# ROLE OF ENGINEERING IN DEVELOPMENT OF ECONOMY, SOCIETY AND PEOPLE

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***Prof Satish Dhawan***

It is indeed a great honour and unique privilege for me to be given the opportunity to deliver the first Professor Satish Dhawan Commemoration lecture remembering Professor Satish Dhawan (whose 90th birth anniversary is on September 25, 2010) a great teacher, distinguished researcher, an unparalled leader and administrator of academic institutions and scientific and technology organizations, and above all a committed engineer in heart and real life. The institutions he built are shining before us. For me it is a special memory as much of my life from 1973 was influenced and shaped by him. Our relationship is several combinations of his being Guru, Mentor, Guide, Boss and many more.

True to the tradition in which he has moulded many of us for several years, I am not going to dwell on his life and his contributions to science, technology, engineering, management, economy and society. There are only a few writings on him. I would refer to two recent articles. One by me: Bibliographical memories of the Indian National Science Academy (INSA, Vol. 28, 2005) which gives the earlier references and draws from a few unique writings by him post-retirement. Another is a brilliant piece in the Hindu last year on 25th September 2009 by Dr. Manoranjan Rao.

**Engineering as a Discipline**

The crucial role of engineering for modern civilization is implicit in every aspect of our lives. Rapid progress in the development of the country post-independence has taken place through the application of engineering to different sectors: dams and irrigation systems which paved the way for green revolution; roads, civil construction of many types including building of major cities; sanitation systems; manufacturing industries; transport systems from trucks, buses, trains, ships, aircrafts, shipyards and airports, pharmaceutical industries, one can list many more.

However, the unique role of engineering, got submerged in the romance of the word "science" used by Jawaharlal Nehru who meant it in a broader sense of generation, acquisition and application of modern knowledge as well as a rational way of looking at life, which he termed as scientific temper.

So much so, the prestigious Indian science academies ignored the achievers in engineering discipline and even engineering researchers. This led to the formation of Indian National academy of Engineers (INAE).

Prof. S. Dhawan did not like such a separation even while he was clear about their different roles. Science and engineering intertwine and feed each other. Building of a new improved observing equipment or instrument is an engineering activity. But it can help many new discoveries. Chandrayaan-1 is a great engineering feat of ISRO engineers and technicians and their partners from industries. It also helps first rate science. Similarly some new scientific discovery can pave way for new engineering activities. Prof S Dhawan ensured that the personnel policy of ISRO (Indian Space Research Organisation) does not create such a separation and dichotomy, as is so in many of our scientific and technology establishments. He went even to the detail of the designation of each individual professional in ISRO as Scientist/Engineer, SC, SD, SE......G, H etc., every one carries both the titles, irrespective of the basic degree he/she caries.

But the national science policy makers and public system in general ignored the role of engineering and

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somehow assumed that scientific research alone would suffice and would automatically lead to further developments in industry, agriculture etc. Results of such a negligence was clear with continued and repeated import of technology, engineering drawings and consultancy services by industry in public and private sector. Then these policy makers started using a word "Technology". "Technology Policy" since 1983 started emphasizing more on the research aspects of engineering and forgetting the crucial role of "engineering" which is the delivery of products and services to he society and people and thus growing the economy.

Around mid 1990's the word "technology" almost exclusively got "hijacked" by IT sector! Later the celebration of technology got symbolized by a high-tech event. It was, of course, a great engineering event with high intensity of scientific knowledge, important in itself for the country.

But engineering (and therefore technology) is much more inclusive and pervasive of all sectors and all walks of human endeavor. Where ever there is an actual delivery of goods and services, engineering has to come in. No wonder most of our youngsters rush for engineering degrees as in the final analysis industries or government agencies responsible for development have to deliver goods and services.

Even so, it is necessary for the country to recognize "Engineering" as a crucial discipline. Then alone a strong foundation for all round national development can take place. Present growth in the industrial and services sector is predominantly based on borrowed technologies ranging from engineering designs, drawings, know-how and above all heavy import of embodied technologies (and engineering) through import of machinery, equipment, software etc.

It is important in this context, to dwell upon some of the definitions of technology, science and engineering etc., and understand the distinctions as well.

Thereafter, we will briefly describe two major engineering challenges given by Prof. S Dhawan in one of his later speeches. After that we will touch upon a mega-challenge for the country, the people, society and the economy as a whole, which needs immediate, attention by the engineering community.

**What is Science, Engineering And Technology?**

And how they relate to economy society and people? Also how they are interlinked? It is better to see a few quotes from the address Sir David Davies. (Sir David Davies, "Engineering as an Innovator of change in Society and the Role of Engineering Academies", address by Sir David Davies, CBE, F Eng. FRS, Chief Adviser to the Ministry of Defence, UK and President, the Royal Academy of Engineering, at the annual Function of the Indian National Academy of Engineering (INAE). New Delhi, December 3, 1998).

**About Science**: "Science is unquestionably a search for a better understanding of the laws of nature described in the broadest possible sense from astronomy to medicine and from engineering to genetics. Despite massive steps forward in each field, the understanding always remains incomplete.....".

**About Engineering**: "Engineering on the other hand is about innovation, design and the construction of new products and new capabilities. We must take care not to define this solely in terms of physical products since engineering can also often offer new services often without the need for additional hardware.....". However, whatever the form of the new innovation its design is inevitably a compromise between many different parameters. The success of the products is therefore bound up with the efficiency of the design process which has the role of matching the design to the requirements in as efficient a way as possible.....".

**What is Innovation?**: "In terms of an engineering product or service an innovation enables it to offer some new advantage in capability or performance (including cost) that there is a strong coupling between engineering and science but this does not necessarily mean that this engineering innovation derives directly from the latest improvements or understanding in scientific theories.....".

**An example**: "Perhaps the most obvious example here is the steam engine. That innovation arose from experimental observation but is was not based upon any current understanding a theory of heat at the time. Indeed the whole subject of thermodynamics was developed afterwards. It provided better understanding of the performance of heat engines and was further evolved in order to aid the design of improved equipment".

For Sir David Davies the word technology and engineering are synonymous. In the later part of his talk he has discussed the role of Engineering Academies (I would place the Institution of Engineers also as one, though it may not have been very active in terms of new and innovative engineering aspects recently). He points out that for the implementation of most of the Government policies for various social and economic sectors the strong link required is engineering (technology). Policies have to link to engineering aspects in the implementation. He has implied that without such strong links most policy statements may not achieve the stated goals.

You may judge for yourselves what has happened in India over the past six decades and why the Indian performance lags seriously behind the policy and programme statements.

Another quote about the definition of technology and technology policy by Lewis M. Branscomb, Empowering technology: implementing a US strategy edited by LMB, 1993, MIT Press emphasizes this point again: "A technology is the aggregation of capabilities, facilities, skills, knowledge, and organization required to successfully create a useful service or product. Technology policy concerns the public means for nurturing those capabilities and optimizing their applications in the service of national goals and the public interest".

The word technology here encompasses engineering and the processes of engineering.

The boundaries which distinguish technology (engineering) policy from economic and industrial policy are fuzzy at best. It is therefore necessary for Engineers and Engineering Academies or Institutions not to be quiet spectators or mere implementers of policies done elsewhere but to be proactive shapers of various socio-economic-trade and industrial policies. I have elaborated in detail the interplay of these policies in my book "Empowering Indians with economic, business, and technology strengths for the 21$^{st}$ century" (2001, revised print 2002).

It is with this spirit and a special appeal, I outline there major tasks which the Engineering community can give attention to. To be sure India needs many more such mega engineering tasks but I give these three important ones as illustrations due to limitations of time. One of these tasks is for medium term; second is for very very long term (these two are drawn from Prof. S Dhawan's address "Whither Space and Astronautics", delivered at the Astronautical Society of India Bangalore, September 6,1996) and the third one is for immediate action and just now (already too late!) type of attention and implementation.

**Mega Task One**

**The National Early Warning and Response System (NEWARS)** : This useful and grand idea was proposed by Prof Satish Dhawan about 14 years ago and he was passionate about it. Being an engineer and par excellence programme manager he built the system (programme) design around the existing and proven systems established by ISRO especially the National Natural Resources Management System (NNRMS) and Indian National Satellites (INSAT) system, though the scale, scope and complexity of NEWARS will be much greater. In his words as in the address quoted earlier "Consolidation, extension and systematic utilization of what has been accomplished in the last 15 years of NNRMS and INSAT locally leads to NEWARS - a Space Based Early Warning and Response System which would collect timely information on all major aspects of national life which have a strong coupling with and depend upon protection and effective use of natural and organized human resources. The system goes well beyond information collection and dissemination and seeks to feed and nurture not only organized sectors of public life but also create awareness, initiative and action among wide sections of rural and urban India".

He explains in detail how NEWARS can develop without seeking to displace the existing systems and tune them into a comprehensive network in stages.

While the current systems are useful and really touch the lives of people in many beneficial ways, there are still many gaps in giving early warning/alerts which can reach village groupings or urban areas, in providing real time monitoring as well as in receiving the (ultimate) user feedback on issues concerning their lives.

The main areas to be covered by NEWARS include:

- Agriculture
- Geology
- Plants and Forests
- Soils
- Industry and Mining
- Ecology and environment
- Urbanization

- Transport and Energy sectors etc.,

*Note : etc., etc., which is from his lecture.*

In addition to several useful early warnings and post event information such as crop stress, water/moisture availability, pest formation, crop yield forecast, post harvest crop yield estimates etc., in "Agriculture" sector: and similarly for other items listed above, he envisaged the following benefits as well:

"NEWARS encompass all the above elements and one can envisage in addition during the course of growth

| | | |
|---|---|---|
| Smuggling - Land and Sea | - | Loss to the economy |
| | - | Distress to fisher and farm folk |
| | - | Illegal intrusions into Indian Territory |
| Large Scale community gatherings | - | Pilgrimage areas (Oct 29, 1995) |
| Amarnath - Sabarimalai - Kurukshetra | - | A million visit Sabarimalai |
| 10 lakh persons Holy Dip | - | Sravanabelagola |
| Holy fairs of Sangams | - | Accidents, illness etc. |
| Population migrations | - | Bangladesh displaced. Biharis drivan towards Delhi |
| Large scale Epidemics | - | Induced by Natural/Man made disasters/Spread of Virus etc |
| Insurgency and Terriorists | - | Disruptive of Civil life |
| And National Security | - | India's borders and within the country" |

He points out the crucial element of NEWARS as: "It is in the transformation of the acquired data/information into a variety of practically useful forms that the challenge lies".

Look at the huge engineering challenge before us. NEWARS is something that can be executed in about 3 decades if several private and public sector institutions industries and NGOs join together. Engineering community can take the lead, as NEWARS can help make most engineering efforts environment friendly and people friendly. And also help a true democratic participation in development and growth. Would persons from Bangalore chapter of Institution of Engineers like to take the lead along with institutions and industries here as well as with the help of state of Karnataka and ISRO? No doubt government money is required for building up the system and maintaining it. But if creative administrative and financial policies and procedures are adopted, it is possible to intertwine very effectively private commercial operators as well along with some user fees for some sectors. Such a government-private-public participation will reduce the government budgetary support.

I leave it here and go to another great engineering challenge "larger in scope, scale and time frame requiring participation in international multi disciplinary research with the inevitable geopolitics and uncertainties" that is in the next section.

**Mega Task Two**

**Planetary Engineering**

Basically he has described the following elements:

"First some definitions:

**Ecopoleses** - A term coined by R Haynes from the Greek (The words Greek root means the making of a home) it implies the fabrication of an ecosystem or biosphere on a lifeless plant.

**Planetary Engineering** - Implies application of engineering and scientific principles to planets to change them to suit human purposes.

**Terra Forming** - implies creation of an Aerobic Biosphere on another planet, suitable for humans and higher animals in effect a second inhabitable Earth"

Prof. Dhawan also cautions as in the following:

"Before briefly seeing what would be involved in Planetary Engineering we note that serious ethical questions have been raised:

- Is it morally justified for man to change the climate and environment of another planet?
- If life exists on the planet has man the right to modify the ecosystem to suit humans? This may harm the life

forms there/a problem man has encountered on Earth and is yet to fully understand and solve.

- If no life exists on the planet is it right to change the conditions to suit earth based life?"

He has then described in detail as to what is involved in transforming a planet and given an example for performing such a mission for Mars. He has posed a number questions from an engineering and project management view points.

This engineering mission is ridden with intellectual and aspirational challenges which you can all carry with you and transmit to subsequent generations.

I would like end this section with a quote from the end part of Prof S Dhawan's address:

"One may ask: can the advent into space provide a moral and practical substitute for WAR? War between people and also Man's war on the ECO SYSTEM? Can exploring the Solar System fulfill a psychological need and also unify Mankind?

Civilizations have for long sought answers to problems of existence. In the last half a century it has slowly dawned on mankind that of the great variety of life forms on the earth, one of them Homosapiens- has reached a stage when its actions are endangering the Globe. The Skeptics asks: What is the moral justification for exploring the Planets and Stars when there is so much Hunger, misery, Poverty and Strife on earth? The optimist says: Programmes which focus on space and encounter complex issues of survival in a hostile environment, facing unexpected dangers andsituations and overcoming them - enhance Man's capability to faced the unknown and survive as a truly civilized being.

Collectively can mankind enhance its capabilities to evolve a civilization on earth which is more humane, sensitive and harmonious not only to humans but to all forms of life? If yes, then we go into space to understand and resolve problems of life on earth.

Journeys in Place and Time are Symbolic with Matter, Mind and Values - The Message of the Vedas"

After describing these two Mega tasks derived from Prof. Satish Dhawan's address, I would like to emphasize that the first one NEWARS is with us and we can develop it at a pace desired by all of us. It will be immensely useful in taking the benefits science, technology, engineering and other knowledge systems directly to the people of India. It is a great engineering challenge. It comprises mostly known elements and nearly proven elements. The challenge is to put them together.

Now I would describe the third Mega task which is crucial for our economy, society and people. It is an item needed by all. It is something fully in the domain of engineering except for policy making on some aspects.

**Mega Task Three**

**Water for the Nation and People**

We have all heard an old saying: "Water water everywhere but no water to drink". Most of us are familiar with the news of flooding and resultant damages in many parts of our country about two times in per year. We also read reports about severe water shortage for many crops. In the cities including metros we have continuous year round flow of large sewage systems even while there is a drinking water shortage in almost all cities.

Science, technology, engineering and academic institutions have neglected a holistic look at the solutions to the water problem. Most of the media with some exceptions would like to highlight only scenarios water wars, or flood or drought or drying lakes or pollution by industries or romantic solutions of rain water harvesting or issues of water rights etc. We get excited at the news of finding some water on Moon! Very little attention has gone in terms of available engineering solutions in terms of maximizing efficiency in the use of water, conserving existing water resources, recycling the waste water for repeated reuse and above all continual maintenance of water related engineering systems which is crucial for the sustainability. The latter requires a lot of awareness and training of the users - ordinary citizens to households to farmers to industry persons, as well.

In order to have a clear perspective of the dimensions of the issues relating to water, true to the scientific and engineering traditions, let us look at some numbers. I have drawn them primarily from two excellent reports / books.

i. Integrated Water Resource Development - A Plan for Action, Report of The National Commission for Integrated Water Resources Development, Government of India, Ministry of Water Resources, New Delhi, September, 1999

ii. State of the Indian Farmer, A Millennium Study, Volume 3, Water Resources, K.V.Raju, A.Narayanamoorthy, Govind Gopakumar, H.K.Amarnath Ministry of Agriculture - Government of India, 2004, New Delhi.

Major sources of water are rain, and surface water supplemented by ground water. Some data on them are as under. (From Report (i) above).

a. All India average rainfall is 1,170 mm, but it varies respectively from 100 to 11,000 mm in Western deserts to North Eastern region. More than 50 percent of precipitation takes place in about 15 days and less than 100 hours altogether in a year. The rainy days may be only about five in deserts to 150 in the North East.

b. Average annual precipitation in India including snowfall has been estimated as 4,000 $km^3$. We have estimated the total annual water resources of the country (including both surface water and ground water) as 1,953 $km^3$. Some of this originate beyond our borders, and in turn some of it cross our borders on its way to the sea and goes into downstream countries.

**Another Factor in terms of per Capita Utilization**: India, which has 2.45 percent of the world's land resources, has roughly 4 percent of the world's fresh water resources, whereas the country's population is 16 percent of the world's population.

**Total availability as per Report (i) above is**: "It has been estimated by this commission that as against a total annual availability of 1,953 $km^3$ (inclusive of 432 $km^3$ of groundwater), approximately 690 $km^3$ of surface water and 396$km^3$ from groundwater resources, making a total of 1,086 $km^3$, can be put to use. So far, a quantum of about 600 $km^3$ only out of this available water, has been put to use. However, pollution problems have been growing, posing a serious threat to availability for use. Municipal sewage (often untreated), urban and rural wastes, industrial effluents, chemical fertilizers and pesticides, have all contributed to the pollution of both surface water and groundwater. At the same time, the demand for water will grow with population growth and the processes of economic development. It has been estimated that the available supplies on certain premises will be matched if not exceeded by demand by the year 2050. Water - stress conditions will be experienced in many parts of the country unless remedial measures are taken in time".

There are some marginal differences of number between the two reports.

From report (ii) let us look at the sectoral utilization of the water. Of the 180Mham of surface run - off, 15Mham is stored in reservoirs and various tanks: The loss due to evaporation is about 40% in shallow storage places and 20% in deep reservoirs (on the whole about 5Mham is lost). About 15Mham of the river flow is utilized directly or by pumping. Remaining 150Mham flows into sea or adjoining countries. Ground water resources that are periodically replenished amount to 67Mham of which 13Mham are utilized for various sectors.

Of the total utilization of water resources (described above) amount to 38Mham of this.

- 35Mham goes for irrigation (11Mham from ground water and 24Mham from surface water)
- 3Mham are utilized for other purposes, predominantly domestic, industries, and power generation.

There are variations in these estimates (see Table-1) from the Report (ii), (Units Mham)

One thing is clear even amid these variations. Irrigation is the bulk user. Domestic and industrial uses are almost equal.

Intersectoral projection of water demand for coming years from Report (ii) is in Table-2. Units of water in $km^3$.

**Table-1**

| Year | Domestic | Irrigation | Industries | Misc. | Total | Source |
|---|---|---|---|---|---|---|
| 1985 | 1.7 | 47 | 1.3 | 4.1 | 54.1 | CWC, 1995 |
| 1990 | 2.5 | 49.3 | 3.4 | - | 55.2 | Reddy, 1992 |
| 1995 | 3.3 | 63 | 3.3 | 5.4 | 75 | CWC, 2000 |
| 1998 | 4.4 | 52 | 5.7 | 4.1 | 66.2 | CWC, 2000 |

**Table-2**

| Projections | Domes-tic | Agri-cultural | Indus-trial | Misc. | Total |
|---|---|---|---|---|---|
| **2010** | | | | | |
| NCIWRDP | 48 | 557 | 51.1 | 54 | 710.1 |
| World Bank | - | - | - | - | - |
| IWIMI | - | - | - | - | - |
| **2025** | | | | | |
| NCIWRDP | 67 | 611 | 100.1 | 70 | 848.1 |
| World Bank | 52 | 770 | 228 | NA | 1050 |
| IWMI | 39.6 | 525 | 33.4 | NA | 598 |
| **2050** | | | | | |
| NCIWRDP | 117 | 807 | 150.2 | 111 | 1185.2 |
| World Bank | - | - | - | - | - |
| IWMI | - | - | - | - | - |
| *Source : MoWR, 1999a; World Bank; Seckler et al., 1998* | | | | | |

Having looked at some of the above macro - data let us look at the percentage of the Net irrigated area to Net sown area taken from Report (ii)

| Size Class | 1970-1971 | 1975-1976 | 1980-1981 | 1985-1986 | 1990-1991 | ACGR (%) |
|---|---|---|---|---|---|---|
| Marginal (< 1ha) | 33.8 | 37.5 | 40.2 | 42.8 | 43.6 | 1.28 |
| Small (1-2 ha) | 27.9 | 30.6 | 32.7 | 34.3 | 35.7 | 1.24 |
| Semi-Medium (2-4 ha) | 25.2 | 26.6 | 29.3 | 30.7 | 32.8 | 1.33 |
| Medium (4-10ha) | 20.4 | 20.3 | 24.2 | 26.1 | 29.7 | 1.90 |
| Large (> 10ha) | 13.0 | 12.4 | 16.3 | 18.8 | 22.5 | 2.78 |
| All Size class | 21.4 | 23.2 | 26.9 | 29.4 | 32.6 | 2.13 |
| CV | 32.64 | 37.74 | 31.46 | 29.38 | 23.61 | |

It shows the continuing gross inequity in use of water for agricultural use. No wonder most Indian farmers are abysmally poor and therefore India is poor (since about 65% of Indian s depend upon agriculture - we need to change this figure drastically. That has been dealt with by me elsewhere and I won't talk about it here).

The total availability of water resources, per capita possibility etc indicate the challenge to eradicate this inequity and make available good irrigation (i.e. enough water to the plants at right times) is not expansion as usual but it is an engineering challenge. Engineers have to work with agricultural experts and local communities to make them learn and use water saving systems, use the recycled water, maintain the facilities, and to keep a vigil on new polluting sources and give solutions for them, etc.

It is difficult to cover comprehensively all aspects of engineering / technology / project management tasks required for this Mega Task - 3. If one considers locale specific aspects then the complexity becomes more. For example water conservation aspects relating to agriculture in Punjab will be different from that required for Rajasthan. Hence the engineering considerations will be different. So with different sectors and sizes of industries etc. Therefore we will attempt to have a broad profile of various critical aspects of this Mega Task - 3 on Water. Engineering professionals can expand on these elements when they actually get into action mode.

**Availability of Water**

As discussed earlier the source can be from static surface water, flowing surface water (run off, rivers, canals etc), ground water, rain water collection and recycled water.

Of the water sources, the ones which are monitored well are the 81 major reservoirs; as of the first week of September 2010, the water in these 81 reservoirs was about 103 billion $m^3$ (32% more than last year). A good news for the Ministry of Power as the hydroelectric power will be good this year. Some places may have threat of flooding, when the reservoirs cross danger levels!

But when we consider the water sources for most of India monitoring these 81 is not enough. One needs monitoring of river flows and importantly many small - medium - large lakes. On paper we have a system in the country. Many of you will know the inadequacy.

A project to have a regular monitoring of surface water, their quantity and quality will be a great engineering challenge. One element of NEWARS described earlier can help putting such a system into operation. A combination of remote sensing and data collection platforms which can be accessed by local mobile telephones or by satellites, can form an effective monitoring system. Such a data available on a national portal can be of great help. I am not unaware of security concerns that can be raised by some persons. In the current period with high resolution satellite imagery available globally and mobile phones which can take pictures and transmit globally, such worries are at best nave or paranoid.

Well, it is not just enough to record and to monitor all of them, though it could be a first parallel step.

All the major and minor reservoirs, rivers, lakes etc require serious attention in terms of desilting. That will conserve precious water resources.

Let us not for a moment waste our attention on reducing the evaporative losses. May be in future after we finish the simpler and large quantity tasks.

An important issue in conserving the water resources is to keep them clean. Most lakes are full of algae, hyacinths and other plants if they have not dried up already. Many others become easy places to dump solid wastes or the sewage and waste water. This is so even in rural areas. Even the "lost" (due to human apathy) lakes need to be recovered, as much as possible.

Engineers in local areas (under a major project catalyzed and spearheaded by IE's several chapters in India) can very much help in this process.

Similarly one needs to monitor all the ground water usage points. With local help and modern communication (mobile, telephone and satellite) technologies, it is not a difficult task.

Then there are other areas like wetlands, marshy lands etc. they need preservation too, for ecological balance.

Rain water harvesting is another useful water source. But this needs to be done with some caution. Somehow in our country we seem to have an implicit faith in things which were used several centuries ago. While rain water harvesting is good, in the distant past we had very little human and cattle population. Also other newer technologies were not available, not even deep ground drilling.

Indiscriminate rain water harvesting in rain scarce areas may stop downstream flows and affect the ecology at a distance. (Remember how oasis in a desert gets formed). More importantly the indiscriminate decentralization of rain water harvesting to the household levels in big cities like Delhi etc. are one of the cause of spread of mosquito borne diseases. In bigger cities we need to rethink rain water collection strategies. We need to use the storm - water flow channels to aggregate in a local area and have good engineering practices to store and re-use. It is sad that in many housing layouts and also in cities, the storm water channels are being converted into sewage channels.

Again coming back to water sources, their use and reuse are vital to conserve their use. It is possible to use the existing resources to give sufficient per capita water for all Indians for various uses listed before. Let us examine some of the water use technologies.

**Water use Technologies**

In its simplest form, they are micro irrigation systems mostly operating in villages - often not even constructed by govt. agencies. Most of these areas belong to the unirrigated part of agricultural statistics quoted earlier.

Due to the drinking water mission, some of these areas may have a ground water hand pump - some working, some defunct. Otherwise traditional wells, small ponds etc are there. During rains they fill better especially helping the cattle. The fields of the marginal and small farmer receive rain directly and through micro-irrigation channels.

Due the costs involved, it is difficult to imagine that all these unirrigated areas are covered through good water supply and irrigation systems as in the "green revolution" areas of agriculture (about 1/3rd of the total irrigated area).

This is where the real first challenge to the Indian engineer lies. Use of modern plastic liners can reduce wasteful leakages; also drip or sprinkler systems can reduce the need for water to the minimum but capital costs can be higher; some govt. funds are available. Also single local pump systems can be used... many more ways to reach water; I am not unaware of the poor electricity supply in most areas.

In recent USAID conference titles "Transforming Development through Science, Technology and Innovation" (July 13-14, 2010) held at Washington D.C, for which I was a special invitee, the background papers indicated that a Grand Challenge in Development at a global level to fight against poverty is as under:

Reduction of agricultural water consumption in non - arid and semi - arid regions of Africa by 70%, with an increase in agricultural yields over 5 years.

What is told here for Africa is applicable to most parts of rain fed, unirrigated arid and semi - arid agricultural regions for India.

The engineering challenge would need work with farmers, agricultural experts, technology developers, energy source providers, NGO's etc.

I have placed it first because it affects most people of India (about 40 to 50%) and the challenge is to work with water sources available nearby and at a low cost, which can be used productively and cost effectively.

**Use in High End Agriculture**

Major use of water is in the upper end agriculture - irrigated 1/3rd of agricultural area (we have seen the statistics earlier). In these areas, water use is often extravagant so much so it makes the soils go saline along with the fertilizers and chemicals which float upwards. It is essential to devise engineering methods against such a water - wastage. In addition, such an agriculture which takes away almost 70% of used water in India, waste water not recycled. It is sent away from the fields along with agro - chemicals which further pollute many downstream water bodies.

It is necessary to work with farmers and local governments, convince them and have recycling plants set up near their village. Also reuse the recycled water. In Israel about 80% of water used for agriculture is recycled and used. They are increasing the percentage. In Spain it is about 35%.

A bigger sociological challenge is because water is given free or practically free to most of these farmers, who are relatively rich and influential.

I am reminded of the experience of India's greatest engineer Bharat Ratna Sir M.Visvesvaraya in the Poona Irrigation District, when he was posted in April 1899. Among many books by him and on him, I will refer to one: Memories of My Working Life (written by him 1951) published by Karnataka Engineers Association and Karnataka Engineering Service Association (2001). It has 158 pages. I am amazed at the range of water works he has done all over India (even the present areas of Pakistan)! It is a book worth reading by all engineers interested in water works. It will inspire them to go through the variety of challenges successfully. His works post retirement were huge and immense. So those who are retired or nearing retirement may look at such major possibilities around water.

**Use of Village Ponds**

Most villages in India have about two ponds. Punjab has about 13,000. Dr. R.Venkataraman former Chief Engineer, ISRO and who is a part of the fraternity of IE, had taken up a major task for advising the then Punjab Govt. (2000-2001) on many water related issues referred to the office of Principal Scientific Adviser (then Dr. Kalam) and TIFAC (Technology Information, Forecasting and Assessment Council). I being the Chief Executive of TIFAC and Scientific Secretary PSA Office, had been closely associated with them. The village ponds which existed for centuries had to support about 5 times more human population and also much bigger sized cattle. Naturally the sewage and the cattle wastes find their way to the ponds. BOD (Biological Oxygen Demand) levels (we had them measured for several of them) were intolerable.

A plan for central sewage collection, recycling and reuse of water and clearing up the ponds initially etc were drawn up. It was also for reuse in agriculture. About to be launched. People supported the project and were ready to give free manual service and their land for establishing the treatment plant free of cost. (They asked us to reduce the labour cost from the Project Estimate.) Alas! The state assembly elections were announced and all new works came to a halt! Govt. changes, priorities change.... Well that is India.

But it has given us a rich experience.

It is a great engineering challenge to clean up all village ponds including use of recycled water for continued reuse on sound engineering principles and hand them over to the villagers to manage. They will !

Their health will improve. Cattle will be better. It will be a great boost to economy, society and people in terms of income increase and quality of life.

There are several other items in terms of use of water in rural India and in agricultural sector. Due to limitations of time, let us move to urban domestic and industrial use.

**Urban Domestic Users**

When we consider the big metros, and over 5000 cities and towns, domestic water supply is a serious problem - not just in terms of quality but also in terms of regular availability. Delhi the capital city is no exception. Reasons are manifold: from poor planning to mindless designs to callous maintenance. The so called treated water to the lawns of the palacious buildings in the Lutyen Delhi, will be an illustration as to how primitive we are in waste water recycling and reuse.

In a metro city, typical use of a 5 members household would be about 20,000 litres per month. In cities and towns it will be much less. In the metros the same municipal water or the municipal water or the pumped ground water from the apartment complexes are used for cooking, bathing, toilets, house cleaning and car washing. Assuming the corporation supplied water is really of a potable standard, is it the way to waste it, when most of the city dwellers struggle for water? Now a days I find year round movement of private water supply trucks in most cities. So much is the shortage.

Now what happens to the used water? They are discharged as sewage, either in open channels or in buried pipes. There are often over flows of sewage from the buried sewage pipes, year round, through manholes.

Most households are ill-equipped to use stored rain water, as they were not originally conceived in the house design. Best use of them without treatment would be for gardens or washing outside the houses. Where in metros and cities can we find houses with lawns, plants or trees? There is a pressure for land and space, understandably due to rocketing prices of real estates.

As far the drinking water, middle class is resorting to water purifiers. Low cost purifiers have been launched by Tatas recently. Also there is an increasing resort to bottled water (costly imitation of the developed countries). For those who talk about climate change issues from the podiums studded with bottled water, I would like to quote some statistics:

- Worldwide, nearly 2.7 million tons of plastic is used to bottle water each year.
- Making plastic bottles to meet demand for bottled water requires millions of containers of oil annually.
- Burning used plastic bottles releases toxic chlorine gas in air and leaves toxic ashes containing heavy metals which pollutes the soil and ground water

Real environmental friendly solution would lie in providing a good quality potable water in the taps, if necessary by a separate plumbing line and use another plumbing line for the supply of clean recycled water for other domestic uses.

In addition the amount of leakages in domestic taps, garden taps in apartment complexes etc is a huge waste. Engineering solutions for reduction of consumption right from the time people open the tap in the morning for brushing their teeth to the time when they go to sleep, are required. Engineers may also take into account the sad fact that we Indians in general lack a civic or public good sense. Of course all solutions cannot be from engineering and technology. There has to be public education through celebrities and also through ‘micro economic’ measures of water charges. Of course, a government can acquire the moral right to charge more for water only when it gives regular, dependable and quality water supply: that primarily comes in the domain of engineering in terms of meticulous planning, design, foresight, quality implementation and above all maintenance which should be built into planning, design, and foresight exercises.

**Urban Public Use**

In addition to domestic use, in the urban areas there is a considerable use of water in the public domain. Parks, shopping areas, hotels, restaurants, public toilets, bus stations, railway stations, places of worship etc.

What happens in a typical city has been described beautifully and professionally in a recent article in Hindu, September 11, 2010 by S.Viswanath under the title "Treating the sick water". It is worth looking at some extracts from the concluding part of the article:

"We need urgent steps to rectify this problem in urban India. Unless a vigilant citizenry demands that their local self - governments take up sewage collection and treatment on high priority we will pay through epidemics such as dengue, chikungunya and malaria, taking lives and debilitating a populace.

Islands of excellence exist. Some apartments and some layouts have very good functioning waste water treatment and reuse plants. But many are simply 'garbage-in-garbage-out' systems.

At a larger scale the wastewater treatment plants at Cubbon Park and at Lalbagh in Bangalore are almost state-of the-art and one simply cannot make out the treated wastewater as sewage.

The need of the hour is to invest enough attention in collecting every drop of sewage generated from the city, convey it to decentralized wastewater treatment plants, treat them to high standards and release or reuse them as appropriate".

Wastewater recycling and repeated reuse alone can solve the water and health problems of urban India.

At this point I would like to mention a few words about the Cubbon Park and Lalbagh in Bengaluru referred to above. The engineering expert deeply involved in these projects is Dr. R.Venkataraman former Chief Engineer ISRO. He did them post-retirement from ISRO, at Bengaluru and several plants at Hyderabad.

But the linkage to these plants was way back to his ISRO days. When Prof. Dhawan was Chairman, ISRO, the ISRO Satellite Centre (ISAC) needed (during 1984) additional water of about 0.5 MLD than allotted to them by the water supply authorities, who had released the quota for ISAC as per norms. Instead of trying to use governmental pressures (as is the usual mode we all adopt even today!) ISRO chose a method of engineering solution. Dr.Venkataraman gave the design for recycling the waste water from ISAC and the reuse was primarily for use in gardening, landscape maintenance etc. Mr. R.D. John, Chief Engineer supported it. ISRO top management agreed to the novel idea. Water use goes up as organizations grow. So it was expanded to 1 MLD during 1988, with some additional design features of secondary treatment with pressure filters, disinfection etc. To get the water source, additional sewage water from NAL (then National Aeronautics Laboratory) in whose campus ISAC was located, was obtained! The recycled water was used for several other internal uses in ISAC including toilet flushing and cooling water for central AC plant. The plant is functioning even now. ISRO adopted such systems for a few other ISRO centres as well.

It is the outgrowth of these experiences and of course continual learning and application by Dr. R.Venkataraman, led to his building the state-of-the-art Lalbagh and Cubbon Park plants which are about 1.5 mld.

Many of you present here and not present here can make wonders to urban India, if you all and IE crusade for proper urban water planning: for separating storm water channels and sewage channels and more importantly by establishing several sewage / wastewater recycling plants and facilities for the repeated reuse of the water.

City should almost be self-sufficient with only about 25% of fresh water coming from surface and ground water sources and the rest coming from recycling. Not a difficult target for our capable engineers.

**Industrial Use**

Many of the huge water consuming industries need to bring down their consumption. Compared to the international standards of water consumption, we are very poor in most industries. This is an urgent task.

Simultaneously wastewater recycling and reuse is a must.

Even those who cannot reuse for various reasons have to let out only the clean recycled water (either collectively - a few small medium industries together or individually). May I suggest that some of you approach the management of big industries located in and around Bangalore to help them audit their water use and also their recycling capability.

Let us not get into escapism of saying that there are pollution control boards etc. We all know the reality. As engineering professionals we should avoid the cynical acceptance of a situation for which there are sound and cost effective engineering solutions.

**Major Users**

If we tackle the above mentioned areas described above such as rural use, agricultural users, urban domestic users, urban public use and industries, we would have solved the immediate water problems of India and also improve health of people. And also the income levels of many rural Indians will increase, thus giving a special boost to the Indian economy. The real market size can go to 1.2 billion unlike the present one which is half of it or less as rest of them are just subsisting.

**Other Issues**

There are many more items, I cannot cover here. Therefore I would mention some of them. There are areas of India which have brackish water, or water with arsenic, fluoride etc. There has been a lot of talk on them, R and D papers etc. for several decades. But ground solutions are eluding. Many of you know the reasons. They require practical and urgent solutions. People living in such areas suffer.

Desalination is another area which is talked about, sometimes hyped. If waste water reuse on the lines suggested above is adopted on a large scale, pressure for desalination will not be high even for coastal cities. It may be needed in select places where other solutions may not be easily implementable. Also in terms of ecological balance including marine life, I am not sure whether a large scale resort to desalinated water from sea can be sustainable solution.

Interlinking of Rivers is another complex issue. To adopt it as a panacea is ridden with many engineering, sociological and ecological issues. Small scale interlinking locally may be attractive for a few areas.

Use of big rivers for internal Water Ways can be attractive proposition as it is very energy efficient. There is a full fledged study by TIFAC as a part of its Technology Vision 2020 exercise.

These are some of the engineering challenges. Also there are a number of areas attractive for R and D both in terms of commercial prospects as well as social good. Amongst the several pragmatic and immediate-to-implement items mentioned in this brief address, R and D in select topics will also require attention, as future new engineering ventures will emerge out of them.

In the world governed by Word Trade Organisation (WTO) regimes, engineers need to be aware of the legal issues of Intellectual Property Rights (IPR).

## Conclusion

I have galloped through three mega engineering tasks for the engineering community as a whole. They will touch the lives of our people very positively and help the society in many ways. Also most of them will make good business propositions as well, thus contributing to the growth of the economy. Professional commitment and pride are crucial for these to be implemented. May the dreams and actions of Sir M. Visvesvaraya (whose 150$^{th}$ birth anniversary falls this month) and the visionary and practical wisdom of Prof.S. Dhawan (whose 90$^{th}$ birth anniversary falls this month - a unique September) be our guiding lights and inspiring forces.

Engineers have to wake up and jump out of their routine grooves to create a positive dynamism all rounds.

Thank you.

Some units used relating to volume of Water:

1. 1 Cubic Metre equal to 35.315 cubic feet; 1 Kilolitre; 1000 litres.

2. 1 Hectare metre (ha m) equal to 8.10 Acre ft; 10,000 Cubic metre.

3. 1 Cubic Metre equal to 1 Billion Cubic Meter (BCM); 109 m3; 0.1 million ham (M ham).