures, integrated and optimal use of various transport modes is essential.**

S.4.1.6 A European Study gives details of carbon dioxide (CO_2) emissions from various transport modes, both for the passenger and the freight traffic (see Table No. 2). Such emissions may even be higher for Indian conditions with less stringent fuel quality and vehicle maintenance norms. It will be seen from it that Rail is more environment-friendly with lower CO_2 emissions. On the other hand Table No.1 indicates that while the volume of freight traffic is increasing, the proportionate volume of traffic carried by Rail, which is **Greener** and so more environment-friendly, is declining.

Table 2 : Carbon-Dioxide (CO_2) Emissions

CO_2 Emissions from Freight Transport (gms/tonne-km)

Road	158
Water Transport	31
Rail	29

CO_2 Emissions from Passenger Transport (gms/passenger-km)

Air	229
Road (Car)	175
Rail	75

Source : Soft Mobility Paper – Europe – July 2006.

S.4.1.7 The approaches that need to be adopted to reduce green-house gas (GHG) emissions in the transport sector can be classified into the following groups :

- Reducing transport demand by suitable relocation of production and consumption activities; use of Information and Communication Technology (ICT) including the use of geographic information systems (GIS) and the global positioning systems (GPS) to reduce movements or to make them more efficient;
- Behavioural changes by moving towards an optimum utilization of seating space and load factor;
- **Planned Shift to Non-motorised Transport (NMT)** e.g., for low lead intra-regional freight traffic and for passenger traffic in busy metropolitan areas;
- **Encouraging a shift of commuters from use of road to rail and from personalized vehicles to public mass transport;**
- **Modal shift of freight traffic towards more environment friendly modes like Rail and Inland Water Transport (IWT);**
- Fuel efficiency improvements – A European Study indicated that upto 25% of fuel consumption could be saved through the use of efficient driving methods (Ecodriving);
- System efficiency improvements through traffic engineering and management measures; and
- Technological and fuel changes through upgrading automobile technology and fuel quality and promoting alternative fuels.

S.4.1.8 In this Technology Foresight Exercise while the various measures to make the Transport Greener have been outlined **but the emphasis is basically on improving the share of Rail in the overall Transport scenario**. About 91% of the traffic in our country is carried by Road and Rail, Rail is 4-6 times environment-friendly vis-à-vis Road and uses much less space (land use) for carrying the same volume of traffic. A 3% shift from Road to Rail transport will reduce GHG emissions by 10% and thus the potential is enormous. Planning Commission has also been endorsing modal shift to Rail. An independent analysis by Balance Research Institute, Melbourne, also points towards much greater role for Rail in future World Transport scenario. Fast growing network and role of Railways in China, the fastest growing economy of the world, also justifies this line of action. It will not be out of place to mention that about a decade back the Chinese Railway network was smaller than that of Indian Railways (IR) but has since overtaken it. **The proposed action plan in broad terms is as under** :

- All transport modes must function in an integrated manner to get optimal output. There is urgent need for a centralized monitoring authority / institution for regulating coordinated operation and integrated growth of various transport modes.

- Directed efforts have to be made to reduce transport demand, choose environmentally efficient modes and make the operations and fuel systems of all transport modes more effective / efficient.

- While all transport modes be tackled in this manner but for Rail incremental efforts will not be enough. Rail needs special inputs on fast track to improve its market share besides other system improvements.

S.4.2 Suggested Plan for Action

S.4.2.1 Need for Three Policy Directions

S.4.2.1.1 **Level Playing Field to Rail vis-à-vis Road**

In our country 91% of the traffic is carried by Rail (31%) and Road (60%). For carriage of freight traffic, Rail is nine times fuel efficient vis-à-vis road but is loosing its market share (from 89% in 1950-51 to 30% as of now) resulting in enhanced pollution for the transport sector as a whole. Earlier efforts to contain this decline in Rail's market share have not succeeded but the environmental concerns now necessitate urgent action to rectify the situation. The main reason for the Rail to loose vis-à-vis Road is that 'social costs' are not suitably factored in. While authentic data in this regard is not available for our conditions, a recourse to other international studies clearly highlights that its impact is substantial.

This also highlights the need for a detailed Study and evaluation of the Social Costs for our conditions and till this is done to provide inputs to Rail on the same pattern as being done for the Road very much like the National Highways Development Programme (NHDP) and the Pradahan Mantri Gram Sadak Yojana (PMGSY). As a matter of fact Rail should be given some further inputs so that the skew already created could be rectified with speed.

S.4.2.1.2 **Rail to correct its Tariff Ratio**

Once a level playing field is provided to Rail vis-à-vis Road, the Rail tariffs can be fixed in a more rational and pragmatic manner. In such a situation, the Indian Railways can plan to correct the Tariff ratio (Ratio between the average passenger fare per km to the average freight rate per tonne km) from a value of around 0.3 to a value of about 0.5, as was existing in the year 1950-51. Cross subsidising passenger traffic at the cost of freight traffic, is not desirable. This correction could be accomplished by suitably enhancing the passenger fares and/or reducing the freight rates and will generate some extra revenue for the IR which could be gainfully utilized in the development of facilities for the passengers.

S.4.2.1.3 **Formation of a Centralised Metro Rail Transport Authority**

Metro Rail projects are not only essential to carry heavy urban traffic but also considerably reduce environmental pollution. The Integrated Energy Policy of the Planning Commission, August 2006 lays special emphasis towards development of rail-based urban transport systems in major cities to conserve fuel/energy. Construction of metro rail projects in our country has far lagged behind. Even though urban transport is a State subject but the Metro Rail projects need highly specialized knowledge and inputs. To give a boost and direction to this activity constitution of 'Centralised Metro Rail Transport Authority' appears necessary. This will ensure faster and effective coordination between the Ministry of Urban Development, Ministry of Railways, concerned State Governments, Urban Local Bodies (ULBs) and other Stake holders.

S.4.2.2 **Two Rail Projects as National Projects**

Expeditious development of Rail transport capacity on busy routes and development of rail network in the country are being suggested. The IR is taking action in this regard and have also developed a Vision 2020 document and an Action plan. **However, to ensure timely availability of adequate rail infrastructure it will be desirable to undertake the following two rail projects as National Projects by the Government of India.**

I. Dedicated Freight Corridors (DFCs) – See Box 1.

II. Construction of 10,000 Km of New Railway Lines @ 1,000 Km/yr. – See Box 2.

Box 1 : Dedicated Freight Corridors on the Indian Railways

- The Golden Quadrilateral (connecting four metro cities of Delhi, Kolkata, Chennai and Mumbai) and its two diagonals, which constitutes about 16% of Route Kms or 25% of Running Track Kms carries more than 55% of the traffic of the Indian Railways (IR).
- Dedicated Freight Corridors (DFCs) are planned for the entire Golden Quadrilateral and its two diagonals by laying two new parallel double lines exclusively for freight traffic thereby making the existing system a passenger corridor. The approximate length of six DFCs (Four sides of the quadrilateral plus two diagonals) will be 11,500 km of double line (23,000 km of rail track). The DFCs will mostly run parallel to the existing system but in busy areas and yards detours will be necessary. Currently, work on Eastern and Western DFCs is already in progress.
- Existing network is mostly a double line section (except for some stretches where 3rd or 4th lines exist) and the construction of DFCs will virtually mean quadrupling (Two Passenger lines + Two Freight lines) of the sections. **With four lines, increasing traffic, and improving average speeds of trains (due to enhanced mobility) the operation of existing level crossing (surface crossings of road and rail) will not be practically possible and so grade separation becomes an essential prerequisite, needing provision of Road Over Bridges (ROBs) or Road Under Bridges (RUBs) in lieu of existing level crossings.**
- The existing axle loads on the IR system are 20.3t and have recently been enhanced on some selected routes to 22.9t. The DFCs are being designed to take axle loads of 32.5t and for the present 25.0 t axle load wagons are proposed to be run for which Feeder Routes (about 4,500 km; axle load 22.9t) are also being upgraded to enable carriage of 25.0t axle load wagons.
- **Container traffic will be growing faster than the normal traffic**. Accordingly, running of double stack container trains is contemplated on the DFCs and overhead clearances of structures like Road Over Bridges (ROBs), Foot Over Bridges (FOBs),

Tunnels etc. are being planed accordingly, also keeping in mind the aspects of electrification of the lines now or in future. For heavier traffic, electrification of routes proves to be a more economical proposition in addition to an overall reduction in the consumption of energy vis-à-vis use of fossil fuels.

- Construction of DFCs will greatly enhance capacity and mobility, mainly due to the following :

  (a) Slow moving goods trains (75 kmph/100 kmph) will not come in the way of passenger trains (100 kmph/140kmph) nor the slow moving freight trains will have to wait for giving precedence to faster moving passenger trains. This will reduce congestion and improve average speeds of both the passenger and the freight trains. The sectional capacity will also markedly improve.

  (b) Higher axle load wagons plying on DFCs will carry more load per train.

  (c) Existing corridors (passenger corridors) will be relieved of heavier freight trains thus giving relief in maintenance especially to old existing bridges.

  (d) Since level crossings will not be existing (complete grade separation), the existing passenger corridors could run normal trains at 160 kmph speeds as also tilt body passenger trains upto speeds of 200 kmph (similar to Swedish X2000) by suitably fencing the existing tracks and providing cab signalling. This will also enhance safety of travel.

  (e) The Rajdhanis' which currently run at a maximum speed of 130/140 kmph and take about 16 hours for journeys between New Delhi and Mumbai and about 28 hours between New Delhi and Chennai may be able to cover these distances in about 11 and 18 hours respectively.

- Completion of DFC project, in a period of about ten years is essential to meet the growing traffic demands (traffic is likely to double in next 7-10 years). However, it will be a difficult and challenging task involving construction of about 2300 km of rail lines every year.

- Completion of all the six DFC lines (Quadrilateral and two diagonals) in about ten years will not be possible unless adequate funds are assured. In this regard, **Government of India should consider providing 40% of the Project Cost as a Grant in the form of Viability Gap cum Accelerated Development cum Environment Mitigation Fund.**

- **It will be desirable to execute the DFC Project as a National Project in view of its importance to the country's economy.** A special purpose vehicle (SPV) viz., Dedicated Freight Corridor Corporation of India Limited (DFCCIL) of the Indian Railways is already in place and work on the Eastern and Western DFC corridors is currently in progress.

Box 2 : Construction of New Railway Lines

- New Railway Lines are being constructed at a very slow pace, primarily because of fund constraints and their financial non viability. Since 1950-51, only 21% addition has been done to the Route Kms which indicates that the pace of New Line construction has been about one third of what it was in the 100 year period prior to Independence (1947).

- Such lines open the system to traffic from new markets and are also needed to develop rural areas including the vulnerable 'border' areas. In addition to generation of employment during construction and subsequently for the maintenance and operation, such lines generate considerable amount of employment in the related non-railway sectors. Environmental consideration also necessitate improved transport share for Rail clearly pointing towards the need for expeditious growth of the Rail network.

- Some may argue that such lines are not necessary for the Indian Railways (IR) but more than 11,000 km New Line projects already sanctioned (IR Vision 2020 – Dec. 2009) and waiting to be executed tell a different story. The progress of New Line construction in the pre-Independence era was more than 500 km/yr which reduced to about one third (about 180 km/yr.) after the Independence (1947). The five years (2004-05 to 2008-09) have seen a construction rate of about 230 km/yr. (IR White Paper - 2009). The need for a major thrust towards this vital area of Network Expansion has been recognized and the IR's Vision 2020 document suggests a growth rate of 2500 km/yr for the New Lines which has been scaled down to 1000 km/yr in the Rail Budget (24^{th} Feb. 2010). The target of 1000 km/yr appears more pragmatic but even for it funds will be a major constraint. **It is suggested that construction of New Railway Lines should be considered in the same light as the Pradhan Mantri Gram Sadak Yojna (PMGSY) and the Government of India (GOI) should consider a support for this vital need in the form of viability gap cum accelerated development cum environment mitigation fund.** Other inputs like the rolling stock, operation and maintenance costs, and the allied losses for such lines could be borne by the IR.

S.4.2.3 **Need for a National Transport Authority**

There is no centralized monitoring authority/institution for regulating coordinated operation and integrated growth of different transport modes in our country. Authentic relevant data is also not available for our conditions. The current environmental scene necessitates much greater weightage towards 'social costs' and it has to be duly reflected in the optimization process in addition to the usual 'economic costs'. **There is an urgent need to have a National Transport Authority for the purpose and also for taking further action on the Three Policy Directions elaborated in Para S.4.2.1.**

INAE Forum on Technology Foresight and Management for Addressing National Challenges

The Indian National Academy of Engineering (INAE) founded in 1987 comprises India's most distinguished engineers, engineer-scientists and technologists covering the entire spectrum of engineering disciplines, and functions as an apex body to promote and advance the practice of engineering and technology and the related sciences and disciplines in India and their application to problems of national importance. The Academy provides a forum for futuristic planning for country's development requiring engineering and technological inputs and brings together specialists from such fields as may be necessary for comprehensive solutions to the needs of the country. The Academy is an autonomous institution supported partly through grant-in-aid by Department of Science & Technology, Government of India. As the only engineering Academy of the country, INAE represents India at the International Council of Academies of Engineering and Technological Sciences (CAETS).

Among other activities, one of the important objectives of the Academy is to assist the Government from time to time in formulating policies on critical technical issues. . Five Forums have been set up by the Academy to bring out the comprehensive report related to the issues of National Importance. The objective of these forums is to bring out comprehensive/exhaustive document covering review of existing aspects, analysis of options, future trends and specific implementable policy/recommendations and methodology of execution. One of such forum is INAE forum on Technology Foresight and Management Forum for addressing National Challenges.

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