GREEN TECHNOLOGIES

FOR A BETTER FUTURE

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"Global Warming? Asia Melting?"

A painting done by the author in 2008 in acrylic on canvass and displayed at the National Environmental Engineering Research Institute (NEERI), Nagpur, India.

Preface

Global warming is still something not fully appreciated by many. But, whether it happens or not, our fuel resources are running out and that is something we cannot neglect. In a world that is warming up year by year, all countries will eventually need to live in a low-carbon economy and there will be more and more business opportunities in the new 'green' economy.

The book indicates the direction in which business and technology will develop in future, and will, hopefully, serve as a valuable and informative guide for all developers, town-planners, architects, engineers, infrastructure handlers, industrialists and business people in general. The world is poised for large investments in clean energy and environment protection. The book does not enter into the UN's political debate on how much each country must do, and by what time. The book emphasizes the green technologies involved so that we know what has to be done, and how it will help. It is hoped that as Benjamin Franklin once said: 'an investment in knowledge pays the best interest'.

As explained in Chapter 3, 'greening' essentially involves three related activities: minimizing use of fossil fuels like coal and oil, adopting renewable sources of energy like wind, solar, and biomass, and protecting existing forests and developing new ones. All three of these activities present us with business opportunities. We may begin with those items that will cost us little or nothing to reduce carbon emissions, and, in fact, benefit us by conserving our scarce resources of fossil fuels and water.

Business opportunities also include the measures that all countries will have to take to protect their own people against the emerging problems from climate change and rising sea levels. Finally, all the measures we take will have to remain sustainable as explained in the book. Sustainability will be ensured when the people see its benefits and gain something from it.

This book updates and adds new material to an earlier version of the book entitled 'Global Warming and Climate Change' by the same author published by the Indian Environment Association in 2010. This book concentrates on 'Green Technologies' which will help us attain a low-carbon economy so that we can all develop our own countries without ruining the universe.

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In recent times, to encourage research and practice of sustainable and renewable energy a 'Nobel Sustainability Trust' has been instituted (not to be confused with the Nobel Prize) and they have given a new award for work in the field of renewable energy. It is interesting to note that the Trust that earned money from good old fossil fuels has now donated a prize for sustainable and renewable energy!

History records that the famous Nobel family had 3 brothers, Alfred, Ludwig and Robert, all of whom made money from their activities. Alfred (who donated the world-famous Nobel Prizes) made money from explosives, while Ludwig and Robert earned from oil. Alfred also earned from oil through investments in his brothers' firm. Oil was plentiful in Baku near the Caspian Sea where oil-fires were to be seen almost at ground-level. Their first ship, a tanker for carrying oil to Russia in 1878 was made of all-steel to avoid fire-risk and called "ZOROASTER" perhaps in tribute to the fire-worshipping Zoroastrians whose theses were popular among Europeans at that time. Their designs were copied by other ship-builders building oil tankers.

Acknowledgements

I am indebted to The Indian Environment Association for publishing my initial book on 'Global Warming and Climate Change' in 2010, which has led to this book with emphasis on Green Technologies. I would like to acknowledge the various authorities who kindly contributed to the case studies, mentioned in Appendices 2 and 3 of this book. Without their cooperation this book would have diminished in value. The author is also grateful to the various newspapers, magazines and the Internet which have highlighted some of the findings in this interesting subject across the world.

Finally, I would like to acknowledge the patience and support given by his own family and by the publishers, McGraw Hill Education (India), and McGraw-Hill Construction during the preparation of this book.

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CHAPTER 1

What is Global Warming? Does it Really Affect Us?

When it comes to the future, there are three kinds of people: those who let it happen, those who make it happen, and those who wonder what happened!

—John Richardson, Jr.

1.1 The New Carbon Problem: Accumulation, Long Half-Life, Heating Potential

As is well known, dry air on the earth consists of nitrogen (78%), oxygen (21%), argon (0.9%), CO_2 (0.035%) and other gases to a smaller extent. Oxygen comes from photosynthesis. Some oxygen is consumed in respiration, combustion and decomposition, the rest accumulates and supports life on this earth. The relative proportion of each constituent varies in every pocket of air depending on which action predominates in that pocket. Consequently, air moves from one region to another according to pressure and temperature variations.

The three major gases emitted from human and animal activities are listed as follows together with their approximate relative proportion released:

1. Carbon dioxide (CO_2) 77% of gases released
2. Nitrous oxide (N_2O) 14% of gases released
3. Methane (CH_4) 8% of gases released

The other three gases which together constitute only about 1% of the gases released are the following:

1. Hydrofluorocarbons (HFCs)
2. Perfluorocarbons (PFCs), and
3. Sulphur hexafluoride (SF_6)

These three gases are emitted from industries and are also responsible for ozone depletion.

Water vapour is also included in the earlier list as it traps heat in the atmosphere, thus adding to global warming. Water vapour in the atmosphere is mainly the result of natural evaporation from water bodies, wetlands, agriculture, etc., with evaporation increasing as the local temperature increases.

The six gases mentioned above are also referred to as 'green house gases' (GHG) of which carbon is the major constituent. What are the sources of these gases? A few of the major sources are listed below:

1. Natural sources (e.g., human and animal respiration, enteric fermentation in animal guts leading to release of methane from animal belching, anaerobic decomposition of organic matter, evaporation from water bodies).
2. Industrial chemicals and solvents used in manufacture.
3. Power generation and power use for industrial, commercial and domestic purposes using fossil fuels like coal, oil and gas.
4. Transport traffic by road, rail, air and sea using fossil fuels like oil, petroleum and gases.
5. Agricultural sources and soils giving nitrous oxide, carbon dioxide, etc.

Major Emission Sources of Concern

India has been a party to the UN Framework Convention on Climate Change (UNFCCC), the ultimate objective of which is 'to achieve the stabilisation of greenhouse gas concentration in the atmosphere at a level that would prevent dangerous interference with the climate system'. The Convention was started in March 1994 and required all signatories to prepare an inventory of greenhouse gases and their removals by 'sinks', in accordance with specified methodologies. The greenhouse gases of concern were identified as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Their sources were many.

All participants were trained through workshops. Several national laboratories in India including agricultural, forestry, environmental, mining, petroleum, industrial and other subjects were harnessed in this work to develop India-specific emission factors wherever possible. Otherwise, the default emission factors given by the Intergovernmental Panel on Climate Change (IPCC) were used.

All countries (including India) are preparing and/or updating *source-wise inventories of greenhouse gas emissions* from urban and rural areas so that they may prepare or revise their policies and programs for control accordingly. These inventories are based on the emissions of GHGs from the area or country in question, due to various activities such as:

- Power plants for electricity generation for all housing, commercial and industrial activities using various fossil fuels (coal, oil, gas, etc.) in public or private (individual) installations
- Transport by cars, trucks, aircraft, ships, etc., using various fossil fuels (petrol, CNG, diesel, etc.)
- Specific industrial manufacturing processes
- General commercial retail and services
- Agriculture, livestock, forestry and other land use
- Municipal services and infrastructure for water supply and waste disposal

On a global basis, the percentages of emissions from a few major sources are approximately noted as follows:

Source	Percentage
Electricity and heating	24.6
Deforestation and other change in land use	20.6
Transportation	14.5
Industry	12.8
Agriculture	13.5
Other fuel burning	9.0
Fugitive emissions	3.4
Waste	1.6

The previous list helps to bring out clearly that deforestation releases more greenhouse gases (CO_2, etc.) than either the whole transport sector or the industrial sector. The control of deforestation seems to be urgently necessary. With regard to transportation, it is shown that air travel, globally, accounts for only about 1% of the emission whereas ground travel (by cars, etc.) accounts for the remaining 13.5%.

The Energy Research Institute (TERI) Estimates

TERI estimates that, by 2031, India may be importing 750 million tonnes of oil and 1300 million tonnes of coal, besides its own internal production of coal and oil. This enormous quantity of fossil fuel would cause various other problems in transportation, storage and carbon emissions. Both the outgo of foreign exchange and carbon emissions will be staggering. The government's expenditure on subsidies will also be staggering. If India has to compete in the global market in future, renewable sources of energy will have to be developed early on, even obtaining at somewhat higher prices today, so as to keep industries and transportation going in the future without adding to the carbon emissions.

Long Half-life

For years, we did not realise that the carbon dioxide, methane and other gases (collectively called GHGs) released by us from various activities were accumulating in the atmosphere and leading to a slow change in our climate. Climate change is a very important phenomenon affecting our lives currently (of which we have learnt only recently) and which is also going to affect our lives seriously in the years to come.

The major constituent carbon dioxide (CO_2) has a half-life of about 120–150 years. This means that the carbon dioxide released about 120–150 years ago is still there. The accumulation continues to increase at a faster and faster rate as the years go by and population and industrialisation keep on increasing. In 2005, the average CO_2 concentration in the atmosphere was estimated at 385 parts per million (ppm) and found to be rising by 2 to 3 ppm per year. With the help of data from several stations and complicated mathematical modelling, the average (CO_2) worldwide temperature increase is estimated to require capping at 2°C by 2050 to avoid irreversible changes. The general data seem to show that the world has already warmed, on an average, by 0.8°C above its level in 1750. Experts say that the difference between the earth being an ice ball and being comfortable for human development is a mere 5 to 6°C. Hence, 0.8°C is quite a significant increase. Much greater increase is predicted over the next 30 years.

Methane (CH_4) has a half-life of 9 to 15 years while nitrous oxide (N_2O) has an estimated half-life of 120 years.

Heating Potential

Different gases have different global warming potential (GWP). So, we try to express everything in terms of 'CO_2-equivalent' (CO_2-e) by multiplying its volume by a factor to express its GWP compared to a GWP of 1.0 for CO_2. For example, compared to CO_2, methane appears to have 20–30 times greater potential for earth warming than CO_2. Actually, its mass is often multiplied by 21 in order to get 'equivalent CO_2'.

In India, animals are a substantial source of methane (cows, sheep, goats, etc.). Cows are venerated in Indian culture and not butchered for their meat. In Western countries, cows are generally ready for butchering after they stop giving milk. Therefore, there are many old cows in India which live long after they have stopped giving milk, but continue to give methane and carbon dioxide from belching! India is reputed to have the world's largest livestock population totalling around 485 million, collectively emitting 11.5 million tonnes of methane annually.

Similarly, N_2O from agriculture and soil has to be multiplied by 310 to get its CO_2-e value. Community wastes (faeces, dung, solid wastes), discussed later, are other important source of carbon emissions. For obvious reasons, CO_2-e is a better measure of the warming potential than CO_2 alone.

1.2 Carbon Emission Factors

Estimation of Emission Factors

One could estimate the theoretical emission factor from stoichiometric considerations knowing the chemical equation of the reaction. However, in practice, these factors are given as ranges because the actual emissions depend on the chemical composition of the substance and the efficiency with which it is burnt. Coal, for example, may be lignite or hard coal, and oil may be heavy diesel or light diesel, etc. The efficiency of the ignition device also affects emission.

A few commonly used emission factors are given in **Appendix 1** for the benefit of those who wish to compute the emissions due to the use of various typical fuels and activities. An example is also given to show how carbon emissions from a building in Mumbai are calculated.

1.3 Carbon Absorption in Nature (Photosynthesis and 'Sinks')

As is to be expected in an efficient ecosystem, carbon production is balanced by carbon absorption in nature so that recycling can go on. There are several ways in which carbon released to the atmosphere is absorbed back in nature, making a cyclic turnover from time to time. These carbon absorption sites are called 'sinks'. Some of the important sinks are grass, trees, forests, soils, peat, permafrost, ocean waters, carbonate deposits in deep oceans and the natural sequestration (storage) process by which carbon is locked up for ages and ages in the earth in the form of oil and coal.

Photosynthesis is another main mechanism by which carbon is removed from the atmosphere. It is denoted by the following chemical reaction:

$$106\,CO_2 + 122\,H_2O + 16\,NO_3 + HPO_4 + 18\,H \rightarrow \underset{\textbf{(algae)}}{C_{106}H_{263}3O_{110}N_{16}P1} + \underset{\textbf{+ Oxygen}}{138O_2}$$

On this basis, the weight of oxygen produced is about 1.6 times the weight of algae produced by photosynthesis. Algae is the primary source of food, and together with the oxygen it keeps the world functioning. This is nature's way of turning carbon into advantage.

All living things breathe in oxygen and give off carbon dioxide. During daylight hours, trees, grass, etc., undergo both respiration and photosynthesis. During night time, they undergo only respiration. About 14% of the oxygen produced through photosynthesis is consumed back in respiration, and the rest helps all living things to survive.

As it happens, natural calamities (storms, floods, etc.) sometimes occur. Some of the dead vegetation (containing carbon) eventually reaches deep underground and with the heat and pressure present there it gets converted over millions of years into coal, oil, etc., collectively called 'fossil fuels'. This is nature's way of withdrawing carbon from the atmosphere and 'sequestering' it for years and years. It is only when the fossil fuels are burnt that carbon is released back to the atmosphere and the circuit is completed. Thus, this cycle takes millions of years to complete. It is an irony to behold that what takes millions of years to form is converted back to carbon in just a moment through combustion.

Of course, the sad part is the fear that what takes millions of years to form into coal or oil will be exhausted through over use by mankind in the next few years.

Grass, bamboo, and such vegetation, however, constitute a much shorter time cycle as they grow quickly in a few days withdrawing carbon from the atmosphere by photosynthesis and die just as quickly returning the carbon to the atmosphere. They are, in fact, referred to as 'carbon-neutral' items.

Carbon sinks have been discussed further in Chapter 3.

Net Accumulation

Net accumulation of GHGs can be expressed in terms of 'CO_2-equivalent' contained in the atmosphere. It is the result of CO_2 produced from all the sources, ($\sum$Sources) less the CO_2 absorbed by the various sinks ($\sum$Sinks), i.e.,

$$\sum\text{Sources} - \sum\text{Sinks} = \text{Net accumulation, } \Delta s$$

Figure 1.1 gives an idea of the necessary strategy to be followed in controlling the carbon build-up in the atmosphere, namely to minimise the sources and maximise the sinks, worldwide. It does not matter where the source is located or where the sink is located. Both are part of the overall atmosphere around the earth and the earth is revolving. This means that the source may be in one country and the sink may be in another country.

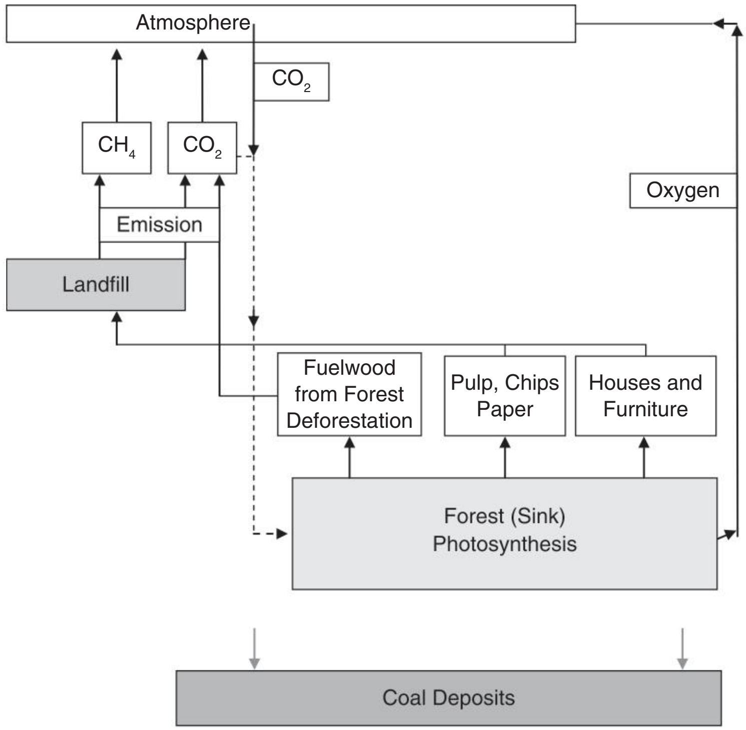

Figure 1.1 *Forests play an important role as a source and sink of O_2 and CO_2 in the atmosphere. The carbon is held sequestered in the wood of the forest trees and the furniture, paper, wood products and housing made from the wood. When this wood finds its way into a landfill and decays, it releases carbon. The forest may also get buried in earth and eventually, after centuries of exposure to heat and pressure, the wood may be turned into coal. When coal is burnt, carbon is released back to the atmosphere and the cycle goes on.*

India's Emissions have been Increasing

According to Ganga et al (2011), the emission data for India as a whole from the year 1990 to the year 2000 show that the CO_2-e value has increased nearly 50% in just one decade.

Data	1990	1995	2000
Pop, millions	855	930	1000
CO_2, tera-grams	615	849	1032
CH_4	17.92	18.85	19.61
N_2O	0.158	0.185	0.217
CO_2-e	1040.3	1302.2	1511

Tera-gram = 10^{12} gram

They have also shown that the major contributors to the emissions were the power plants and industries. The relative contribution of carbon from power plants compared to industries increased between 1990 and 2000. After power plants, the next largest increase came from the transport sector followed by the domestic sector. Carbon dioxide remained the major emission gas from a control point of view although India is regarded as an agricultural country.

Global Warming May be Due to Other Reasons

All scientists do not seem to subscribe to the carbon theory. Some feel that it may be due to other reasons. Notable among the latter is Dr U R Rao, former chairman of ISRO, India, who states in a paper that 'cosmic rays enter the solar system and contribute to the formation of low-level clouds which keep the earth's heat from dissipating and lead to warming'. It is felt that perhaps global warming is due to cosmic rays as well as carbon build-up. Whatever the cause, it is clear that the world is running out of resources (coal, oil, water, etc.) and we must make some effort to find other (and perhaps renewable) resources before it is too late. It seems that we may also save some money in operation by using renewables like solar and wind energy, and thereby improve the economy.

1.4 The Global Emission Situation and India

Standard procedures have evolved for estimating emissions from various sources and various types of fuels so that the emission inventories prepared by different countries can become comparable. Some useful 'emission factors' are given in Appendix 1.

Summing up all the different emissions and the population involved, one can determine the total emissions and the emission per capita per year. Vast differences are seen between countries because of their climate, their standard of living, their natural resources and lifestyles.

For the same reason, within each country, the per capita emissions from urban and rural communities vary considerably. A country may add up all its emissions for the sake of comparing with

Table 1.1 World Average Emissions of CO_2 (2005–2006)

Country	Approx CO_2 Emission (Tonnes/Person/yr)	Approx Population (Million)	Approx Total Emission (Billion Tonnes/yr)
USA	20	300	6.1
Canada	20	30	0.60
Australia	18	20	0.36
Saudi Arabia	15.7		0.43
Russia	11		1.6
Japan	10		1.3
Germany	10.4		0.86
UK	9.2	75	0.7
Italy	8.3		0.5
France	6.6		0.42
South Africa	8.6		0.40
China	4.62	1,250	6.0
Turkey	3.7		0.3
India	1.3	1,200	1.56
Tanzania	0.14	–	0.05
World Average	**4.5**	**6.6 bn**	**29.7**

other countries. A selected list of countries is included in Table 1.1 to show their total and per capita emissions. However, for its own studies, the information might need to be segregated into its rural average and its urban average to get a better understanding of the true situation.

Of the 29.7 billion tonnes of CO_2 emitted worldwide per year (2005–2006), 65% is reported to be from fossil fuels (coal, oil, etc.) while 18% is said to be released from deforestation, and the rest from other sources. As said earlier, deforestation is thus a major contributor worldwide.

On *total* emission basis, USA was the maximum emitter in 2005–2006, and China came a close second. In 2010, it became the other way around. China became the highest (total) carbon emitter because of its high population, and USA was the second highest.

Although *USA* has the highest per capita emission rate, it is not a signatory to the Kyoto Protocol since the Bush regime. However, some of its states such as *California and New Mexico* have prescribed emission 'caps' without waiting for the Federal Government. With Barak Obama coming in as president, a big policy change has occurred. The USA has pledged that 30% reduction in emissions will occur by 2030.

India and *China,* as developing countries, have not yet been required to cap their emissions under the Kyoto Protocol, but both have large populations and, thus, large total emissions. This is a sore point with many countries. China is the largest contributor and India is among the top 10 emitters of CO_2 in the world because of its large population, although its per capita emission is still low. India's total emissions in 2007 have been estimated at 1.74 billion tonnes per year, which is a jump of 118% from the 1990 emission figures. In fact, crude estimates of the Government of India suggest that, by 2030, the country's emissions may be somewhere between 2.77 and 5.0 tonnes per person per year or the total emissions may be anything from 4.0 to 7.3 billion tonnes per year.

On a per capita basis, it is clear that many of the world's poorest countries emit less than 1.0 tonne/cap-year. In the past decade, India has been emitting 1.3 tonnes/cap-year. A few other countries (e.g., Turkey, China) occupy the next higher slot of around 3 to 4 tonnes/cap-year. The European countries emit around 10 to 12 tonnes/cap-year while USA and Canada are in a slot of their own. The world average is 4.5 tonnes/cap-year. India is evidently well below the world average on per cap basis. But, this argument is increasingly not finding much favour owing to India's (and China's) large population.

Europe as well as many other countries have put voluntary 'caps' on their emissions. France generates 78% of its electricity from nuclear sources which are free from CO_2 emissions. Denmark is exemplary in developing most of its new energy requirements from renewable sources (wind, especially, which is plentiful in the northern countries). Gasoline is made prohibitively expensive in Denmark—a carbon tax is levied on CO_2 emissions. The UK is another country which is windswept, and several wind turbines and wind farms exist with a well-organised feed-in system to enhance the availability of power in their city grids. One authority estimates that the per capita emissions would have to be brought down from the current 9.2 to 2.0 tonnes/person/year by 2050 to meet global requirements. This is difficult. A newspaper in the UK states that a 10% reduction in per capita emissions from the country should be possible without much effort if the public determines to do something about it.

It is reported that, globally, carbon which was being added to the atmosphere at about 0.9% per year up to 1990 is being added at a *higher* rate of 3.5% per year since 2009. This is said to be mainly due to countries such as USA and China. There are some (*Economic Times*, January 2011) who suggest that countries be allotted a target emission on per capita basis depending on their GDP per capita (adjusted for purchasing power parity). Countries that exceed the target could be fined which would fund a 'green climate fund'.

1.5 The Kyoto and Other Protocols

The UN has been arranging conferences of countries to arrive at a consensus on how to control carbon emissions and promote carbon absorption.

The Kyoto Protocol was first adopted in 1997, came into force in 2005 and was to expire in 2012. However, it has now been extended for another 10 years. Its principle has been 'common but differentiated responsibility 'for the present situation, and works on a slow, but sure, consensus basis. It singled out some 36 countries initially for early action (China and India were excluded). Under the Kyoto Protocol, countries are also rewarded financially for what are called certified emission reductions (CER) under the clean development mechanism (CDM). Indian entrepreneurs are reported to have benefitted from this arrangement in more than 300 instances. Payment has also been made to some countries for setting up new *dedicated* forests especially for carbon absorption through photosynthesis for reducing carbon accumulation.

Another global meeting took place in Copenhagen in 2011. Earlier, it was found that many of the listed countries had exceeded their targets. The meeting decided to go by what is called 'NAMA' (nationally appropriate mitigative action) for each country, a sort of laissez-faire, targetless scheme. The Copenhagen meeting, however, worked on an important scheme called the *REDD scheme* under which payment is made for control of deforestation because considerable deforestation (and consequent carbon emission) is occurring worldwide for the sake of clearing forest land for more agriculture and habitation.

Stopping 'deforestation' is evidently the first thing that we must do. It is estimated that this would straight away reduce the CO_2 by as much as a good 20%. The REDD program (*reducing emissions from deforestation and degradation)* instituted in 2010–2011 by the UN is meant to do just that. It evidently admits that what we need is both reduction of carbon emission sources *and* increase in sinks to absorb the carbon. We need both equally. We should, therefore, be willing to pay for both. In fact, we are already making payments through 'carbon credits' to secure rights over newly developed dedicated forests. Now, we have to make payments under the REDD scheme for saving our existing forests.

Many more such transactions have to take place and the concept has to be formally incorporated into every country's carbon-reduction strategy. Every country will need to have its own equivalent national 'carbon credit' and 'REDD' programs so that an overall increase in sinks occurs, worldwide. We can say that our programs are working out to be successful when carbon sources reduce and carbon sinks increase. We need an inventory of both to tell us so. We would be able to do this better if only we knew exactly what we have, and what scope we have for improving upon them.

The Indian Viewpoint

Regarding emission control, India argues that it would not like to be bound down by 'caps' on emissions at this stage when so much development has yet to take place in the country. A large part of the country, for instance, is yet to be electrified (a government report states that nearly 44% of the population is without access to electricity). The Bureau of Energy Efficiency, India, argues that based on the observations from many countries of the world, a minimum oil-equivalent consumption of 3.5 tonnes per person is needed to reach a human development index of 0.9. Energy availability in India today is only 0.53 tonnes oil-equivalent per capita. Thus, at least a six-fold increase in energy availability is needed.

A transition to a developed society is not possible with less than six-fold increase in energy. Given a stable global population of 10 billion people, it implies that the average per cap emissions would have to be stabilised at less than 3.5 tonnes per person per year. This implies that the scope for India to increase its emissions is only two- to three-fold while energy availability has to increase six-fold. *This is possible only with a heavy emphasis on renewable sources of energy and increase in 'sinks'.*

Historic Accumulated Load

The emissions given in Table 1.1 are the estimated emissions of 2005–2006 from a few countries. However, as stated earlier, the 'half-life' of CO_2 is long, 120–150 years. Hence, it takes a long time dying out and meanwhile it goes on accumulating in the atmosphere. Any CO_2 released by a country over 200 years ago is still there in the atmosphere to exert its warming effect. Thus, those countries that industrialised early have historically contributed to the problem since early times and need to do something about it more urgently than others. India and China say they came much later into the picture, but are not given any benefit due to their late entry.

Historically, it was the developed countries which filled up the atmosphere with their own emissions all these years and have now left very little 'space' for any additions to take place. According to some, the developed nations have already occupied 70% of the carbon space, though population-wise they account for only about 20% of the world's population.

According to some countries, if caps have to be specified for developing countries, the developed ones should be prepared to pay for the costs and provide technology support for achieving the targets. The developed countries do not agree with this reasoning. On the sides of the developed countries, it is argued that more than two-thirdsof the global emissions have occurred since 1970. There are strong back and forth arguments as each country would like to spend the least it can.

1.6 How Does Climate Change Affect Us?

In recent times, we seem to be hearing frequently about two things that are happening in terms of climate change: extreme weather fluctuations/conditions in different parts of the world (including India) and rising sea levels owing to melting glaciers and decreasing snow cover in the polar regions. These are two major signs to indicate that the inevitable climate change is occurring.

When temperature increases (even slightly), the whole world's ecosystem is affected and climate change results. According to scientists of the Indian Institute of Science, Bangalore (2010), the world has already warmed by 1°C and if nothing is done to reduce carbon in the atmosphere, it will warm further by another degree Centigrade to become 1.7 to 2°C by 2030.If we do nothing about carbon, rainfall would increase by 4–5% by 2030 and 6–14% by the end of the century. As the temperature changes, wind patterns also change. As a consequence, rainfall patterns change. By warming the troposphere, we change the weather patterns globally and increase the likelihood of extreme weather events.

Some parts of the world face droughts or dry spells while some others face floods and heavy rains. Some face cyclones and hurricanes. Recently, Indonesia and Philippines have been ravaged by cyclones while Hurricane Katrina ravaged New Orleans in the USA. Many countries in Asia faced tsunamis. In February 2009, London was paralyzed by an unusually heavy snowfall, while in the same season Mumbai had an unusually warm winter. In 2010, Kerala, India, experienced an unusually warm winter. These variations may be just a result of the vagaries of the weather—or may be a result of global warming. Only statistical analysis of the data over many years will tell the true situation. It will, however, be too late by that time. Climate change is likely to become irreversible by that time.

Some people joke that when predicting the weather, the meteorology department never seems to be right for any specific location over a very short period of a day or two, then how can one expect it to be right about climate change on a global scale and years in advance! They dismiss all talk about climate change.

Sea level rise: Snow melt due to temperature rise may or may not affect the sea level depending on where the snow was originally located. Glaciers and melted snow located on land above sea level (e.g., Greenland) will flow into the sea as new water and increase its level. Global sea level rise has been averaging at 1 to 2 mm per year. A sea level rise of several feet is forecast over the years to come. However, icebergs already floating on sea will also melt but they will *not* affect sea level (it is like ice melting in a glass of water that does not raise its water level).

It's Getting Hotter, Faster than We Think

The latest observation (2009) is that the release of CO_2 and the consequent temperature increase on our earth are taking place even faster than anticipated earlier. The global average sea level was observed in 1961 to be rising at 1.8 mm per year, but since

1993 it has been observed to be rising at 3.1 mm per year. During the past one century, as a whole, there has been an increase of about 17 cm in the level of the seas. Sea level is expected to rise further by a total of 15 to 38 cm by 2050 and 46 to 60 cm by 2100.

1.7 The Many Impacts of Climate Change

Climate change can potentially have many impacts on us, and the impacts may have many follow-up impacts too.* The impacts will be felt in several direct, indirect and cyclical or further follow-up ways. These impacts will be over and above those caused by natural calamities such as earthquakes, floods, tsunamis, etc., which are more violent in nature, and which we assume will keep occurring in the future also.

The impacts of climate change and its follow-up impacts are relatively more subtle in nature but just as devastating eventually. The direct impact of temperature rise may be glacial melt while its indirect impact may be flooding downstream and soil erosion and landslides. These impacts may result in further follow-up impacts in the form of soil damage, water quality deterioration, disruption of farming activity and farmers' livelihood. The glacial melt may also lead to sea-level rise which has its own follow-up impacts on coastal areas, ports and towns, and their drainage. The impacts may be quite serious for a country like India with a long coastline.

A few of the important impacts which may be caused by climate change are listed as follows:

- Health
- Habitat
- Drainage

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*In recognition of their outstanding work drawing the attention of the world to global warming and the resulting impacts of climate change and sea level rise, a Nobel Prize was awarded in 2008 to Mr Al Gore, former Vice-President of USA and the International Panel on Climate Change (IPCC) whose Chairman is Dr R K Pachauri, Director-Gen, The Energy Research Institute (TERI), India. Many will never forget Al Gore's classic film *An Inconvenient Truth* which brings out the story of global warming as greenhouse gases are trapped in the atmosphere.

- Agriculture
- Resources
- Business
- Political

Health-Related Impacts

According to WHO, some of the health impacts are, for example, temperature-related illnesses and even death, extreme weather-related health effects, air pollution-related health effects, water and food-borne illnesses, vector-borne and rodent-borne diseases, effects of food and water shortages, psycho-social impacts on displaced populations and conflicts over domain.

Public health: The incidence of malaria, dengue and other vector-borne diseases in coastal areas will increase. Already these are serious public health problems of the poorer countries located in warm and wet areas. Now, they are likely to be aggravated due to global warming and sea-level rise. Health authorities will not be able to rest on their laurels. Kevin Lafferty, an ecologist at the US Geological Survey, says that the positive global picture hides shifting regional ones. Malaria is expected to move to different areas, even as its overall range may decrease, he says.

According to reports from Mumbai, owing to various causes, the number of cases of malaria that have occurred in 2010 have doubled compared to the previous year. Pathogen and insect population dynamics are affected by temperature and humidity. Besides malaria, filaria and dengue, Kala-azar and Japanese encephalitis are also prevalent in India. The mosquito transmission window is likely to increase by 2 to 5 months in a year in Rajasthan and Jammu and Kashmir. It may also decrease somewhat in Orissa and some of the southern states.

Even in a richer country like the USA (where pollen count is usually given in city newspapers every day for allergy reasons), an excessively high pollen count was experienced in the spring of 2010 reportedly due to global warming. High pollen count leads to an increase in allergy cases.

In all countries, some species will be lost forever, while some others will adapt to the change and survive. We hope the famous Indian tiger will survive in the future.

Habitat-Related Impacts

Habitat-related impacts occur mainly in coastal areas owing to cyclones, hurricanes and the like and due to submergence of large tracks of coastal lands as the sea level rises. Many species may get wiped out and people displaced. After all, 40% of the world's population lives in coastal areas.

Sea islands and deltas, in particular (Maldives, Bangladesh, etc.), will perhaps vanish under the sea. Already, a small island off Bangladesh has just been reported to be 'missing' in the Bay of Bengal, submerged in the rising sea. The people of Maldives have had their first government-sponsored meeting of officials to see what can be done about Maldives which is similarly threatened by the rising sea. Millions of people living in low elevation coastal zones of China (80 million) and India (30 million) will become homeless, and several millions in Japan, Indonesia, Vietnam, Egypt and the Netherlands will have to move.

Within India, Maharashtra, Gujarat and West Bengal are said to be the most vulnerable. The Arabian Sea's average temperature is rising by 2 to 5°C over the past four decades. This increase is leading to an increasing number of cyclones originating in the Arabian Sea and hitting the west coast of India and Pakistan.

Harbours of coastal towns will need to be raised or rebuilt or relocated to keep them functional. A recent (2009) study by the Indian Space Research Organisation (ISRO) shows that the sea has moved inland by around 15 meters in Gujarat's Valsad district in the past decade. This year, waves as high as 12 meters at Udvada on the Gujarat coast pushed the waters of the Arabian Sea dangerously close to the structure (fire temple) housing the holy fire of the Parsi Zoroastrians.

In this chaotic situation, it is well known that the poor people will suffer the most. The poor often settle in the most vulnerable areas because these areas are the ones available at lesser cost, and the poor people generally have weaker health and inadequate nutrition. India is not new to the problems of refugees for political reasons. Now, there will be refuges for climatic reasons (either flooding or drought, climate extremes).

Another habitat-related problem is reduction in *species diversity*. It is claimed that a species can survive temperature changes if they occur relatively slowly giving time to move away to more optimum temperatures, either up a mountain or horizontally up a latitude. Warming has a slow but sure effect on species diversity. Each species has its optimum range of temperature for good growth, and enormous changes are likely to occur relatively rapidly everywhere in the coming decades. The Eucalyptus tree of Australia, the beautiful flowers of Africa, the fruit trees of the tropics, the vineyards of Spain, all will move higher up a mountain or up a latitude to get away from the warm climate dogging them. About 18 to 33% of the species are expected to disappear in the bargain.

Habitat-related impact is likely to be severest at the North and South poles where snow melt has started and may increase over the years. Many species (such as polar bears) that thrive in very cold temperatures will find themselves stranded in the summer.

Yet another habitat-related impact is due to the high level of carbon dioxide in the atmosphere. This CO_2 is acidic and tends to dissolve in sea water which is alkaline. The oceans act as enormous 'sinks' for absorbing carbon from the atmosphere. The pH drops from, say, 8.1 or 8.2 to 7.8 or so. At a pH of less than 7.7, reef development ceases altogether.

Storm Drainage

Adverse effects will occur on the natural drainage (rain water run-off) of coastal towns. Proper drainage is essential for controlling all mosquito infections. In fact, there will be no urban storm run-off to the sea but perhaps the reverse. Many areas of coastal cities such as Mumbai will need pumping to clear accumulated rain waters. Mumbai is already constructing its first storm water pumping station at Haji Ali (first conceived in the early 90s as a result of expected rise in sea level).

Agriculture

In general, the rising sea level will affect agriculture, forestry, water resource, health and all economic activity in coastal areas. Wells in coastal areas will turn brackish in quality. Agriculture will suffer. People living in low-lying areas (generally, poor people) will have to migrate to higher lands. This movement of people will cause social and, in some cases, political problems. Every one degree rise in temperature is said to reduce wheat production by 4 to 5 million tonnes per year. India's famous mango crop output is also reported to be suffering owing to climate change. India's famous agriculture

Guru, M S Swaminathan feels that India should 'go into battle mode on the climate front'.

Governments will have to survey coastal lands and earmark areas that are likely to be affected by rising sea levels in the next 20 or 30 years. And, make sure such areas are either not habited or the people already living in such areas are moved in time and resettled elsewhere. We will also have to make sure that new people do not settle and begin activities in such areas.

Fresh water resources are expected to be affected by even one degree change in temperature. By the year 2020, millions of people in parts of Africa and Asia are expected to experience increasing water stress as a result of climate change. Crop productivity and food security will also diminish. In India, the gross per capita water availability due to various causes is expected to decline from 1820 cum per year in 2001 to 1140 cum per year in 2050. As more than half of the agricultural land in India is rain-fed, climate change in the form of drought will be devastating for the country.

Warming of the highlands in the central part of Asia, where practically all major Asian rivers have their origin, will affect the volume and timing of their river flows. These are all international rivers and the sharing of their waters has always been a major source of friction between upstream and downstream states. Water wars have been predicted.

Risks to Conventional Businesses from Climate Change

The overall 'risks' to various businesses will be enormous owing to the occurrence of extreme events and rising sea level. For instance, life and property insurers will have to insure against risk of floods, droughts, health problems, damage to property, etc. There will be more insurance business but increased risks too. Insurance premiums will increase.

Agricultural credit and crop insurance business will increase, if not farmer suicides.

Municipal engineers of coastal towns will receive 'kicks' from the public as drainage systems will fail to work for no fault of theirs. The meteorology department will also be a difficult place to work in. Predictions will be more than likely to fail.

Medical and hospital personnel will often be overloaded with accident work (victims of floods, heat waves, cold waves, etc.). So will automobile and aircraft industry be affected by various 'extreme' events (too many or too few passengers).

Hotel and restaurant businesses will have uncertainty of clients (too many or too few clients) for the same reasons.

Agricultural and agro-industrial businesses will be much affected not only in coastal areas but also in other places. Some will be totally displaced. Fruits, vegetables, tea, coffee, aromatic and medicinal plants, basmati rice and wine cultivation can all be affected by temperature and humidity changes. It is estimated that crop reduction could be as high as 40% by the year 2100. Similarly, shifts in forest produce will occur affecting tribal and other populations that depend on it.

Global warming will tend to distort the resources picture. Countries that had some resource advantages or technical knowhows may suddenly find themselves devoid of buyers, and others equally suddenly in demand. Sites which were once populated may, perhaps, be unable to support any human habitation at all. Agricultural areas may be inundated and soils ruined.

Those who have resources (such as petroleum, bauxite, etc.) that can be developed in spite of the earlier-mentioned problems will tend to become 'aggressive' (show their clout) and increase prices.

Security and Political Risks

India will perhaps have another huge exodus on hand from Bangladesh and other areas such as the Maldives, Lakshadweep, Andaman, etc. from where people will be fleeing low-lying lands. There will, thus, be a strain on India in terms of land, water and food security. All this will lead to certain dangers and political insecurity as well. The people of Tuvalu near New Zealand have negotiated with New Zealand for full migration rights for their entire population (small as it is).

Global warming is one of the most serious problems facing us in the near future, but only few people seem to realise it. Especially, India will suffer because of its long coastline (7600 km) with many low-lying areas, its large number of poor people inhabiting disaster-prone areas, and the adverse impacts on health and agriculture. Climate change will eventually lead to three broad groups of problems of strategic importance for every country:

1. Global water stress affecting water supplies and agriculture and related business everywhere,
2. Large-scale uprooting of people and their migration to more favourable areas, throwing the existing infrastructure, employment and business patterns out of gear, and
3. Disasters of a high magnitude, again affecting employment and business.

India does not have the infrastructure to deal with extreme weather events and disasters. Some other countries like India also lack infrastructure and have a high proportion of poor people among them, such as some countries in Asia and Africa. They will be equally badly hit by climate change. It is felt that at least two countries, Russia and Canada, will surely be the gainers in some ways from global warming. Their climate, agriculture and local business opportunities will stand to improve with a little warming!

Business Opportunities in the New Green Economy

Perhaps, the world is witnessing a major change in business opportunities. As we have seen earlier, the older, conventional businesses are likely to undergo disturbing and difficult times caused by climate change and sea-level rise. At the same time, several new businesses will start emerging to respond to the changing times. This is how life goes on. The people who respond adequately and rapidly to the changing times will prosper. Those who do not will fall by the wayside. Governments will probably resist as long as they can. Business organisations, on the other hand, will more readily realise that their future depends on developing a low-carbon economy and will increasingly support efforts for:

- Undertaking carbon emission reduction programs, wherever possible, in domestic commercial and industrial applications.
- Finding more and more efficient ways of using the country's scarce resources, such as coal, oil, water, minerals, etc.
- Developing and applying new and renewable sources of energy for power generation and transportation.

- Promoting new and more effective ways of using the country's 'sinks' for carbon absorption and sequestration.
- Promoting new and more effective ways of controlling 'deforestation'.

This is what the book is all about. The reader will see from the following chapters that many new businesses will be thrown up because of this thinking, and prosperity will come to those who grab these emerging opportunities at the right time. Unfortunately, experience shows that the more thickly populated regions in developing countries which need economic development the most are often the slowest to grab new ideas, while the regions that are already doing well are the ones which have welcomed new ideas and technologies.

Russia and Canada are already reported to be claiming parts of the North Pole (in anticipation of its melting) to explore oil and gas which is stated to be lodged there in good quantity. The US Energy Dept and industry partners have just proved that it is not necessary for the area to melt. They have extracted frozen 'methane hydrate' from a well in Alaska. The frozen piece was found to burn like a candle. Looks like fossil fuels will continue with us for a long time.

CHAPTER 2

Planning for the Future

In planning for the future, it is safest to assume that climate change will occur in spite of our best efforts. Every member of our global society is playing a role in damaging the environment.

2.1 Can the World Control Carbon Emissions?

A question often asked is:

Q: 'Now that we know carbon is the problem, can the world control carbon emissions?'

A: The answer is an emphatic YES—but the yes comes with a caveat: 'Give us enough time!'

Thereupon, the second question is: How much more time? We have little time left!

It has been estimated that the total annual global carbon dioxide emissions have to be less than 30 billion tonnes by 2050 so that the carbon dioxide concentration stabilises at about 450 ppm in the atmosphere by that time, and the average temperature increase is limited to 2°C to keep the impact acceptable. In this effort to maintain a balance between the sources and sinks, India as well as all the countries of the world are being asked to do their bit, as we are all in the same global boat discharging our waste gases to a common pool called 'atmosphere'.

We have no doubt that the world will control its carbon emissions gradually. People do have the intelligence to find solutions to difficult problems. For example, years ago we were told that our wastewaters were contaminating drinking waters, and we developed disinfection technologies. Then, we were told that our wastewaters were causing other pollution problems, and we developed various wastewater treatment methods—natural and mechanised—to solve the problems. Then, we looked at sludge and said that it needs improvement or otherwise the food chain will be contaminated and health will suffer. We even developed the use of membrane technologies to remove finer and finer material. We undertook process change and operations change and tried to take a holistic view of the matter. But, we left out the gaseous emissions which we thought went up to the sky and got lost. We have no doubt that we will find ways of controlling these gaseous emissions too. But, time is the problem.

It is estimated that, with 'business as usual', the emissions will double by 2050. The difficulty comes from the fact that all the countries of the world are developing industrially, their populations are growing and their lifestyles are becoming more and more affluent. Control is being increasingly frowned upon by the people. Hence, cooperation between countries in control matters is unpopular, and it takes time for building up of the necessary political will for action. As a strategy, only stepwise measures can be taken to reduce carbon in the atmosphere. Essentially, the steps to be taken are to somehow reduce the carbon emissions, ensure that this carbon is absorbed as much as possible in nature through photosynthesis so that the amount accumulated in the atmosphere is below the estimated limit of 450 ppm. This means we need to pay more attention to control methods, have more 'sinks' and less deforestation.

2.2 Use of Promotional and Punitive Mechanisms for Reducing Carbon in Atmosphere

Promotional: Carbon Credits for Reducing Carbon Emissions

An interesting method has been developed on an international basis for reducing carbon emissions by encouraging people in developed countries to pay, willingly, people in developing countries for helping them meet their specific caps (emission limits) in developed countries. On the whole, the method is good as a starter (because it is voluntary), but, for the same reason, it is rather slow in reducing emissions.

The theory goes as follows: Since all people are discharging to the *same* atmosphere–stratosphere, it does not matter whether 'x' controls or 'y' controls its emission as long as the overall total carbon emission of the world reduces. So, the thinking goes that let the ones which can reduce their emissions cheapest (developing countries) control their emissions and the others which benefit from it (developed countries) foot the bill. Thus, carbon emission control has led to a new kind of 'trading' between countries. A share-bazaar-like market transaction takes place, located in London, Chicago and elsewhere.

Certified Emission Reductions (CERs)

Over 300 Indian beneficiaries have so far developed acceptable methods for reducing carbon emissions from their factories or operations located in India. Others active in this direction are China, Korea, Brazil, Chile, Mexico and Egypt. China is reported to be next to India in this activity (with 123 successful cases). Within India, Gujarat ranks the highest. The Indian people have been quick to grab the incentives given by the UN in the form of carbon credits for certified emission reductions (CERs) carried out under the Clean Development Mechanism (CDM) and the Kyoto Protocol.

The carbon reduction 'credit' is paid for by a beneficiary located in a developed country in Europe which benefits from this reduction towards meeting the target set by his/her own country for reducing carbon emission. This speaks well of the Indian entrepreneur who takes the risk of developing and implementing a carbon reduction process in his/her operation in India from which he/she ultimately benefits on a yearly basis when a person from a developed country pays for it.

A UN sponsored agency in *London* is designated to certify emission reductions (CERs)* and validate the trading under UN's CDM which funds it. They have teams to visit factories and ensure claims are justified and sustainable before payment is made.

A new agency called Chicago Climate Exchange (CCX) has recently come up in the USA for similar transactions from the USA. It is said to have over 400 members and controls over 600 million metric tonnes of CO_2. Similar exchanges are coming up elsewhere (including one in India).

Some 'win-win' Examples from India and Elsewhere

At present, Indian companies try reducing carbon under *corporate social responsibility* (CSR) projects and proudly mention it in their annual reports. Some have happily added to their bottom lines too through the international route of CDMs such as the following examples:

- The Aditya Birla group's Grasim Industries which manufactures cement aims to reduce 1% of its carbon dioxide emissions per year. It has earned ₹17 crores so far by selling credits in Europe.
- A Fluoride manufacturing company in Gujarat has made a process change which earns it nearly $1 million/year.
- By using low-cost *solar energy* for cooking meals for schools, temples, trusts, hotels, a company earns credits besides saving use of expensive LPG gas for cooking.
- Biogas plants are built on BOOT basis for industries producing wastewaters which can be treated in UASB-type digesters. The biogas is used to replace use of coal in boilers for producing steam in the same factory.

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*A carbon credit signifies 1 tonne of carbon-equivalent/year *less* emitted (i.e., saved or reduced). Some time ago, it used to sell on the market for about Euros 8.00 per unit per year. At present, the price is less (the price is variable according to supply/demand).

- Waste-to-energy plants based on industrial and municipal solid wastes have become a big source of power for many industries, thus saving on fossil fuels.
- Hindustan Unilever has just patented a process for soap-making using 'mixers' instead of steam (which requires boilers and fuel). 15,000 carbon credits, 10 years.
- Delhi Metro and Indian Railways are installing more efficient electrical coaches and signaling systems so as to reduce CO_2 emissions, and earn CERs. The Delhi Metro is estimated to have reduced the equivalent of 51,000 cars on the roads.
- An industrial group is similarly benefiting by setting up a wind farm (Suzlon) to generate electricity in a windy location.
- Almost every house in certain parts of Turkey has a solar panel on its roof to produce hot water for bathing/washing. India with more sunshine could benefit similarly.
- Any municipal body can benefit by collecting gas (CO_2 and methane) from its garbage landfill site and using the methane as fuel (Mumbai? Navi Mumbai?)
- The State Bank of India is lending ₹17 crores to farmers for setting up gobar gas plants to reduce their need to burn fossil fuels. They expect to be able to help 500,000 farmers over the next 3 years and earn 25 million carbon credits in return. Their project will also give sanitation to the villages and reduce deforestation besides saving time for the womenfolk daily looking for dried twigs to light their stoves.

Instances of emission reduction are continually added to the earlier list and speak well of Indian talent and Indian efforts in mitigating carbon emissions. Fresh carbon credits worth ₹4,000 crores are reported to be due to India in 2010. Some joke that Indians are good at finding ways where money is involved. But, this is by no means an Indian trait alone. The whole world does the same. So, we must be proud that we are good at it.

Some Win-win Examples of Carbon Credits for Afforestation

- A German industry has shown 'a farmer's patience' by cultivating a large forest and dedicating it for absorbing atmospheric CO_2 through photosynthesis. (A single tree can absorb

1 tonne CO_2 over its lifetime.) The industry gets paid under CDM's carbon credits.

- Two similar cases of 'dedicated' forests are reported to have come up successfully in India, one in Haryana and another in Andhra Pradesh.
- Small farmers in Africa are reported to be planting trees (with a farmer's patience) so that they can harvest timber or fruit and also profit from selling 'carbon credits' on the world market.

There are no examples as yet of international or national awards being given for control of deforestation under the REDD scheme. This is discussed further in Chapter 3.

Risks and Costs Involved in Development

There are obviously certain risks and costs involved in seeking 'carbon credits'. Cost is first involved for development of technology within the industry for reducing carbon emission. This cost is followed by costs for verification of claims by required authorities, consultation fees of agents, etc. Finally, the technology has to stand the test of sustainability, or it may be refused and the development costs may go to waste.

CDM is now said to be a maturing global market. Transaction costs for CDM projects are said to vary between US $8,000–105,000 for small projects and US $50,000–250,000 for larger ones. The revenues generated by the projects are generally much higher.

Special mention must be made of *'dedicated forest'* projects for which there is seemingly much scope in a tropical country like India. For CDM support, the requirements are that the land set aside for a dedicated forest should *not* already be a 'forest land' nor should it be mandated by the local government to become forest land. The dedicated forest should either be a new 'afforestation' project where there was no forest standing for many years earlier or it should be a 're-forestation' project with nothing prior to 1989. The idea is that CDM wants its funds to help a new additional forest to come up as a result of its intervention. CDM funding is more in the nature of bridging finance to make a scheme attractive. It is not for supporting existing forests or forests which would have come up anyway as a result of a mandate.

This system operates under the Kyoto Protocol which was to end in 2012, but has now been extended for another 10 years, namely until 2022. What will happen after that? Will it be extended in the same or some other form?

Caps on Indian Companies?

As said earlier, the pace at which things are moving is much too slow at present. In spite of mandatory requirements for capping emissions from the developed countries of the West, carbon emissions globally have increased quite substantially. And the developing countries, especially China and India, have increased because of their large populations; China is currently ranked no.1 in total emissions (ahead of the USA) and India is no.4 in total emissions, although it is low on a per capita basis.

Post-2012, the world would, in fact, like to put some 'caps' on emissions from Chinese and Indian companies as well. Caps on Indian emissions would mean two things: first, the sellable credits in Indian hands would be somewhat reduced because Indian Companies would first have to meet their own cap requirements and only sell the surplus credits. Thus, Indian Companies would have less carbon credits to sell, and this may lead to an overall increase in price of credits. Second, the global demand for carbon trading would increase as more Indian companies would also want to buy the available credits in order to meet their own caps. The prices would increase as the carbon credits available for sale may remain more or less the same.

Punitive Measures to Reduce Carbon Emissions—The Carbon Tax

There are countries visualizing a carbon tax to promote use of cleaner fuels in their respective countries. To equalise its effect on goods imported from other countries where a carbon tax does not exist, they wish to levy tariffs calculated to equalise these taxes. In this way, their own country's competitiveness is protected. It is feared that such levies may have little effect on total emission reductions of a country where imports constitute only a small fraction of their national supplies.

New Zealand aims to levy a carbon tax at the rate of US $24.74 per tonne of carbon dioxide emitted.

International airlines flying over Europe are also likely to come under such a punitive measure. Airlines landing or taking off from European airports may be soon required to pay a Carbon Emission Tax based on their aircraft emissions. This measure may not much succeed in reducing emissions, but rather be another way of adding to the income of the airports.

2.3 The General Approach in Planning for the Future

In planning for the future, it is safest to assume that climate change will occur in spite of our best efforts. With climate change, two major follow-up effects will occur: climate instability and sea level rise. We saw earlier in Chapter 1 that both these effects will have serious consequences. Hence, we should be prepared for the worst.

The general approach adopted world over for planning counter-control measures for the future are two-fold:

1. Adaptive measures and
2. Mitigative measures.

These measures are explained in the following:

1. *Adaptive measures* are taken individually at each country level for the benefit of protecting its own people, to forestall the harsh ill effects of climate change. Knowing that climate change has already set in, each country would like to identify what needs to be done and do its best to help its people to manage the likely ill effects of climate change and sea level rise. *Adaptive measures* depend on the country's topography, ability and affordability to undertake them. The measures are country-specific and are taken by each country at its own cost for the benefit of their own people.
2. *Mitigative measures* are measures adopted by each country to fulfill their global obligations to satisfy their 'common but differentiated responsibilities' by meeting protocols set by other agencies for decreasing use of fossil fuels, increasing use of renewable energy, etc., and for developing other

mechanisms (afforestation, etc.) for reducing GHGs globally. *Mitigative measures* are also expected to be undertaken by each country at its own cost although they are taken for the common good of the world. The targets for reduction set earlier are likely to get revised in due course as realities of the situation face us.

The question is who pays for these measures? For both measures, the country itself pays. Both adaptive and mitigative measures are generally planned and paid for by the countries themselves.

The developing countries want the developed countries to pay for the former's efforts, and also provide the necessary technology at no cost, as their historical emissions over the past several years (when they developed unrestrictedly) have caused the problem in the first place. This is a contentious issue and we have not yet heard the last word on it.

2.4 Developing Countrywide Adaptive Measures for Safety of Local People

Various *adaptive* measures have to be planned for the well-being of our own people to protect them wherever they are, either in our coastal areas or in our inland areas, against the impacts of climate change and sea level rise. Global warming has already set in and as the world's countries continue to dither on mitigative measures, climate change and sea level rise will only increase as time goes and the security of all our habitats, water and other natural resources will be at stake.

For example, the island countries (such as Maldives) and countries with long coastlines (such as India) will have the problem of rising sea levels, and the possibilities of facing hurricanes, tsunamis, etc., besides the vagaries of uncertain rainfall, while inland areas may have the problem of climate and rainfall extremes, melting glaciers, floods followed by diminishing river flows and severe water shortages.

A few of the broad adaptation strategies desirable for *all* countries to develop are indicated in the following:

- better knowledge on impacts and vulnerabilities so that they can plan their control measures better,

- improved disaster preparedness and management, including monitoring and an efficient and rapid communications system,
- improved healthcare facilities and systems including their extension services, and
- good governance including responsible decision-making and community empowerment.

As Dr R K Pachauri, Director General, The Energy Research Institute, New Delhi, states 'developing countries should take simple steps to deal with extreme climatic events'. In fact, these measures are of a general nature and require all countries to adopt them. In the case of India, additional specific measures depending upon the actual location (coastal, inland and Himalayan) also have to be undertaken. These are described as follows:

- Coastal areas
- Inland areas and
- Himalayan areas

Different measures have to be taken to suit each specific terrain. Also, there are substantial differences between the states. Some states are coastal, whereas some are fully inland. The measures, therefore, have to be state-specific and need to be administered state-wise. Mitigative measures are more country-specific as they have to be a part of global efforts. They have, therefore, to be planned centrally and executed either state-wise or through centrally administered mechanisms.

Developing Specific Adaptive Measures for Low-lying Coastal Areas

As an example of adaptive measures for a large coastal city, let us take the example of Mumbai City, India, to which people from all over India gravitate for seeking employment. Mumbai has been identified as one of the six major cities vulnerable to global warming and sea level rise. The measures contemplated are:

- Some years down the line, flooding of low-lying lands is expected to occur in coastal areas near Mumbai. These areas have to be identified from now and people living in such areas have to be warned and moved in course of time. It is generally the very poor people who settle in low-lying areas as such areas are often available more cheaply. New development in such areas has to be prevented also for the same reasons.

Flooding due to rain (storm runoff) will also occur in some parts of urban areas of coastal cities. To clear this runoff, more pumping stations (and, therefore, more electric power) will be needed to remove accumulated storm water from the streets of such cities to keep traffic moving. (The first pumping station in Mumbai is already under construction.)

- Wells in coastal areas will turn brackish. Agriculture and mangroves in these areas will be affected by saline intrusion.
- More storage of grain will be needed to tide over difficult food periods. Better seed banks will be needed all over the country.
- Fresh water resources will become crucial in such regions. Water conservation and recycling will be needed. Evaporation from lakes will need control. Better waste management will be needed too.
- Foundations of buildings will need special protection against sea water ingress and resultant corrosion.
- Malaria, dengue, etc., will increase with flood and cause health problems. Increased control measures against accumulated pools of water and easier availability of medical facilities will, therefore, be needed.
- Besides health, all business and commerce will be affected by uncertainties in climate and sea level rise. Sea level rise will affect every port and harbour in India.
- Most importantly, migration of people will occur from low-lying coastal areas to higher areas to avoid rising sea levels. This will cause severe hardships. These migrations will be not only from areas within the country but also from neighbouring countries. Political and security problems will have to be envisaged and some steps taken.

Developing Adaptive Measures for Inland Areas

Inland areas will suffer from a different set of problems from the coastal areas just referred to. The adaptive measures needed for inland areas will have to take into account the same erratic climatic situation besides the effects of drought and early snow and glacier-melting especially of its northern rivers. Populations will tend to move from coastal to upland areas.

- Snowfall and glaciers in the North have their own dynamics. As everyone knows, snow, as long as it remains snow, holds the water in a solid form (much like a dam holds it in a liquid form). As soon as the temperature warms up, the snow melts and the liquid gushes forth. Thus, the major north Indian rivers which are snow-fed, will have floods in them as the snow melts early with global warming and will perhaps have no water in them in later months. There will, therefore, be problems of too much and too little. This will also affect agriculture.
- Rapid snow melting will cause flooding of low-lying lands adjacent to the river banks. These areas have to be identified from now and people living in such areas will have to be warned and moved in course of time. It is good to recapitulate that generally it is the very poor people who settle in such areas as they are often available more cheaply. New development in such areas has also to be prevented for the same reason.
- Cyclones can damage areas irretrievably. Areas in the Sundarbans of India and Bangladesh have had their soils irretrievably damaged by the resulting floods making it necessary for people to migrate to other areas in the interest of agriculture.
- Flooding due to rain will also occur in some parts of urban areas of cities on river banks. More pumping stations (and, therefore, more electric power) will be needed to remove accumulated storm water from the streets of such cities to keep traffic moving. An example can be quoted from Bihar where the Kosi river (known as the river of sorrow) leads to flooding and much damage. With their fields under water for long periods, people have turned to growing 'makhana' or fox nut which grows well in water-logged farms/ponds. From hesitant beginnings, it has become a flourishing business today. The benefits of adaptation.
- In Assam's flood-prone districts, people have learnt to survive floods by building their houses on stilts, planting more flood-tolerant crops, innovating more flood-holding systems, undertaking more biodiversity conservation methods and other coping strategies.
- Wells adjoining such rivers will reflect the same situation of too much and too little water in them. Agriculture in these areas will demand a renewed need for irrigation to tide over

difficult periods of snow and manage the new water situation. The entire river status in North India will need review. The much advertised system of 'linking the rivers of India' will perhaps have to be reviewed/modified to meet the new situation taking an eco-system view.

- Agricultural practices will have to change in drier areas (such as Rajasthan). Crops requiring less water will have to be cultivated. More storage of grain will be needed to tide over difficult food periods. Better seed banks will be needed all over the country.
- Water conservation and recycling will be needed. Greater importance will have to be given to rainwater harvesting and groundwater recharge. Evaporation from lakes will need control or replenishment with water or treated wastewater. Better waste management and use of natural soil treatment will be needed too. Desert-like areas have to be converted into oasis areas where agriculture can be undertaken. Forest cover can also be similarly increased. Odisha has some examples to offer.
- Malaria, dengue, etc., will increase with floods and cause health problems. Increased medical facilities will, therefore, be needed.
- Besides health, all business and commerce will be affected by uncertainties in climate.
- Most importantly, migration of people will occur from low-lying coastal areas to higher areas to avoid rising sea levels. This will cause severe hardships. These migrations will be not only from areas within the country but also from neighbouring countries. Political and security problems will have to be envisaged and suitable steps taken.

Developing Measures for Himalayan Areas

The Himalayan area is important for India as it provides sustenance to the main land mass by feeding its three major and perennial rivers, the Ganges, Indus and Brahmaputra, with waters that help to provide drinking water to millions of people, and waters for various industrial, hydropower and irrigation purposes. The Himalayan area also has its unique eco-system and biodiversity, its agriculture and spectacular tourism.

Climate change may affect snow melt, endanger river flows and bring drought. It may need integration with forest preservation programs and need better monitoring and understanding of various phenomena.

Thus, the adaptive measures required are so many, so varied and so expensive that a developing country like India will hardly be able to afford them all and yet have resources left over for a meaningful program of mitigative measures. Yet, we will have to find the resources at least for the inescapable measures.

Coastal and low-lying areas continue to be developed as if nothing will ever happen. Business goes on as usual. The rate of change is so slow that we fail to see that it is actually happening and we fail to understand its full significance. In many parts of the world, land values in coastal areas actually keep on increasing with time instead of being sold at a discount. This convinces the people that all's right with the world. No need to worry now! Such is the deception caused by its slow speed. Many governments that cannot afford or feel timid about taking adaptive measures find this a good excuse for delaying the necessary budgetary allocations. Where political will is lacking, even basic actions such as strengthening the construction bye-laws, formulating locational guidelines and such other developmental guidelines are sometimes not taken.

2.5 Developing Mitigative Measures for Global Reduction of Carbon

The various *mitigative measures* the countries could take to reduce global carbon emissions and their accumulation are many and depend upon their location, their climate, their lifestyle and other factors including financial resources. As a general strategy for managing carbon abatement, a step-wise approach to reduction is proposed, but it is necessary that all countries do something to reduce their emissions and facilitate absorption of carbon from the atmosphere. One country doing something and its neighbouring country doing nothing is not envisaged. All must do something.

Our approach in developing *mitigative* measures specifically for India is based on the belief that some scope for reduction in emissions perhaps exists in the larger, metropolitan industrial cities of

India, while relatively little scope, if any, exists in the villages and small towns of India where the per capita emissions are already very low. Yet, we have to develop our villages and small towns where India really resides. *Poverty alleviation has to, therefore, go hand in hand with mitigation if public support is desired.*

We may join other countries in a global effort to undertake some mitigative measures for reducing carbon emissions, *provided these efforts also benefit our country, in some way, and help in poverty alleviation. Every measure proposed should meet this test of benefit to the country before it is adopted.* It would be true to say that what is good for a country like India, is also likely to be good for the world at large. This is the principle established by the Prime Minister's Council for National Action Plan, details of which are given further in this chapter.

1. India has already announced (ahead of the Copenhagen Conference) that it proposes to bring down carbon emissions by 20–25% between 2020 and 2030. It is said that the biggest impact will be felt by small and medium enterprises that form India's manufacturing base, but are carbon intensive. They also do not have the capital to shift quickly to cleaner fuels. Steel and cement industry, traditionally carbon intensive, could come under stress. Nearly 75% of rural and 25% of urban population still burn wood and want to shift to kerosene or gas. This shift will need resources and affect the emissions picture. In any event, the world can be assured that India's per capita emissions will never rise above the average of developed countries. The proposed approaches to the development of mitigative measures for India are discussed further in Chapter 8.

China has also announced that it hopes to cut carbon emissions by 40–45% by 2020 from its 2005 levels.

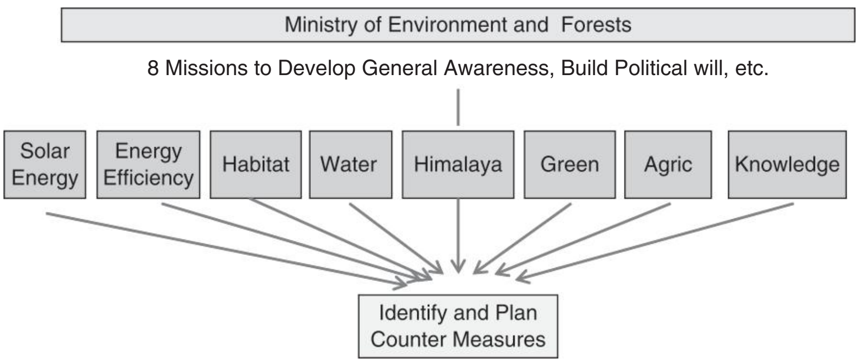
2.6 India's National Action Plan on Climate Change (NAPCC)

India, to its credit, is developing a National Action Plan on Climate Change (NAPCC) for which several national 'missions' have been identified to cover the following eight important aspects:

1. Solar energy
2. Enhanced energy efficiency
3. Sustainable habitat
4. Water (soon expected to become crucial)
5. Sustaining the Himalayan ecosystem
6. Green India (afforestation)
7. Sustainable agriculture
8. Strategic knowledge for climate change.

While the missions are under the various ministries, an overall Council has been established under the Prime Minister bringing government, industry and civil society together. The missions are expected to not only help control emissions but also put India on a low carbon pathway. The Council first met in 2007. The Council noted that the average world concentration of CO_2 in 1820 (pre-industrial era) was 280 ppm while in 2005 it was 379 ppm and by 2050 it was desired to be stabilised at 450 ppm. In planning for the future, India hopes to become prosperous but not wasteful.

The Council rightly felt that, in view of the large uncertainties in magnitude of climate change impacts, it was not desirable to design strategies for responding to climate change alone. The Council rather felt that it was needed to identify and prioritise strategies that would promote development while also co-benefitting climate change objectives. For this goal to be achieved, it realised that higher growth rates were necessary and this growth would have to be inclusive and sustainable.



Details of each mission were spelt out, hopefully to be refined as necessary through experience.

Mission	Status	Objective
Solar	Launched	To increase the share of solar energy in total energy mix from 1,000 MW in 2013 to 3,000 MW in 2017. Also expand other renewable energy options (nuclear, wind, biomass) and issue tradable renewable energy bonds. Also to aim for PV production @ 1000 MW plant and concentrator solar power of 1000 MW.
Solar Phase II	Launched June 2013	Targets deployment of 1,000 MW of rooftop projects, both off-grid and grid connected. Phase II is targeting to bring cumulative solar capacity to 10 Gigawatt by 2017.
Enhanced energy efficiency	Launched June 2010	To enhance energy efficiency through improved efficiency, better appliances, finance and fiscal measures. Expected to reduce CO_2 emissions by 99 million tonnes and oil-equivalent by 23 million tonnes per year.
Sustainable habitat	Draft prepared	To integrate urban planning with energy conservation, recycling, urban waste management, etc., and shift to public transport. Set up bio-diesel plantations to enable 20% blend by 2012. Finance public transport systems.
Water	Under Preparation	To integrate water resources management, conserve and distribute equitably, improve recycling, pricing, adopt new and appropriate technologies especially for coastal areas.
Sustain Himalayan Ecosystem	Under Preparation	To understand how the Himalayan glaciers are in recession and how the problem can be addressed.
Greening India	Draft prepared	To enhance forests from the present 23% to at least 33% of India's land area. To have 10 million hectares of forest cover by 2020.
Sustainable Agriculture	Under Preparation	To devise strategies to make agriculture more resilient to climate change. Manage risk factor. Develop GIS and remote sensing.
Strategic knowledge	Under Preparation	To enlist collaboration of all in R&D in climate change and its socio-economic, health and other impacts. Establish Climate Science Research Fund. Develop climate models.

Turning Awareness into Action

So far, we have seen the various factors which affect carbon sources and sinks, and we have seen India's National Action Plan to achieve certain objectives. It is hoped that the objectives will be achieved. It is also not clear if the missions themselves consider the resources and facilities afforded to them as adequate for meeting the goals. It is also not clear who bears the responsibility for achieving results. It is only hoped that once we have a plan of action, we will improve upon it as we go along. Will we find ways and means of turning the plan into timely action?

India's NAPCC seems essentially an effort to make the people aware of the problem and understand it in all its dimensions. For this reason, the problem has been broken up into eight different sections and a mission set up to address each section. This is perhaps also done to understand the problem more fully and to build up the political will for taking action. The NAPCC has been set up more to analyse the problem and identify the measures necessary for the country to take. In the author's opinion, a definite' action plan' has yet to be developed and an apex body identified for turning awareness into targeted action.

In developing this theme further, we must remember what Gandhiji said a long time ago: 'You may never know what results may come of your action, but if you do nothing, there will be no result!' We have to do something. The missions will certainly help us to generate awareness and build the political will for required action. The question is 'What is the required action that we must take after we have acquired awareness and the political will?' The reader is referred to Chapter 8 for further discussion on the subject.

2.7 The MRV Debate

The term 'MRV' stands for *'measurable, reportable, verifiable'*. That is the test that all carbon reduction technologies will have to meet. The reductions in carbon emission must be measurable by a national agency and reportable to a common UN authority after which it is important that the results should be verifiable by an agency nominated for the purpose.

Claims made by countries must be verified and confirmed. This is done when an industry claims that CO_2 has been reduced and it should be rewarded under the 'carbon credit' scheme. A similar regime is proposed to be applied for claims made by countries—even where no payment is involved. The debate starts when countries want their national integrity to be accepted without cross-verification.

Whatever the debate, it seems inevitable that in course of time the MRV regime will have to be imposed in some form or another on all countries, whether their funding comes from domestic or international sources. Claims must be verified and confirmed.

CHAPTER

3

Opportunities in Control of Carbon Emissions and Accumulation

People in India are uncertain about climate change. Many come to see; only a few with vision seek action. Governments also do not wish to proceed with emission control programmes unless they see other governments doing the same. Business opportunities often remain unexplored in the absence of supportive and consistent policies.

3.1 Essential Steps for Control of Carbon Emissions and Accumulation

As will be seen from the following chapters, several steps can possibly be taken for controlling carbon emissions and for their reduced accumulation in the atmosphere. The basic approach is *to produce less carbon and absorb more of it* so that we build up less in the atmosphere. The general philosophy for reducing the accumulation is based on the following three guidelines for any country:

- *Minimise use of fossil fuels*, by improving the efficiency of electrical appliances, fixtures and fittings used in domestic, commercial and industrial applications, and for keeping the transport systems working.

- *Adopt alternative sources of energy production* which either do not need fossil fuels or which produce lesser carbon dioxide than fossil fuels upon combustion.
- *Protect existing* sinks *and develop new ones* to facilitate carbon adsorption through photosynthesis so as to be able to diminish its natural accumulation in the atmosphere.

Towards this end, various measures (collectively called 'green' *technologies*) need to be adopted in each country, including India, at different levels as indicated in the following:

- Personal level
- Local authority or city level
- State or central government level
- Commercial, construction and industry level
- Transport level
- Infrastructure level

Obviously, at each level, various business opportunities present themselves. The present situation in India is that, as a poor country, people have already been economizing on electricity usage to save money, and so the scope for further reduction is relatively low. Some parts of rural India are not yet served with electrical facilities at all. As the country develops, there will be a greater use of electricity. Alternative sources of energy are not yet developed much as their costs are presently reported to be higher than those with the use of fossil fuels.

At the individual level, careful and economic use of electricity for domestic purposes and fuel for transport can be expected. At the local authority or city level, the extent of action that may be expected depends on the administration in place. Much wider opportunities often prevail for economy if good housekeeping and good city-keeping, including transport and public advertising, are practiced.

At the state and central government level, more basic changes in ways of producing energy for different uses can be attempted. Alternative sources of energy (wind, solar, hybrid, etc.) can be considered, and use of biofuels can be encouraged. More can be achieved through public–private participation and the government's pricing policy. Green buildings and green area development schemes can be promoted.

Much can be done at the industry level to reduce electric power consumption through process change, operations change, change of equipment, change of raw material, etc. Transport is often a major consumer of oil and petroleum products and their consumption can be reduced to some extent by improved traffic conditions and an increase in mass transport.

In many countries afforestation is unfortunately slow whereas deforestation is brisk. The situation demands greater attention all round.

3.2 Each Country has to Develop its own Priorities and Business Opportunities

It is commonsense that the priority for action for each country must be determined by the country itself to keep the national expenditure at a minimum affordable level and not to damage its business interests as far as possible. Each country must explore how to make the most of its relative advantages and use its natural resources. The choices and priorities will, of course, depend upon the site in question, the extent of public–private participation available and the political will. All countries would like to help reduce global warming, but not at the cost of their own progress.

The sad part is that no one seems to have any incentive for taking action to reduce carbon. An *individual* in India normally feels that he/she is too insignificant and too powerless to make any difference to the situation, especially when so many things need improvement. *Politicians* feel that this is too new and uncertain a subject and anyway it may not get them more votes at the next election. *Businessmen* see opportunities but are not sure what government policies will be and whether it will be desirable to invest in its development at this stage or wait just a little while longer. Everybody is uncertain. The only people who have some chance of being induced to take action are the business people, provided public policies are supportive and consistent.

Green Technologies

The reader must be told why the word 'GREEN' is often used in describing these activities.

1. *Greenhouse gases (GHGs)* is a term derived from the garden-variety of greenhouses with glass roofs and walls which allow the penetration of the rays of sunshine (which are short wave) to pass through the glass and heat up the stuff inside. Heat waves, on the other hand, are long wave and cannot pass through the glass. Thus, the glass house accumulates heat and warms up which is good for plant growth. A somewhat similar heating occurs on a global scale when various carbon-containing gases accumulate in it and warm the atmosphere.
2. *Green technologies* are technologies used to get over the problems caused by global warming. The technologies depend heavily on nature (trees, photosynthesis, etc.) and natural resources (wind, solar energy, etc.) The word 'green' in this case is perhaps used as an acronym. It probably has its roots in the following phrase:

   'Growth with Resources, Environment Enhancement and Nature'.

   Green technologies are mainly natural and do not produce any CO_2 upon combustion. Instead, they absorb GHGs, and do not place any undue strain on a country's resources or on its environment. In that sense, they are ideal technologies to consider in any country.

3.3 Mckinsey's Findings for Greenhouse Gas Reduction, Globally

McKinsey launched a study in 2006 to estimate costs, globally, of reducing GHGs. They conceded, from the outset, that whatever regulations result from the study they will have profound implications for business, and hence their interest. The study covered power generation, manufacturing industry, transportation, residential and commercial buildings, forestry, agriculture and waste in six regions of the world: North America, Western Europe, Eastern Europe (including Russia), other developed countries, China, and other developing nations. The study covered 2010, 2020 and 2030 and focused on methods of abatement that will cost upto 40 € per tonne or less in 2030.

The following conclusions are based on the study (without going into the details) and are aimed at giving an understanding of the significance of each possible method of reducing emissions. It was apparent that the relative importance of the findings would be different for different regions and different sectors.

- Power generation and the manufacturing industry, so often the focus of climate change debates, were found to account for only less than half of the potential for reducing emissions at a cost of 40 € or less per tonne. Other sources of carbon besides power generation and the manufacturing industry also needed to be controlled.
- A strong correlation was found between economic growth and the ability to implement low-cost measures to reduce emissions for it is cheaper to apply energy-efficient technologies when building a new unit than to retrofit an old one. Almost three-quarters of the potential come from technologies.
- In cold weather, almost a quarter of possible emission reduction could result from measures (such as better insulation in buildings) that carry no life-cycle cost, and, in effect, they come free of charge. Insulation is equally important in air-conditioned buildings in the tropics.
- In tropical climates, forestry measures (protecting, planting or replanting) have as high as 25% abatement potential considering Asia, Africa and Latin America together. A large potential also exists for reducing emissions by controlling deforestation in developing economies.
- The power generation situation is likely to be as shown below. A major shift is likely to be created globally away from traditional coal-based power generation plants. Much lesser number of new coal-based plants will come up in future years. (In some countries where the geology is favourable, coal plants with carbon capture and storage (CCS) will come up by the year 2030.)

  Renewables (including hydro) will find increasing applications in many countries, with the installations nearly doubling in the next 20 years. A few more nuclear installations will also appear.

Plant	Year 2002	Year 2030
Traditional coal and gas plants	65%	30%
Coal + CCS	–	17
Renewables (including hydro)	18	32
Nuclear	17	21

It would appear from this report that being a tropical country, the best chances for India would lie in development of all forms of renewables. In fact, India needs a mix of green and traditional power sources to meet growth requirements along with sustainability. Promotion of afforestation and control of deforestation are equally necessary.

3.4 India Needs a Mix of Green and Traditional Power Sources

The Global Environment Fund (GEF) says that there are opportunities in India for clean energy and environment and natural resource management. Growth opportunities in the renewable energy field are rapidly shifting from the developed world to South-East Asia. European countries such as Spain are cutting down on subsidies, and since the overall business environment is dull, companies are looking at countries such as India to drive their growth, says a KPMG partner. Spain was the most sought after country until 5 years ago. Incentives are not necessary anymore and have now been rolled back in Spain. They have also been rolled back in Portugal, Italy and Ireland. Thus, business opportunities from new installations seem profitable in India.

Solar power capacity in India has leaped from only 8 MW three years ago to 905 MW. Reliance Power has recently commissioned a 40 MW solar power plant in Pokhran near Rajasthan, reducing CO_2 emission by 70,000 metric tonnes per year. Reliance Power handles a portfolio that includes various forms of power generation from coal and gas to solar, wind and hydro. Gas plants seem to have a great future as their emissions are lesser than those from coal. India needs a mix of green and traditional power sources to meet growth requirements along with sustainability.

The promise that renewables hold for India also depend on their pricing, the government's fiscal policy, their availability and such other factors discussed in later chapters. The provision of renewable sources of energy is later identified in Chapter 8 as one of the principal thrust programmes for both urban and rural areas to bring up the Indian economy.

3.5 A Logical Approach for Carbon Reduction, Worldwide—More Forests, Less Deforestation

The proceedings of the Copenhagen meeting have saddened us to see how each country, with a political eye, wants to do the least, and at least cost. This was to be expected. For this reason, the Kyoto Protocol and such other protocols (including the Copenhagen Accord) do not have much of a future. They are only good as *interim* measures.

Since carbon has been building up in the atmosphere, our ultimate objective has to be to maintain a balance between the *'sources'* and the *'sinks'* of CO_2, worldwide, so that further build up stops. This has to be our logical approach to avoid global warming and prevent climate change.

Presently, much emphasis seems to be given only to mitigation of carbon at source. We are told to try and reduce carbon emissions at source. But, after all our mitigation efforts, a substantial amount of carbon still remains unabsorbed and goes to the atmosphere, causing global warming. That's why more 'sinks' are needed. That is why deforestation must be strictly controlled.

Obviously, the world does not have enough sinks (forests, trees, oceans, fresh water bodies, wetlands, etc.) on an overall worldwide basis to take care of present day emissions; otherwise carbon dioxide build-up in the atmosphere would not be occurring so much. It would, therefore, seem that there is an equally strong case for increasing the 'sinks', worldwide, as there is for source reduction.

The next question, therefore, is: Can we develop more new sinks? The answer is yes, we can.

First, Prevent Deforestation

Our commonsense tells us that we must first protect the 'sinks' we already have. Some of the important carbon removal sinks are no doubt the forests, soils, wetlands, peat, permafrost, ocean water and carbonate deposits in deep oceans. Most sinks are very large and slow moving. Human influence on them is said to be fairly minimal. We need to revisit them to see if they can be expanded in future. Among them, forests need our greatest protection. Forests need years to mature, and when burnt to make way for habitation or agriculture or mining, the burning of wood (as part of deforestation) produces CO_2which we do not want to add to the atmosphere. Thus, deforestation is the first thing we have to stop.

To stop deforestation, two approaches are recommended:

- Pay for protecting the forests just as we pay for creating new dedicated forests
- Take the help of the 40 million tribals in India to protect the forests since they depend on forests for their livelihood

The UN's REDD program (Reducing Emissions from Deforestation and Degradation) addresses this question at the international level by making payments for preventing deforestation. This is an international program. A similar program (but more easily accessible to the local people) is necessary to be developed at the national level. In India, too many bits and pieces of forests are lost for clearing land for agriculture, mining and habitation.

Forests are noted to increase in India at the rate of 1.1 million hectares per year. Our stock of stored carbon in the woods is said to have increased to 9–10 gigatonnes (GtC),according to data available in 2005.

Tribal Help

We should remember that planting trees and forests as well as protecting existing forests from deforestation is an ongoing, never-ending, process. We can never have enough of trees. To achieve this, the local villagers, the *vanvasis* or the *adivasis,* have to be made the owner of the forest they guard.

An example of the benefit accruing to a tribal community (and to the world as a whole) can be given from Shahapur in Thane District, Maharashtra, India, or Mendha in Gadchiroli also in Maharashtra, where a 1700 ha tract of forest land, denuded over the years, was beautifully re-forested after the local tribal people were given a stake in its development. A joint forest management committee entitled them to benefit from sale of produce such as gum, dried leaves, flowers, bamboo and mahua oil. The villagers were also entitled to 50% of the income earned by the forest department from the auction of timber. Deforestation turned into re-forestation by generating income and employment.

But, this is not always the case. There have also been reports of deforestation accelerating after tribal land grants were made—perhaps these are examples of poverty and environmental degradation going hand in hand.

3.6 Are Higher Payment Rates Warranted for Sinks in Warmer Climates?

Another reason for concentrating on 'sinks' is that the carbon absorption capacity of sinks in warmer regions is known to be theoretically much higher than that in colder regions. A tree located in a cold or temperate climate (from which much of our data presently comes) is said to absorb only about 1 tonne of carbon dioxide within its lifetime, whereas a tree in a warm country, where photosynthesis occurs faster and for longer duration in a year, absorbs as much as 2 or 2.5 tonnes within its lifetime. Careful studies will need to be instituted to examine the carbon absorption rate of tropical forests, ensuring that the methodology used will stand scrutiny at any level. If more studies could show this to be true, it means that developing countries in warmer climates should be paid at least twice as much as they are paid now.

This would tempt warmer countries to pay more attention to developing forests and other sinks. Of course, developing more sinks will not solve the global warming problem by itself. We have to concentrate our attention on both sources and sinks.

Sustainability is also Important

Another question that arises is whether this balancing of sources and sinks will be *'sustainable'* in the long run? We need *sustainability* in everything we do. For this to happen, we should not forget that in future, sinks must increase at the same rate as the sources do, and some clever 'social engineering' has to be practiced to keep the people interested in looking after the sinks to continue reducing carbon accumulations. The system must generate some new funds and the funds should be used to give back some income to the local people so that they are motivated to ensure its sustainability. This has to be our second guiding principle.

Thus to repeat our 'mantra' in simple words: *Give equal importance to both sources and sinks of carbon, and make sure the people earn something from it all!*

As the sinks and sources do not have to be adjacent to each other, many countries located in warmer regions must get attracted to protect their forests and cultivate new forests and new sinks dedicated to absorb CO_2 from sources located elsewhere. The carbon trading mechanism under the Kyoto Protocol already practices this concept and it should be continued (and even extended to become a nationally encouraged activity) so as to greatly increase its coverage. It should make it financially worthwhile to cultivate new dedicated sinks (forests, etc.) in every country, especially the countries in warmer regions.

We have not made any serious effort, *nationally,* as yet to develop new sinks for absorbing CO_2. There are other sinks besides trees and forests. For example, coastal waters and soils are enormous sinks. Water bodies filled with algae, such as swamps, marshes and other natural landscapes, are also carbon absorbers.

Advantages of the Proposed Approach

The proposed approach has many advantages. The main advantage is that the countries are no longer divided into rich and poor. Each country can exploit its own resources as best as it can because equal emphasis is given to mitigation and carbon absorption. Countries that are richer in technology and located in colder regions can concentrate on source reduction while those located in warmer regions can concentrate on their forests and other wealth of sinks, so to speak. The richer and poorer countries as well as the countries in colder and warmer regions must all feel that they are making an equal contribution.

Moreover, higher rates of payment would act as a welcome incentive for developing newer sinks by using land to grow more trees and forests to absorb carbon dioxide and develop water bodies for the same purpose. It would make people exercise greater vigilance against deforestation. It would also promote conservation of water (and wastewater) as well as promote rainwater harvesting followed by groundwater recharge since water would be in greater demand than ever before.

Finally, the system would be robust and sustainable as the people would develop a vested interest in its continuation, and become a kind of road map to follow in achieving our ultimate goal.

3.7 Are Promotional Mechanisms also Needed at Country Level?

Thanks to external agencies, the forest department's earlier monopoly over forest surveys is diminishing. Given the declining forest areas, their monitoring is too important to be left to forest departments alone. A recent report in the *Times of India* dated 4 June 2012 paints a grim picture of how rapidly deforestation is occurring all over the country.

State	Forest Cover Shrinkage between 2009 and 2011, ha.
Andhra Pradesh	28,100
Manipur	19,000
Nagaland	14,600
Arunachal Pradesh	7,400
Mizoram	6,600
Meghalaya	4,600
Kerala	2,400
Assam	1,900
Tripura	800
Maharashtra	400
Chhattisgarh	400
Uttar Pradesh	300
Gujarat	100
Delhi	100

Deforestation is evidently highest in Andhra Pradesh (for various reasons) and generally high in the seven states of North-East India (due to smuggling), although one could say that why should even 100 hectares be lost from Gujarat or Delhi. Direct loss could run into several crores of rupees considering wood-stock, vegetation, etc. A further loss in intangible terms could result owing to birds, wildlife and ecosystem damage occurring within the affected areas as well as connecting patches between forests. In case of lakes located within the forests and supplying water to urban areas, a further direct loss could occur.

Deforestation is rampant in spite of REDD at the international level. A similar and tailor-made program is necessary at the *country* level. For countries like India, the way to go seems to be to discourage deforestation at any cost and develop more new dedicated forests as 'sinks'. Moreover, in order to keep it all sustainable, make sure the technology is correct and the people make some money from it. This is the theme India has to develop.

We propose that the various incentives given by the UN at the *international* level be reviewed and, if possible, similar awards be offered at the *country* level by the national governments. This would have a far greater effect on forest preservation than what happens because of international awards. The prescribed conditions need to be worked out and may not be exactly the same but generally can be a little more relaxed than required by the UN, and also take local realities, areas, sizes, and likely incentives into account. Costs and risks for putting up proposals must also come down. The areas to be covered are recapitulated as follows:

1. Development of dedicated forests to earn 'carbon credits' at the *country* level, similar to those earned from certified emission reductions (CERs) from industries, etc., at the international level
2. Control of deforestation at the country level (similar to the international REDD program)
3. Development of new areas as 'sinks'.

As already mentioned in the previous section, higher payment rates appear to be necessary to account for higher photosynthesis and carbon absorption rates in tropical climates. Whatever new rates are fixed after field studies, the basis of payment at the country level can be reviewed from time to time as necessary in order to encourage local talent and local initiative.

CHAPTER

4

Green Technologies for Energy Production

The future belongs to green energy sources, not fossil fuels.

4.1 Various Technologies Available for Energy Production

Fortunately, the world has been using a variety of sources of energy including coal and oil, listed as follows, to meet its energy needs. Some of these sources, however, are finite, some are polluting, some are renewable, some are free from CO_2 production or produce very little of it, and some are totally unexplored by us at present. All these sources are listed as follows to show that a large variety of forms are available for exploitation.

Energy Sources Available at Present

- Fossil fuels (coal, oil, petroleum)
- Hydropower
- Renewable sources (wind, solar, hybrid, wave, geothermal, etc.)
- Gases [coal gas, natural gas, LNG, CNG, liquid petroleum gas (LPG), shale gas]

- Agricultural biomass and community wastes
- Municipal and industrial solid wastes
- Nuclear energy

We have been traditionally using mainly fossil fuels such as coal and oil. These are gradually depleting the world over, and we are also beginning to find that the carbon dioxide and other gases simultaneously produced during combustion are causing other problems such as global warming and climate change. The world is, therefore, getting disenchanted with fossil fuels and slowly shifting over to renewable sources which are free from such emissions. These alternative sources of energy are grouped according to their readiness for application in India.

Alternative Sources Ready for use in India

- Wind
- Solar (thermal and photovoltaic)
- Hybrid (both wind and solar together)
- Biofuels from oil-bearing plants

Alternative Sources in Development Stage

- Shale gas
- Wave energy
- Geothermal energy

As shown earlier, some methods are already in use and we have experience in using them. Some are ready for use. Others need R&D work before they can be used. The methods are discussed in the following sections.

4.2 Cost Comparison of a Few Typical Systems for Power Generation

At the outset, it may be a good idea to give the extent of coverage in India and the comparative costs of a few typical systems which are usually used for power generation. The world is both price sensitive and resource conscious.

Table 4.1 Approximate Capital Costs of Different Power Generating Systems (2010–2011)

System Used in India	Gen Capacity %	Capital Cost ₹ Crores/MW	Remarks
Coal-fired, thermal	55	4.00–5.00	India has large coal reserves and is planning to use them in future too. India is also importing coal to meet heavy demand. Coal gives much CO_2
Oil and gas, thermal	10	5.00–5.50	Gas gives less CO_2 than coal. But India has less oil resources and oil prices are ever increasing
Hydro	26	5.00–6.00	Hydro is preferred where sites are available. No CO_2 produced. It adds to water resources also, but capital cost depends on site and pop. displaced
Wind energy	–	5.50–6.50	Low running cost. No CO_2 produced. But possible only at windy sites.
Solar PV	6 (w+s)	8.50–9.00	Costs expected to reduce still further. Solar PV panels manufactured in India, China and other countries
Solar Concentrator (CSP)	–	11.00–13.00	First 400 MW plant coming up in Rajasthan, India
Nuclear	3	7.00–8.00	Much land required. Severe risks attached to its operation
Straight biomass combustion	NA	4.00–5.00	Suited for rural areas and small units

The cost comparison based on Indian data (2010–2012) is given in Table 4.1. It must be mentioned that costs keep changing downwards continuously from year to year, and vary from case to case according to local conditions. The cost figures given in the table are, therefore, to be treated as only approximate.

Table 4.1 shows that about two-thirds of the plants presently in India are based on coal or oil—both fossil fuels, whereas only about a quarter of the plants are hydro schemes. Coal-fired systems are the cheapest in capital cost to install. Hydro systems come next depending on site. Wind energy is slightly more expensive but its cost depends on the wind speeds at the site. Solar systems appear to be costlier at present, but costs are expected to reach grid parity soon. Moreover, operating costs of solar systems are normally very low. Also, stand-alone systems can be installed at the site, and long transmission lines can be avoided. Wind and solar plants already exceed nuclear ones, and are likely to do so even more in the future.

With its large deposits of coal, it is unfortunate that India cannot exploit them owing to fear of CO_2 emissions. Research has to be promoted to find new ways of converting this coal asset into a cleaner one and generating electric power at a cost lesser than wind and solar energy. Till then, wind, solar and other forms of renewable energy will need to be explored, some even with subsidy. The government has already set a target of 20,000 MW of power through renewable sources by 2020. To kick-start the process, the government is providing subsidies, tax benefits, attractive feed-in tariffs and other inducements such as renewable energy certificates (RECs) to transfer the benefits from a surplus state to a deficient state upon payment.

4.3 Sources of Energy Production Already in Use

Let us first see the sources of energy production which are already in use and with which we are familiar.

4.3.1 Fossil Fuels (Coal, Oil, Petroleum)

Presently, much electrical energy in India is produced from fossil fuels like coal and oil. Transport activities depend on oil and petroleum. Fossil fuels give energy, but also produce, at the same time, unwanted CO_2 when ignited. Green technologies are preferred as they give energy with little or nil CO_2 at the same time. Even under an active policy scenario, by 2030, 67% of all energy production is expected to be from coal sources. Thus, India will have to make efforts to find more efficient ways of using its coal resources, possibly by setting up coal cleaning facilities or power houses integrated with carbon capture and storage (CCS) facilities of some sort. CCS underground is possible where geology is favourable (discussed in Chapter 7). Other technologies such as supercritical coal-fired power plants or ultra supercritical boilers, etc., could also be considered.

4.3.2 Hydropower

In a monsoon country like India, large hydropower projects have been built since ages and are considered so important that a separate ministry is devoted to handle the subject at the government level. Our neighbor, Bhutan, also has several hydropower projects because of its mountainous terrain, but the electricity so produced is solely for the benefit of India. USA, Germany, China and India rank high in the world in hydropower generation.

In hydropower projects, rainwater is harvested in a natural or man-made reservoir located on a high terrain and released as desired to drive turbines located in a valley below to generate electricity, thus converting the potential energy of stored water into electrical energy. After use, the water may be released to a river downstream to become a source of fresh water for irrigation or for water supply to towns further downstream, or use small flows to just operate a wheel or hydraulic ram or pump to pump up water to an elevated reservoir. In this sense, the water has two roles to play: generate power and then meet irrigation or water supply needs.

In fact, hydropower projects are preferred in modern times, wherever possible, because the whole operation is clean and no CO_2 is released in generating electricity there from, and neither does the water go to waste after use in the turbines. Hydropower projects are not possible in flat terrains with alluvial soils. They are possible where there is a mountainous terrain and rocky soil which can hold water.

There are several examples of commendable hydroelectric and irrigation projects in India.

On the downside, there are some recent studies that refer to the generation of methane and carbon dioxide from anaerobic activity likely from the mud at the edges of a lake as the water level shrinks. The importance of this finding must await further studies on this emission and its impact in warmer countries as it occurs in all lakes.

Mumbai's Large Hydro Projects

Mumbai has been served for many years since the early 1900s by a large and dependable hydroelectric scheme (Tata Hydro at Bhivpuri and at Lonavla, near Mumbai) with the monsoon filling up its reservoirs and renewing their life each year on time. After the lake water operates the turbines, it is released downstream into a river for further use as water supply to several townships and also for irrigation purposes.

The Tatas are now toying with the idea of placing floating solar PV panels on the lake water surface (24,000 acres) so as to make double use of the lake land. The waters will continue to give hydropower while the solar PV panels will help generate additional electric power from solar sources. If the full water surface is used, a potential of 4,000 MW exists. Thus, not only will the water be used twice, but the lake land will also serve two purposes. No new land will have to be purchased for the solar panels. A trial project is first envisaged with only 13.5 kW of electricity. Thereafter, 400 MW is on the cards. Lucky is the country that has the terrain to be able to have hydropower projects.

DOUBLE USE OF LAND

The Tata's (along with an Australian firm) are now reported to be exploring the use of a new type of hybrid system in which a flexible solar energy photovoltaic system is placed on their existing lake's water surface at Lonavla so as to get additional electricity from solar sources while continuing to benefit from the earlier hydroelectric source. This avoids the necessity of buying additional land (which is difficult to get in India). If it proves successful, it will work wonders for the environment and costs can come down still further because, firstly, they will continue to get electricity from the stored water, and secondly, they will get additional electricity from solar sources, thus making double use of the land.

Small Hydropower Projects

Small hydropower projects up to 25 MW capacities are reported to remain a problem because most of the streams and rivulets in India are not perennial. Any attempt at creating small dams on such streams causes objections from the downstream farmers and also often leads to deforestation. Nonetheless, about 2,700 MW of electricity is produced in this manner at present. Pumps (operated with electricity or diesel) have often displaced such items.

4.3.3 Gases

Coal Gas

Coal deposits are substantial in India and coal gas was once produced in large quantity. Coal gas is also referred to as town gas and in the past was the principal fuel for domestic heating and cooking. It has now tended to be replaced by natural gas. Coal burning was also used in the past to generate 'producer gas' to drive vehicles (especially during the war time when imported petrol was scarce but coal was locally available). However, it has tended to lose favour as it is based on a polluting, fossil fuel-like coal.

However, coal gasification is still of interest to India. It consists of sinking two wells in an unworked coal bed below, one to send in oxygen and water, and the other to pump out raw product gas. The gas can be used for power generation, industrial heating, synthetic natural gas (Syngas) production, hydrogen production, etc. The CO_2 generated can be sequestered as explained in Chapter 7, provided geological conditions permit.

Natural Gas Deposits (based on methane)

Liquid Natural Gas (LNG): Natural gas deposits have been found in abundance in the Qatar region of the Middle East, as well as in Russia and in the North Sea above Britain. The gas is composed mainly (>90%) of methane. It is odourless, non-toxic and non-corrosive. It liquefies at atmospheric pressure when cooled to -160^0C. Qatar has invested heavily in refrigerated ships to be able to transport *liquid natural gas (LNG)* in bulk to other countries, whereas Europe receives its supplies in the form of gas through pipes laid from Russia. Natural gas has been extensively used in some cities of India too owing to its relatively non-polluting nature and ease of distribution through pipelines.

India has also been fortunate to recently find enormous *gas resources* which will no doubt be used extensively in the years to come. The gas deposits found in the Krishna–Godavari basin will last for many years to come. They will, in fact, slow down to some extent the development of wind and solar energy unless the latter are made mandatory or some tax benefits are given. Moreover, gas operated turbines for power generation are reported to have a 60% efficiency of conversion to power, which is only next to nuclear power. Gas resources seem to have an excellent future in India.

Compressed Natural Gas (CNG): Natural gas may also be supplied in the form of *compressed natural gas (CNG),* generally supplied at high pressure (200–250 kg/cm^2) in small cylinders (50 L water capacity) and is used both in households as well as in transport vehicles. The properties of CNG make it a safe fuel. It is lighter than air, and hence in case of leakage it disperses into the atmosphere rapidly. Its high auto-ignition temperature of 540 degrees centigrade as against petrol's 360 degrees centigrade makes it even more safe fuel. Limited combustibility, i.e., CNG's concentration in the air is less than 5% or more than 15%, and the gas will not burn even in the presence of a spark, adds further to its safety.

Mumbai's 55,000 taxis have switched over from diesel to CNG as a means of controlling air pollution from their tailpipes. Its attractive pricing has no doubt helped to ease its ready adoption by the taxis. The present usage of CNG in Mumbai city is reported to reduce about 1000 metric tonnes of pollutants every day. The use of CNG is also likely to increase in the future as populations increase and as the people use it increasingly for car and bus transport purposes.

Natural gas may be supplied in any of the following three forms:

1. As natural gas supplied through pipes laid within a city or intra-city
2. As LNG for bulk transport by ships to countries
3. As CNG in small cylinders for use in homes or for transport

Liquid petroleum gas (LPG) is different from LNG. LPG is almost all (95%) propane, and some butane. No cooling is needed but under heavy pressure it liquefies. It is also sometimes used in transport.

4.3.4 Agricultural Biomass and Community Wastes

Agricultural biomass (crop residues, sugarcane bagasse, leaves, twigs, grass, etc.) and community wastes (sewage) and wastewaters from the food and beverage industry, etc., can all be a good source of biogas.

Wastewaters like sewage are sent to municipal wastewater treatment plants, while wastes from market places and food and such industries which are high in organic content may be treated separately in industry-owned plants such as 'upflow anaerobic sludge blanket' (UASB) plants or other 'waste-to-energy' plants, for anaerobic decomposition.

In breaking down organic matter through the action of anaerobic decomposers, CO_2 is released along with CH_4 (methane), both of which are greenhouse gases responsible for global warming. However, this release occurs at the treatment plant site where something can be done to stop its release to the atmosphere. The methane can be used as fuel while the carbon dioxide can be bubbled through an algal pond where it can be absorbed in photosynthesis forming more algae which can be harvested (see Fig. 4.1).

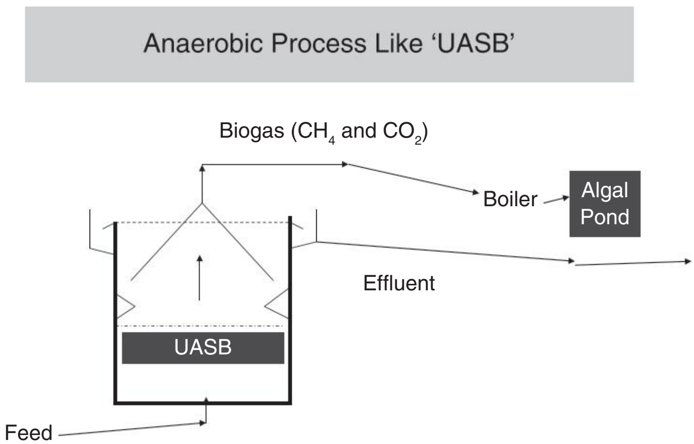


Figure 4.1 *An anaerobic sludge blanket (UASB) unit for wastewater treatment*

Municipal Solid Waste Collection and Disposal

In India, the conventional system of handling solid wastes has been to use petrol- or diesel-driven vehicles for collection of the waste from roadside bins or from houses, followed by transport to a low-lying dump-site for disposal by dumping. The waste is left there to undergo self-stabilisation and the gases produced are allowed to escape to the open atmosphere. In some of the larger cities, the people may be encouraged to segregate the waste so that salvageable material is picked up separately by rag pickers and recycled into the market. The collection system in large cities may also benefit from use of waste compression trucks and transfer stations so as to be able to carry more waste per trip. Ultimately, all solid waste of the city goes to the dump or landfill or composting site for final disposal.

The problems are that we can neither afford

- The fossil fuel we consume in waste collection,
- nor the land (the dump site) that stays locked up for years with waste dumped into it,
- nor the system of disposal we follow,
- nor the staff we require, and their health.

Suggested Disposal of Municipal Solid Wastes

Maharashtra is reported to have a coverage of only 20% as far as solid waste collection and disposal is concerned. Since much work has yet to be done, solid waste collection and disposal need not be done in the conventional way, but rather in the following way so that it is more effective and economical, and will also avoid global warming.

Collection Trucks to Run on Renewable Sources of Energy

Firstly, all collection trucks and other vehicles engaged in solid waste collection must operate on renewable sources of energy. No fossil fuels such as petrol or diesel should be used. If we could do it successfully during the time of the Second World War, why not now? *The collection vehicles* presently use diesel oil mostly. For

India it is an imported item. These vehicles should either run on biogas or CNG or be converted to EV (with electricity generated by solar panels or UASB-type anaerobic systems with dual-fuel engines in tow).

Waste Segregation

Waste segregation in Indian cities must be implemented as it recycles and conserves resources and improves the working condition of the rag-pickers. The wet fraction of the segregated wastes being organic in nature needs to be composted. This can be done ward-wise, in a decentralised system and used locally ward-wise, if area is available. Similarly, organic wastes from selected marketplaces and large industrial canteens, etc., would go to individual '*waste-to-energy units*' for generating biogas.

Solid Wastes Disposal System

The modern trend in larger cities is to go for sanitary landfill or aerobic composting instead of plain dumping of waste in low-lying areas although composting is relatively more expensive than dumping because the compost has to be transported later to the agricultural fields. Where more methodical and expensive land-filling of waste is done, a biogas collection network of pipes with suction pump may be installed in the landfill which would help to collect the biogas for sale as fuel to nearby industries rather than its release to the atmosphere. It would also help meet costs. Gas collection and utilisation is also favoured these days because of global warming considerations and the income it generates for the local body.

Incineration of the solid waste instead of dumping or landfill is done mostly in Western countries, and not yet in India where the waste has a relatively low calorific value. Across Europe, there are over 400 plants of the 'waste-to-heat' type. Such plants use the city's solid wastes as fuel instead of oil or other fossil fuels and have efficient waste gas cleaning devices incorporated in them so as to remove mercury, dioxine, CO_2, etc., besides smoke, soot and dust. Their excess heat is piped for use in adjoining homes or for producing electricity. Denmark, Germany and Netherlands seem to benefit most from such plants. They save land too.

Delhi is reported to be getting its first 'waste-to-energy' plant based on 2,000 tonnes of the city's solid waste and capable of producing 16 MW of electric power in the first phase. Even then, the plant to be established by Jindal Ecopolis at a cost of ₹200 crores will consume only one-third of the city's solid waste.

Biogas from Landfills

If the municipal solid wastes are handled in the conventional manner, both the dry (minus salvageable material) and wet fractions would go to a landfill site for disposal. In such cases, a 'sanitary landfill system' is to be preferred and a biogas collection network of pipes has to be embedded into the site to collect the methane, carbon dioxide and other gases produced through anaerobic activity so that their energy value can be used (not done at present) and disposal regulated. Leachate would also need to be treated before disposal.

Biogas released to the atmosphere from a solid waste disposal site located in India is approximately at the rate of 0.42 g/person-day (because of low organic content of the waste). Thus, biogas from, say, 1 million people would be 420 kg/day or 153.3 tonnes per year. As methane is approximately 50% the volume of biogas, its emission = 210 kg/day. In terms of CO_2-equivalent, it is = 210 × say 25 = 5,250 kg/day. Thus, the total CO_2-equivalent emitted per day = (210 + 5250) × 365 = 1993 tonnes per year. This is a huge quantity from one dump.

Finally, when the disposal site is filled up, it must be 'closed' using acceptable procedures and whatever biogas is still produced for some years should be collected and used, instead of allowing it to escape to the atmosphere.

Use of Biogas from Solid Wastes

Biogas from waste is generally a mixture of methane and CO_2 and has a relatively low calorific value compared to natural gas which is methane (95%+). Hence, it is not profitable to compress and bottle the biogas for retail. Biogas is generally either piped and supplied to a nearby industry for use as a fuel for generating steam in their boilers or supplied to the public for domestic use or sent to a dual-fuel engine for producing electricity. The latter is sometimes avoided as it requires a technical skill beyond the scope of ordinary municipal workers.

Appendix 2(7) gives in detail the case of the Gorai dumpsite where a proper covering was provided after the dumpsite had been exhausted after several years of usage. The covering and reshaping cost the Mumbai municipality over ₹50 crores, while the 'carbon credit' earned by the municipality for avoiding emission of CO_2 to the atmosphere has been nearly ₹70 crores. What's more, the municipality can earn more money from sale of the biogas which is extracted from the covered site. The biogas would have otherwise gone to the atmosphere. (Some discrepancy was noticed later in the estimates prepared and the Municipal Corporation was asked to refund some payments made to it by the bank.)

Appendix 2(8) gives an example from Okhla, New Delhi, where the solid waste is converted aerobically to useful compost (without generating CO_2) and sold to farmers in rural areas. This project was also funded by CDM under 'carbon credit'. The Appendix also gives a decentralised method of aerobic composting which needs a pilot project to show that it could work out cheaper than a centralised method.

4.3.5 Nuclear Energy

Nuclear energy forms a substantial part of the total energy scenario of the western world. Nuclear technology is also the reserve of these same countries.

Country	% of Power
USA	20
France	75+
Japan	29
Russia	20
Germany	30
India	3

In India, at the present time, development of nuclear energy (though not strictly renewable) is being considered although the Chernobyl and recent disasters in Japan are much feared. Capital costs are indicated in Table 4.1. Nuclear fuel's efficiency of conversion to power is high, upwards of 70%, which makes it the cheapest fuel after fossil fuel (coal and oil) and it can reduce India's power shortage without producing any CO_2. India's experience with nuclear energy in the past has been very satisfactory. India already has a few nuclear power plants. But, their safety aspects are facing fresh doubts from the public. Additional safety precautions, however, can be built into new plants from experiences gained elsewhere in the world.

Besides safety aspects, the large land requirement of nuclear energy plants is a severe deterent. A large chunk of land has to be left vacant surrounding a nuclear plant for safety considerations. An additional chunk of land around this area has to be left vacant for controlled activities and controlled habitation. And yet another chunk of land has to be provided nearby for holding the nuclear waste for long periods. Its land requirement seems to be even more than that for solar concentrators. Where is so much land to come from?

Land availability becomes the most severe problem in undertaking a nuclear project. The recent Jaitapur Nuclear project has highlighted these difficulties and showed that people are not so ready to voluntarily part with their existing land. The land acquisition policy of the government has to be reviewed and made more people friendly, if it has to succeed. This is where politics comes in.

Besides safety and land, another constraint is water. Large volumes of water are needed as cooling waters in the reactors. Their location is, therefore, often limited to coastal areas with easily accessible sea water. A danger which comes with seaside location is the danger of Tsunami wave action. Similarly, when located inland near large and perennial rivers, earthquake zones have to be avoided.

Another problem is the long time period required for getting international permits for nuclear plants and their construction (about 8–10 years altogether). Thus, investments have very long pay-back periods. Nonetheless, some countries like France have nearly 80% of their electric power generated from nuclear sources.

Research Needed

India has large thorium deposits whose suitability for power generation has not yet been established. If thorium could be used instead of uranium with equal safety and efficiency to generate power, it would change the face of India, and perhaps a few other countries. Much R&D is needed.

Another R&D item is the present way of dealing with the uranium. Normally, uranium needs to be 'enriched' to develop power, and has to be enriched still further to make a bomb. What happens to the depleted uranium (some 92% of original) that is left behind? Can it be used to generate power?

> One of the severe problems in developing nuclear energy is its enormous land requirement for exclusion zones (apart from safety considerations).

4.4 Alternative Methods Ready for Use

Alternative methods ready for use are wind, solar and hybrid systems and biofuels. These systems have not been used much in the past either because they were not available or because they were relatively more expensive or both. These systems are now being given a fresh look as costs have been reduced and the systems promoted more vigorously than before as they have unique advantages as explained in the following.

4.4.1 Wind Energy—Ready for Use, but Needs Promotion

Use of wind turbines for generating electric power is a ready-to-use alternative method of power generation, and the technology is also ready for export to other countries where wind energy is available for exploitation. A wind energy plant on an average needs an investment of ₹5.5 crore to ₹6.50 crore per MW, compared to ₹4 crore for a thermal and ₹5 crore for a hydropower plant (Table 4.1). Among the renewables at present, wind power comes closest to fossil fuels and hardly needs subsidies or tax benefits. Wind power installations are seen as a tax-saving device since accelerated depreciation at 80% is allowed in the first year itself.

Wind power costs ₹3.50 to ₹4.00 per kWh against ₹2.50 for coal-fired plants. Wind power is made affordable by pooling it with normal supplies. A sum of ₹38,000 crore is reported to have been invested by the private sector in wind energy in India between 2008 and 2011.

Centre for Wind Energy Technology (CWET) in India

There is a Centre for Wind Energy Technology (CWET) for R&D work under the Ministry of New and Renewable Energy (MNRE, New Delhi). According to CWET, Tamil Nadu has the most number of sites where wind power density is greater than 200 watts per sq metre.

The main business opportunity lies in entering the wind energy business and developing newer sites such as the various hill stations where touristic demand for power exists. Other obvious sites for exploitation exist where a natural 'tunneling effect' increases wind speeds and, thirdly, in open coastal areas like the Norwegian case described here. A thing to keep in mind is that the local people's livelihood should not get adversely affected when a new wind farm is set up. With the wind farm, development occurs, roads are built, and man–animal and man–tribal conflicts can occur in which the animals and the tribals may lose unfairly.

To promote greater use of wind energy in India, many more wind mills, wind-turbines, and wind farms need to be set up to generate electric power where wind is found to be blowing reliably. Several steps, such as the following, are necessary to be taken in order to encourage the general public to install and use wind-operated systems.

Identify Windy Sites

Firstly, locate geographic areas in India (e.g., coastal areas, hilly areas and other specific locations) where wind farms can be set up assuredly. A study has identified Kerala, Karnataka and Goa's hills as suitable regions in India. Kutch in Gujarat also has good winds, but some areas are prone to cyclonic conditions.

Ideal Wind Speeds

Anaemometres are generally used to determine wind speeds. Currently, the ideal average wind speeds are reported to be between 7 and 9 metres per second (15–20 miles per hour) for utility-scale wind turbines suitable for commercial applications. Wind speeds less than 2 m/sec are not workable whereas wind speeds in excess of 14 m/sec are considered cyclonic.

Good wind speeds are best achieved by going above trees and buildings, preferably on building terraces. An added advantage of locating on terraces is that additional land is not needed. However, structural stability has to be assured in each case and this is best done early on at the building design stage rather than afterwards.

Power obtainable from wind is a function of the cube of the speed. A wind speed increase from 6 m/sec to 7.5 m/sec would increase the power generated by as much as 50%, with no mean benefit. India is unfortunately reported to be in a region of low wind speeds barring the monsoon months. Strong winds blow during the monsoon season only. Also, the greater the power to be generated, the larger the diametre of the turbine fan has to be provided.

Everybody knows that wind does not keep blowing all the time. It stops after a while. In most countries, it generates power for only 20 to 30%of the time, and needs storage batteries to tide over other times. Tamil Nadu is said to account for 50% of the installations in India

Enable Reverse Selling

The Ministry has estimated a total potential of 48,500 MW between 2011 and 2017 only from wind though new research would tend towards more optimistic predictions. Presently, only 16,000 MW capacity appears to have been installed. For the target to be achieved, one must demonstrate the economic feasibility (profitability) of using modern wind turbines with improved technology for low friction and with low installation and maintenance costs so that more people are attracted to use them.

For this purpose, it is necessary to enable reverse selling of surplus electric power to national power grids so that those who generate power can also earn some money from it. Reverse selling is in a way encouraging private capital to be employed and public–private partnership to occur. As public authorities are short of funds, private capital must be harnessed and public–private partnerships have to be encouraged as a matter of policy.

A recent issue of the *Times of India* (May 2012) also confirms that wind power costs ₹3.50 to ₹4.00 per unit against ₹2.50 for coal-fired plants. Wind power, as is well known, is available only when wind is blowing at certain speeds. It is not available all the time. This gives an opportunity to use it in combination with normal coal-based operation at other times, which makes its use more affordable (storage batteries are not needed). The Indian industry, anyway, welcomes it because government subsidies and tax benefits make it attractive. Energy consultants can help sort out problems.

Some Discouraging Pre-requirements

Incidentally, some of the following pre-requirements may sound discouraging but are often not so in most cases:

Before wind turbines can be installed in certain places, one may need permits from appropriate authorities involving one to submit (i) a noise study (ii) an avian study to determine potential impacts on birds and bats, and (iii) an aviation administration study to determine if the wind turbine might interfere with aviation radar. Their clearances must first be obtained.

Some Indian Installations

A newly formed company called Green Infra Ltd (GIL) sponsored by IDFC Private Equity, has bought up a 60 MW wind farm in Karnataka and another 40 MW installation in Maharashtra from British Petroleum's BP Energy. GIL is also looking to buy 250 MW wind energy capacity from DLF and eventually reach a total of 500 MW capacity in 3 years. ONGC has set up a 50 MW wind farm project in the Kutch district at Bhuj, Gujarat, using 1.5 MW machines installed on 78 m high towers. The technology used is said to be nearly maintenance-free and brings the organisation nearly ₹30 crores per year in the form of electricity charges.

India is considered to be the fifth largest user of wind energy in the world. The Indian Railways are planning wind farms on the Western Ghats and are expected to generate 12 billion units of power and save the Railways nearly ₹12 crore per year on its power bills.

India is reported to be ranking fifth in the world with total installed capacity of 9,645 MW of wind power installed by the end of 2008. Wind energy systems have been provided hitherto in India mostly by Indian companies. Some Indian companies have also provided wind energy systems in other countries. An Indian firm called 'Suzlon' is today a world giant in providing large-sized wind energy systems both in India and overseas to which it exports. A few foreign-based companies are setting up shops in India to benefit from lower costs and lack of conventional electric grids in small and medium-sized cities. Indian installation costs are said to be 30-40% less than that in Europe.

Wind Power in UK and Europe

North European countries such as Demark, Holland and UK are most favourably placed as far as winds are concerned. They are known as windy countries and are capitalizing on them by developing wind energy to generate electricity locally for use in their houses and feed the surplus into their town grids. The electricity tariffs are so fixed as to make individual investment attractive. Holland used wind mills effectively to pump up water since the 18th century before the advent of steam power. Their wind mills are a tourist attraction today.

Today's offshore wind farms consist only of sleek tall masts with a two-bladed fan generating electricity. The farms off the coast of Kent can generate 300 MW of power. UK being a windy country, its companies are producing wind turbines mounted on masts for buildings. Because of likely noise problems, a minimum distance of 100 metres is provided from neighbours. A 6 kW turbine can produce12,000 kWh power annually in certain windy locations and with the existing feed-in tariffs the return period expected on investment is about 6 years. Small-sized (small diametre) turbines have been sought for fixing to roof gables, and for charging 12-volt batteries as used with low voltage appliances. Small-sized turbines are used on boats, yachts and caravans in Europe. It should be noted that, in a very windy situation, possible turbulence can actually diminish the effective power one can expect from a turbine.

Floating Wind Farms in Europe and USA

An article from BBC News reports that the Norwegian energy giant 'Statoil Hydro' has successfully built the world's first full-scale *floating* wind farm on the open sea as an experiment to harvest electricity in an environment of strong, low-level winds and fewer space restrictions than are found on land. This may increase electricity production substantially. In deep sea conditions or where the soil does not permit fixture of the wind turbine to the soil with a solid foundation, the slender tower is kept hollow and filled with gravel and water as ballast. Slack moorings anchor the turbine to the seafloor.

The USA and Germany have also approved construction of the first offshore wind farms in Massachusetts and in the North Sea, respectively. This seems to obviate the necessity of large-scale land acquisition which is today becoming a severe problem in parts of India. However, capital costs are considered to be much higher for sea-based systems than for land-based systems, and permissions are needed from more authorities than noted earlier.

Some Suggestions for India

1. India can also have floating wind farms on the sea like what the Europeans have. India has a long coastline and most of its metropolitan cities are on the coast. Moreover, land is often unavailable on-shore or is available at a very high price and is ridden with politics.
2. Like the wind mills of Holland, we can use wind turbines (not so elaborate looking) to pump up groundwater without having to spend for batteries for storage of power in non-wind hours. As long as the water that is pumped up is stored in adequate-sized storage tanks for the supply intended, it does not matter if the wind blows all the time or not. Much cost can be saved by avoiding batteries for storage of electricity.
3. Like the small-sized wind turbines used on yachts and caravans in Europe, one could also use similar ones in Indian cities with tall buildings in windy areas to charge 12 volt batteries for refrigerators and other appliances in homes. A new business could develop for small-sized wind turbines for domestic use in tall buildings.

4.4.2 Solar Energy—Another Ready-to-Use Technology

Solar energy is another ready-to-use technology whose prices are fast approaching parity with existing grid prices. As a tropical country which receives much sunlight for 250 to 300 days in a year, India tops the world (along with California and Hawaii in the USA) in its *potential* for developing solar energy systems. Spain, Italy, Australia and China come next on the list. Australia is reported to be adding solar PV systems at 40% per year. However, in actual implementation, Germany and Spain top the list at present.

India has many coal deposits, yet its needs have so increased that India will have to import almost 30% of its demand by 2017. Oil imports will be 75% of their demand (KPMG 2011). Even then, 40% of rural households are without electricity. To meet this enormous backlog in an environmentally sensitive and responsible manner, India has to consider *renewable* sources of energy (wind, solar, etc.). Solar power is reported to have the potential to meet 7% of India's electricity needs by 2022. It would reduce its carbon emissions by 2.6% and save India some US $5.5 billion by way of imports. For this reason, the Jawaharlal Nehru National Solar Mission was launched in 2009.

Moreover, development of solar energy would give India added energy security (which is very important for any country), save it some foreign exchange, create new jobs and mitigate some carbon. For industries, this represents a significant investment opportunity in both grid and off-grid installations. The author has always been advocating that if any subsidy has to be given for energy production, it makes more sense to give subsidies for new solar energy installations rather than for importing diesel oil from another country. Fortunately, a well-known independent strategy analyst like Kiran Karnik says the same thing (*Economic Times*, 2 October 2012).

Green Energy Production in India

Green energy production in India is mostly through wind energy and in a few cases solar energy. However, production has been somewhat slower than expected from a warm and sunlit country. The position in a few States is shown in Table 4.2. Tamil Nadu seems to lead with 4,900 MW capacity.

Some Typical Solar Energy Systems

There are three major types of solar systems commercially available in the world.

Table 4.2 Green Energy Production in the States of India

State	Green Energy Production, MW
Tamil Nadu	4,900
Maharashtra	2,500
Gujarat	1,800
Andhra	800
Orissa	300

- **Small solar thermal units** (solar cookers, solar heaters, solar coolers). They are based on direct absorption of heat from solar radiation to heat up water. No electricity is generated.
- **Solar photovoltaic panels** which directly convert sunlight energy into electrical energy by the use of silicon diodes. They can be used either for stand-alone systems or as grid-connected systems.
- **Large solar concentrators** (for larger installations to serve cities and towns) which also work on the thermal principle producing steam to operate turbines.

Indian manufacturers are presently offering only (1) small solar items such as solar PV panel activated lanterns and cookers, (2) solar water heaters for bathrooms and (3) photovoltaic PV panels manufactured in India. Concentrated solar power (CSP) systems for larger habitations exist in Spain and USA. Their first installation in Rajasthan, India, is under construction. Many Indian companies ranging from Tatas, Birlas, Jindals and many more are now jumping on the solar band wagon. Ispat Energy, an Indian Company, is planning to use in India a unique lightweight and flexible photovoltaic device developed by an American group.

(1) Small Solar Thermal Units: *Solar cookers* have been in use since a long time. They have very useful application in schools, hostels, etc., where meals have to be prepared usually in large quantities. They are also useful for religious centres where large crowds visit on certain days and meals have to be prepared for them. Their use makes cooking cheaper and also saves production of CO_2 from use of other cooking media like LPG, wood, charcoal, etc. There are cases where such organisations have benefited from certified emission reductions (CERs) and carbon credits have been profitably sold on the world market.

Solar water heaters are equally popular for bathrooms and kitchens where hot water is required in relatively large volumes for hostels, hotels, hospitals, guest houses, industry canteens and such purposes, generally up to 60–70°C. Many industries (textile, dairy, pulp and paper, Pharma, leather, etc.) also often require hot water up to 100°C or more and may use solar heaters as pre-heaters. Such systems have proved popular with large-scale users of hot water for whom payback periods as short as 2 years have been noted. Several installations of this type have sprung up in different parts of the world including India. Their use is particularly economic where large volumes of hot water are continuously needed each day. Separate plumbing systems may be needed from the roof to the bathrooms to benefit from solar hot water systems.

In Bangalore, rooftops are reported to be dotted with solar-powered water heaters, now mandatory on all new structures. Their use could, and should, be made mandatory in all states of India. A hot water system that gives 125 litres per day comes for about ₹20,000 only. For smaller systems for individual families, the payback periods are much longer and governmental subsidies may be needed to make them more attractive.

In the UK, even with its poor sunshine, more than 100,000 homes are reported to have installed solar water heaters in 2010. In India, with our tropical sunshine, we wonder if we can boast of even half as many installations as the UK has. Perhaps, a policy decision is needed and a mandate has to be issued for action to take place. The scope for new business is extremely high.

Solar coolers are the latest addition to the solar armoury. They capture solar radiation through solar collectors in the form of troughs. This generates hot water whose heat generates chilled water elsewhere of temperature 7°C. The chilled water is circulated to the rooms through a fan coil unit. No energy is consumed from the city grid. A solar energy centre is located in Gurgaon, New Delhi, which does this successfully.

(2) Solar Photo-Voltaic (PV) Panels: Solar photovoltaic (PV) systems directly convert sunlight energy into electrical energy by the use of silicon diodes. It was Becquerel, the French scientist, who first discovered this phenomenon in 1839. However, the conversion efficiency is disappointingly low, being only 10–13% at present for thin film type and 17–18% for crystalline silicone type though efforts are being made to increase it further. A solar industry is gradually coming up in several countries (including India) for manufacturing the basic photovoltaic 'cells' using the more efficient silicone diodes with different technologies. Solar energy business is reducing costs at 5 to 7% per year while coal-fired thermal plants are becoming costlier at 4 to 5% per year. Hence, the two graphs would probably cross over at 2017 or near about—and solar energy would reach grid parity then (KPMG 2011).

The 'cells' are connected together either in series or in parallel to form what are called 'modules' or panels. These modules are encapsulated properly in glass or other material to be able to perform in field conditions for many years (upward of 25 years). A series connection is done to increase output voltage while a parallel connection is done to increase the current output. The maximum area of a single, solar cell at present is about 225 cm^2 (15 cms × 15 cms) and each cell can give about 3.4–4.0 Wp at 15% efficiency (where Wp stands for watts at peak radiation). Several cells can be connected together to give a module or panel capable of giving 230 to 240 Wp or more. Panels capable of giving lesser wattage (like 44 or 75 or other) are also made mainly for smaller stand-alone installations.

In India, among the major manufacturers are Moserbaer, Indosolar, Lanco Solar and Tatas. The global capacity of PV cells was only 2,500 MW just a few years ago, and has now exploded to nearly 40,000 MW mostly built in China and exported everywhere (including India) at unbelievably low prices. The price of PV modules has fallen from $4.00 per watt to less than $1.00 per watt. A single solar PV panel of 230 Watts may today be available for only ₹10,000 to ₹12,000 per panel. But, fitted up on an iron grill and connected to the grid with cables, inverters and metres, etc., its cost may become double of this amount. (See Table 4.1 for capital costs.)

In Central India, the peak occurs around mid-noon lasting from 2 to 4 hours while falling off earlier and later. In areas like Gujarat, each panel or module is found to give almost 0.9–1.0 kWh of power per day. Several modules can be connected together to give what is called an 'array' of modules to meet desired outputs. Using solar PV modules or panels, solar power can now be produced at almost ₹8–10 per unit (kWh) instead of ₹17 per unit just two years ago. Prices will go down still further.

Location is Important

According to the Solar Energy Society of India (SESI) most parts of India receive solar energy of 4–5.5 kW per sq metre per day (which signifies about 5,000 trillion kWh per year of energy received over the whole of India). The map of India with actual radiations is shown at Fig. 4.2 (Courtesy, Kiran Energy, 2012). In UK it may reduce to only about 1 kW/sq metre, making solar energy relatively uneconomic.

The power that is generated with PV systems depends on the latitude and the duration of the peak. As one goes northwards, the available power reduces. At all latitudes, the power is maximum at

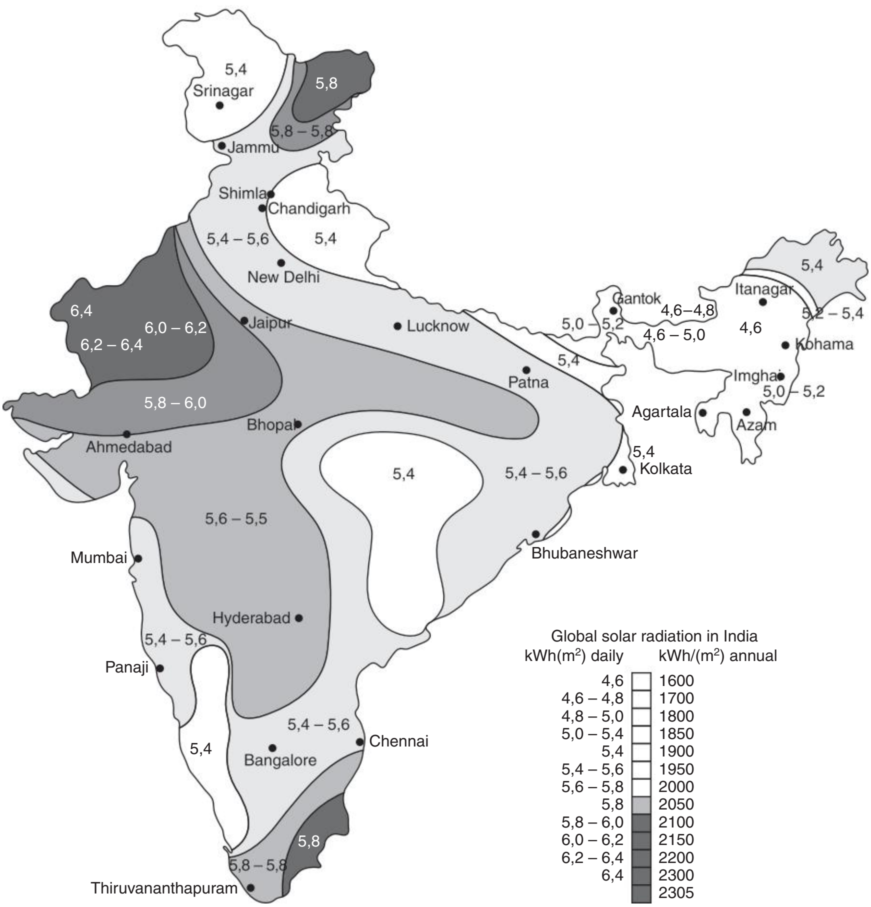


Figure 4.2 *Radiation received in India on a flat surface at different latitudes. (Map supplied by courtesy of Kiran Energy, Mumbai, 2012)*

certain hours around mid-day and reduces on either side. It slowly increases as noon comes on and again reduces as the afternoon becomes late afternoon. Ideally, all solar energy panels should be in full sun for about 6 hours (from 9 AM to 3 PM) in mid-winter and should be inclined at 30 degrees and facing South in central India. Researchers are experimenting with other shapes and sizes and innovative 3-D designs to maximise receipt of solar radiation. Computerised moving of panels is also attempted to be able to get longer full sunshine hours.

Solar PV Panel Installations

PV installations are made for various purposes. Small portable panels are used with lights as described further below. With larger panels, two types of installations are normally done: stand-alone systems and grid connected systems as described later. The main thing to remember is that solar power is ideal to use on a short-time-per day basis, say, for only a few hours in a day, so that the electricity need not be stored. This makes solar energy ideal as a 'peaking supplement' in conjunction with coal or oil-based thermal power stations. Similarly, use of solar energy in villages and rural areas is often restricted to a few hours in the evening.

Solar PV lanterns (TERI-type) are the simplest and smallest type of devices which use solar energy. They require the use of small handy photovoltaic panels (described later) and have relatively short payback periods. They constitute an excellent answer to electrical power for lights in rural and semi-rural areas of India where conventional electric power is still unavailable. Only an initial investment in the unit has to be made (about ₹3,000 to ₹5,000 per lamp and ₹17,000 to ₹20,000 per street light. Thereafter, solar radiation generates the electric power for free. But the power may need to be stored in a battery for a few hours. The running cost then consists of replacement of the battery every 2–3 years. By the year 2022, India expects to install 20 million solar lights in villages and small towns which would result in a saving of about 1 billion litres of kerosene every year.

TERI-type lanterns make excellent items for donation to NGOs and others for installation in villages without electricity. A company based in Delhi has developed a solar powered unit using an LED-based lamp that is long-life, waterproof, portable and runs for 12 hours/day on the same power. It is likely to be an attractive replacement for the conventional kerosene lamps.

In India, where even poor people seem to afford mobile phones, surely a solar lamp is not too much to afford. Its attractiveness increases when it can also operate a mobile phone battery charger and operate a small radio or TV at the village level.

Solar PV Stand-alone Systems

Stand-alone sources of renewable energy find favour in rural and semi-urban areas of India for generating electricity at the spot where it is required to operate items such as the following:

- **Street-lights or telephones along roadways:** A good example of stand-alone systems are the telephone poles provided along the Mumbai–Pune expressway and light poles along some roads in India, each carrying its own solar PV panel on top to generate electricity to run the telephone line or the light.
- **Operating intermediate stations for mobile phones in unelectrified areas:** India is reputed to have more mobile phones than the population of Europe. At 764 million connections, India is only next to China. As rural connections may reach 200 million, many intermediate stations need to be operated by diesel power gensets. The mobile phone industry used an enormous quantity of 2 billion litres of diesel oil in the year 2010 for operating these stations, and generated 5.3 million tonnes of CO_2. Presently, India has about 3.5 lakhs mobile telephone stations. This number is likely to go up to 7 lakhs by 2020. The National Telecom Policy 2011 recommends the use of solar PV panels instead of gensets.
- **Operating small water treatment units in out of way places:** To remove hardness, arsenic or fluoride or such other impurity from locally available drinking water, operating small water treatment units in out of way places may become necessary. The units may be operated for only a few hours each day to save on electricity storage batteries.
- **Operating small wastewater treatment units in out of way places:** Similarly, small wastewater treatment plants like lagoons may need renewable sources of power for operating aerators. Presently, aerators need 24-hour operation whereas solar power is obtained in, say, 6 hours. This makes it relatively uneconomic as electric power has to be stored in batteries. Some R&D is needed to reduce aeration time.

- **As a standby source of electric power in industry:** Instead of a diesel-generating set for operating a machine or process in an industry, one could use a solar PV panel set up. Often a diesel-generating set is used as a standby source of power. According to some users, the real cost of generation of diesel power is reported to come to around ₹17 per kWh if we add the subsidy component. Solar PV power cost can be as low as ₹8 or 9 per kWh.

Solar Systems Cheaper than Gensets for Stand-by

It is interesting to note the statement of an eminent industrialist who states that some companies presently spend as much as ₹20 to ₹30 per unit with a 'genset'. They could as well save some money by switching over to solar PV panels (without any subsidy) and what is more solar energy would be entirely sustainable (24 hour supply if used along with batteries for storage) and would cut down on cost of transporting fossil fuels.

According to Prof. Bannerjee, Head of Energy Systems Engineering, IIT Bombay, the capacity of solar panels varies widely starting from 2 W to about 200 to 250 W. Prof. Bannerjee refers to them as modular units, much like lego sets which can be readily put together. If you intend to set up a 1 kW installation, you would need the panel with its mounting structure, a battery, power conditioning unit, wires, cables, etc. which along with labour would cost about ₹3 lakhs upfront. The batteries, costing about ₹15,000, would need to be replaced every 3–4 years and one would end up paying ₹12–15 per kWh. Operating costs are even lower at present. A PV panel of, say, 230 Wp capacity may cost about ₹20,000 each (including its supporting structure, metres, cables, etc.) and carry a 25-year guarantee (but is likely to last even longer). Several panels may be needed depending upon the size of the installation.

Among other examples of niche applications, a company has stepped in to meet the growing shortage of water by designing a solar system to operate a water generator that converts water from the atmosphere (humidity) into drinking water. A company (Surana Ventures Ltd.) is providing 2,000 stand-alone type Telephone kiosks and ATMs in New Delhi for the Commonwealth Games. A light-weight solar plane has been developed to operate on solar energy. It successfully made its maiden flight from Switzerland to Belgium, a distance of 600 km recently in 2012.

Example 4.1

A 5 HP pump is required to be operated only 4 hours per day to pump up enough water for a village water supply scheme. Solar PV panels are proposed as the area is not served by the local electricity board. The water is stored in a tank and supplied as needed. Estimate the number of panels required for operating the tube well pump.

$$\text{Pump 5 HP} = 746 \text{ Watts/HP} \times 5 \text{ HP} = 3730 \text{ Watts} = 3.73 \text{ kW}$$

Provide 50% more capacity to allow for losses, mismatch, etc., provide $3.73 \times 1.5 = 5.6$ kW capacity. Total power required for 4 hour operation = $5.6 \text{ kW} \times 4.0 \text{ hrs} = 22.4$ kWh.

If a panel can give 230 Wp, it will generate about 1 kWh in 4.35 hours.

Hence, to generate 22.4 kWh, we will need, say, 23 panels

No batteries for power storage are required if operation coincides with sunshine hours. Only the usual water storage tank will be required.

Example 4.2

Prepare an outline design for a solar PV operated system to pump up 20,000 L (20m^3/d) of ground water in 6 hours from a depth of 15 metres (total head including friction loss = 15.5 metres). Pump efficiency is 25%.

Daily water supply needed = 20m^3/day

Energy required = $20 \text{ m}^3/\text{d} \times 1000 \times 9.8 \text{ m/sec}^2 \times 15.5 \text{ m}/3600 =$ 843.8 Wh/d

Since we want to pump up in 6 hours when sunshine is good, energy required/hr = $843.8/6 = 140$ W/h. Provide 50% more for losses and mismatch, i.e., $140.5 \times 1.5 = 211$ W/h.

Number of solar panels required of 70 Wp each = $211/70 = 3$ panels. Alternatively, provide only 1 panel of 230 Wp.

Some of the installations that have come up presently in India in spite of somewhat higher costs are because of the desire to break free from long hours of load-shedding which would otherwise have to be faced by the people, especially in smaller Indian towns. Load-shedding is bad for business.

A conventional-type system capable of giving about 1 kW of energy would need a capital investment of about ₹3 lakhs upfront. Sometimes, the installation costs may increase by another ₹1 lakh if difficult conditions are encountered at site. As more installations come up in India, costs would come down and payback periods get reduced. Tax incentives and subsidies, of course, help.

However, an advantage of PV systems is that long transmission lines are not necessary. Hence, transmission and distribution (T&D) losses are minimal. Another advantage is that much land is not required to install them. They are generally fitted on to the building roofs. However, roof areas are becoming smaller and smaller as land values increase and builders are building taller and taller structures rather than the broader ones of the past when land was cheaper.

As terrace sizes diminish, the space for accommodating solar panels diminishes and other ways have to be found. More and more solar modules are now being fabricated as building materials so that they can be integrated into the building's fabric by architects. They include solar roof tiles, wall materials and semi-transparent roof material for atriums and skylights. These are destined to increase usage in the near future.

Unique installations of solar PV panels exist in some countries. One such exists for providing electricity for the high-speed trains connecting Paris in France to Amsterdam in Holland, a few hundred kilometres away. Nearly 16,000 panels have been used to give a generating capacity of 3,300 MW. The panels have been laid along the railway tract forming a sort of tunnel with the panels supported on the roof. Another instance is in Gujarat nearer home where panels have been placed on a steel structure spanning the Narbada river in order to avoid using additional land. Yet another is the case of Tata Power at Lonavla where floating solar panels are being put up on lake water as a pilot project to avoid buying additional land.

Solar PV Systems for Feedback of Excess Power to City Grids

An attractive inducement for new solar installations is payment for 'feedback' of electricity from private installations into the public grid. It improves the electricity situation in the city as most cities suffer from shortage of electricity, and governments are unable to meet this shortage for want of capital. It encourages private capital to come in and improve the shortage situation since payment is made at a rate that would make such feedback profitable for the investor. First started in Germany around the year 2000 by a man called Hermann Scheer, it is now practiced in many countries. In just 8 years the solar industry in Germany began to employ more people than the automobile industry.

A recent governmental ruling in India requires all electric supply companies and electric boards to have at least 5% of their energy supplied from *renewable* sources, and pay ₹18.50 per KWh for captive feed-in systems. This makes feed-in an attractive proposition. (In Germany, the stipulation is that 15% of energy must be from renewable sources.) Gujarat buys power from private players at ₹15 per unit for the first 12 years, and at ₹5 per unit for the remaining 13 years.

This should give a new fillip to installation of renewable energy systems for feed-in to the existing grids on private initiative in urban areas of power-short cities. Incidentally, the electricity must first be transformed into an alternating current of the correct voltage for the area using an inverter and also synchronised to 50 cycles per minute of the electricity network at the cost of the seller.

Grid connected systems are generally seen fitted on roofs in *urban* areas to provide electric supplies needed by the building occupants and to feed-in the surplus into the town grid when the building does not need it. If it is an office building, it does not need much electricity in the nights and on week-ends. No additional land is required as roofs are used. This can be a great advantage in crowded urban areas. However, terraces are becoming smaller and smaller as land values increase in big cities, and space for installing solar panels is reducing. Electricity from PV systems was reported to cost in 2010 as much as ₹15–16 per kWh without subsidy (₹9.0/kWh reported with subsidy). Costs have reduced nearly 50% in the last 2 years and grid parity is expected soon (also see Table 4.1). A KPMG Consulting report (2011) predicts that by 2017 grid parity is likely to be achieved.

In Gujarat, private parties are willing to install solar energy systems *at their own cost and risk in cities* provided the building terrace is leased out to them at a mutually agreed rent for a long enough period. The party gets paid at the official rate by the electric company for feeding-in the electricity into the town grid, and the party, in turn, pays the building owner ₹3 per kWh fed as per metre. The relative rates may change in future. In this way, the landlord gets paid for the use of the terrace and for generating electricity without investing a single rupee, and the investor has an opportunity to invest profitably and the electric company (and the town) benefits from the electricity fed-in. The business deal benefits all parties. Solar power initiatives in Gujarat are reported to have attracted ₹9,000 crore investment (see Appendix 2(6)).

A disadvantage of the grid feeding system is that T&D losses keep occurring whereas solar panels are really meant to generate electricity at the site where it is needed.

Maharashtra, India, has started to build a 150 MW solar power project in Dhule District. It is reported that the plant will produce electricity at ₹12 per unit and sell it at ₹17.90 to the grid. Two solar energy plants have already been set up in Chandrapur, presumably to assist the local thermal power station to meet its peak loads.

The Indian Oil Company (IOC) is reported to be considering setting up, in association with Bharat Heavy Electricals Ltd (BHEL), a solar power plant worth about ₹100 crore in Barmer, Rajasthan, based on the PV panel technology.

An interesting example comes from Qatar in the Middle East where in preparation for the Olympic Games to be held in 2022, a new stadium is being planned to seat 50,000 people during the games and (with some planned de-construction) to seat only 25,000 later. The stadium will provide solar energy at the time of the games and later to the town's grid—preparing for the time when its oil will run out!

Example 4.3

100 kW of electricity is proposed to be generated by using solar PV panels on the roof surface. Estimate the number of panels needed, area requirement and cost.

Each panel can generate 230 W at sunshine for, say, 6 hours.

Thus, number of panels required to generate 100 kW = 100,000 W/230 = 435 panels.

These panels will be exposed to sunlight effectively for 6 hours/day.

Hence electricity produced per year = 230 W × 435 panels × 6 hrs × 365 days = 219,109 kWh per year. The electricity usage per year also has to be determined taking into account all the fixture consuming electricity for likely number of hours/day, the holidays, ½ working days, Sundays, etc. The balance will go to the grid.

The roof area should be enough to accommodate 435 panels in full sunshine (with the necessary paraphernalia). If each panel takes up 3.0 sq metres including all paraphernalia, space required is 435 × 3.0 = 1305 sq metres. This may be possible with a large building or sports stadium roof, or a railway station roof or factory roof or roof + compound.

The estimated cost as per Table 4.1 will be about ₹1 crore.

Appendix 2(5) gives the example of the Gujarat Pollution Control Board's new office building in Gandhigram, Ahmedabad, where a solar PV installationwas done at a cost of about ₹1 crore for 80 kW capacity in 2011–2012, i.e., ₹1.25 lakhs per kW including the cost of inverter, metering, cables, etc., and maintenance for 10 years, for supplying the electrical needs of the building and feed-in of the excess into the grid.

The panels have been fixed on the building's terrace and, hence, no additional land cost was incurred. It is the first 100% solar building in Gujarat. As the excess electricity is fed into the town's grid, no storage batteries are required. During non-sunshine hours, the building's electricity requirement is met from the grid. The grid serves for balancing the demand and supply. More and more buildings are considering this kind of arrangement as batteries are avoided and grids are happy to benefit from the feed-in.

It is evident that the feed-in occurs mostly on Saturdays, Sundays and holidays when offices are closed. The grids want consumers at that time. Hence, industries are needed as they generally work on holidays and weekends.

Appendix 2(4) gives another example of an ownership residence building in Pune where a solar + wind energy (hybrid) system was set up in the year 2007 for part supply of free electricity to the members of the cooperative society. Here also, the building's terrace was used. But no electricity is given to the grid. It is used within the building. Giving some free electricity to the tenants seems like a great marketing idea for hastening the sale of flats on ownership basis. Perhaps it is a better idea to attract flat buyers than providing a gymnasium or something else for free use by the tenants. However, the installation cost is increased by 20–40% owing to the need for storage of electricity. Batteries also need to be replaced every few years.

Provision of 'Balance of System'

When solar PV panels are provided and supply is either to the public grid or to the building tenants, there is a further cost of providing the necessary so-called 'balance of system' (BoS) to meet the needs of the installation (see Fig. 4.3). These may consist of all or some of the following items:

- Batteries (lead-acid or Ni-Cd batteries are preferred over lithium-ion)
- Inverter (needed because solar power is DC whereas AC is required for feed-in)
- Charge controller
- Metering of power produced by the PV system and power fed into the grid is necessary
- Cables to connect all items
- Supporting structures for mounting of PV panels, batteries, etc.

Both wind and solar energy systems are intermittent in nature. However, where electricity is required all 24 hours by the tenants, the electricity has to be stored. Expensive electricity storage facilities (batteries) thus become necessary. Where electricity has to be fed into a grid, DC has to be converted into AC by an inverter and metering has to be done to measure the quantity of electricity fed in. In both cases, cables and supporting structures are needed. All this adds to the cost of installation and its maintenance.

Where a grid system exists nearby, and can be used, storage cost can be avoided if the electricity produced by solar radiation is directly fed to a city grid and the electricity needed during non-sunshine hours is drawn from the grid as required. This saves the cost

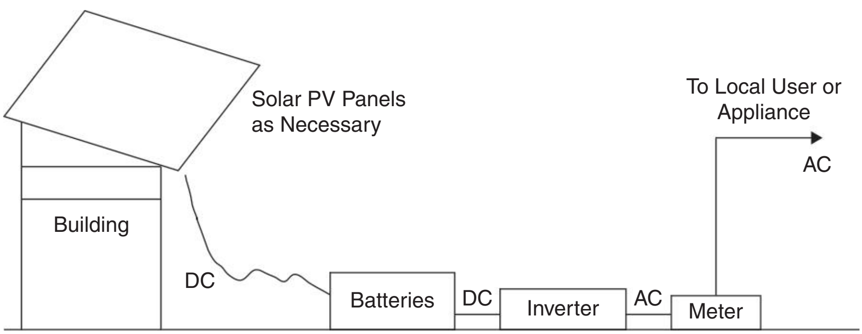


Figure 4.3 *Use of solar PV panels to generate electricity for feed-in into city grid.*

of batteries and their replacement every few years, but it requires the cost of an inverter to convert DC to AC and meter the supply to the grid. Good Indian inverters are available. Recently, the German firm Bosch has entered India to manufacture inverters.

Some Indian Experiences

Charanka lies in a salt plain near India's border with Pakistan. It has installed a solar park consisting of 200 MW capacity solar PV panel type plant, the first of such a large capacity to generate electricity using 'green technology'. It took 16 months to build. Conventional energy generation in India means burning cheap but dirty local coal. Power stations charge local electricity boards ₹3–4 ($0.06–0.08) per kilowatt-hour. The state coal monopoly is unable to dig up enough of the black stuff, forcing power firms to buy pricier imported coal which may be 2–3 times more expensive. Many observers think the price of conventional power will soon have to rise to ₹5 or 6. Meanwhile, the cost of solar equipment has fallen by a third since 2010.

Two other factors make an Indian solar boom seem possible, reckons Alan Rosling of Kiran Energy, a solar firm backed by American private equity. Cheaper solar and pricier conventional power have persuaded many that solar will soon be competitive *without* subsidies. V Saibaba, the boss of Lanco Solar, a firm that makes and operates solar parks, says that by 2016 Indian solar will match the price of conventional electricity. That should mean a boom.

Sunil Gupta of Standard Chartered Bank reckons that India's share of new global solar installations will rise from 1% this year to 5% by 2015. India's central government has set a target for 20,000 MW of installed solar generation by 2022, from less than 1,000 MW today. That would still represent a 5% or less of total power-generation capacity in India, and cost perhaps $30–40 billion to build (a fraction of the investment in new coal-fired plants). So, plenty of folks think that the official target will be smashed. D J Pandian, a civil servant in charge of energy policy in Gujarat, believes that his state alone will easily reach 10,000 MW of capacity in a decade.

But not everyone agrees. Some point out difficulties such as the supply chain and economies of scale are not there. The infrastructure is not there. The difficulty of getting plugged into the grid and a shortage of water to clean panels are common worries. Solar faces two other problems. First, Gujarat's state government has guaranteed a high price of ₹15 for the first 12 years of operation to solar producers, which should mean they make money. But at the national level, there is a separate system. It relies on 'reverse auctions' in which those solar producers who commit to producing power at the lowest cost win the right to operate. In the second national solar auction, of 350 MW, in December, the winning firms committed themselves to selling solar power for as little as ₹7.5. Many people doubt that it is possible to make money at these prices. An Indian engineer says the auction was 'a farce' and that it is impossible to build a solid plant and operate it for less than ₹10.

Second, if prices do not fall steeply, there may be little appetite for solar power. The grid is rickety. Many states' distribution firms (the generators' main customers) are financial zombies. Today the cost of solar subsidies is hidden—pooled with the overall generation bill in states such as Gujarat or, for projects under the national scheme, buried in the finances of a big state-owned conventional power firm. Such bureaucratic subterfuge works on a small scale. But if the bill for solar swells, it is not hard to imagine the kind of public backlash against subsidies that has hit cash-strapped Europe. India's politicians may then start to ignore contracts. To solve India's energy problems, solar firms must deliver blindingly low prices to survive.

Several Indian corporates have set up formidable plans and budgets for undertaking large solar and wind energy projects in near future. Construction times for renewable energy projects range from 1.5 to 2.0 years whereas conventional fossil fuel based projects require 3 to 4 years in India. India is targeting 20,000 MW in solar and 89,000 MW in wind by 2020. The renewable energy market is just taking off!

Renewable Energy Certificates (RECs)

As stated earlier, in order to promote the installation of renewable energy systems in all states, the government has started issuing RECs to those states which have exceeded their mandated 5% quota. These certificates can be sold to other states that have not yet met their 5% purchase obligation. According to the India Energy Exchange, while solar power is costlier, non-solar sources of energy (wind, biomass, etc.) have few takers due to lack of steady returns. An REC represents 1 MWh of energy produced from a renewable source.

(3) PV Solar Panels + Electrolyser + Fuel Cell: A unique arrangement has become possible to generate electricity from solar energy for domestic purposes and to recharge the batteries of an electric vehicle at night. Thanks to an MIT researcher who has developed a cheap self-generating catalyst recently, using which it is possible to run an electrolyser which is hooked up with a PV solar panel system (see Fig. 4.4). The PV solar panel produces electricity during the daytime to meet domestic needs. Surplus electricity is taken to an electrolyser which generates H and O from water and stores it for recombining later in the night hours in a fuel cell to generate electricity once again and give water as a byproduct. Difficulties in storing hydrogen are well known. Newer materials are being experimented with.

Instead of solar PV panels, one could provide a hybrid combination of wind + solar units, depending upon the site situation. Also, if a fuel cell is not available, the surplus electric energy may be stored in a set of batteries for use during non-sunlight hours as mentioned earlier.

In colder countries like the UK, an equivalent scheme has been suggested starting with gas supply to individual houses. The gas is converted into electricity for home use (including house-heating and hot water) and for feed-in into the town grid. This has been shown to be cheaper than generating electric power at a central power station using boilers, etc., where the efficiency

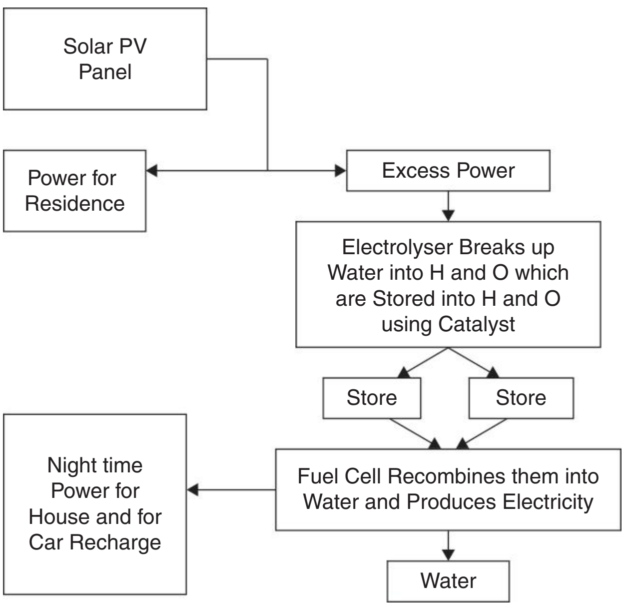


Figure 4.4 *Use of solar PV panels + fuel cells to provide renewable electricity to a house and car.*

can be at most 40% and the rest of the energy lost as heat to the cooling towers. In warmer countries, solar energy can be used instead of gas.

Fuel Cells to Generate Electricity from Wastewater

The Pennsylvania State University's Hydrogen Energy Centre is developing a hybrid arrangement by placing a reverse electro dialysis device between two chambers of a microbial fuel cell (MFC) to create what is called a microbial reverse electro dialysis cell. This hybrid arrangement produces seven times more power than what might be expected from a single MFC. It is expected that if the potential energy in domestic wastewater can be harnessed, wastewater treatment plants could power themselves in future.

The Jawaharlal Nehru National Solar Mission targets are as follows:

- *By the year 2013:* 1100 MW grid solar power, 7 million sq metres solar collectors and 200 MW off-grid solar applications, and
- *By the year 2022:* 20,000 MW of grid solar power, 20 million sq metres solar collectors and 2000 MW off-grid solar applications.

The National Thermal Power Corporation (NTPC) is setting up a 50 MW solar PV installation at Rajgarh in Madhya Pradesh to supply electricity by 2013. The plant will bundle this electricity along with that generated by a coal-fired power plant to make it affordable.

There are several off-grid applications which are already commercially viable or near viable where rapid scale-up is possible, with resulting reduction in imports of fossil fuels. The Indian authorities are hopeful that the target of 20,000 MW of solar generating capacity by the year 2022 will be met even earlier than that year and India will become a global exporter of solar power systems.

Under the National Solar Mission, three major initiatives are proposed to be undertaken:

1. Create volumes to encourage large-scale manufacture,
2. announce a long-term policy to purchase power from renewable sources, and
3. support R&D.

The *Solar Energy Society of India (SESI)* has been formed to promote dissemination of information, cooperate with other research

Table 4.3 A few typical Installing and Operating Costs of Small Renewable Energy Systems

Type Capacity Installation	Cost, ₹	Remarks
Wind Turbine 1 kW	₹1.5 Lakhs	At avge wind speed 5 m/sec, guaranteed power gen = 80% × 3 units = 2.4 units of power
Solar PV Panels 1 kW	₹3 Lakhs	Set of 8 panels, inverter, charge controller, battery, etc., including structure for panels
Solar water heater 1000 L/day	₹2 Lakhs	Complete with tank, piping and wiring. Requires 250 Sq Ft South facing Shadow-Free Area
Hybrid (wind–solar) 0.5 kW each	₹2.5 Lakhs	At avge wind speed 5 m/sec and solar radiation at 6 kWh/sq M guaranteed power gen = (80% × 1.5) + (80% × 1.5) = 2.5 units

Installation costs: The available costs of installing a few different systems are given in Table 4.3. These costs are approximate and have been indicated by some Mumbai dealers. They vary from case to case and area to area. Costs are also variable depending on the size of the installation and government subsidy available. Hence, the costs indicated are approximate and exclusive of taxes, transport and installation costs.

Operating costs: There are no direct operating costs as sunlight and wind are available free of cost. However, there are amortisation costs depending upon the life of the system and replacement costs. There are also annual maintenance costs (AMCs) and specifically the cost of battery replacement every 2–4 years.

bodies, NGOs, etc., and generally to promote R&D in the subject, and further its applications.

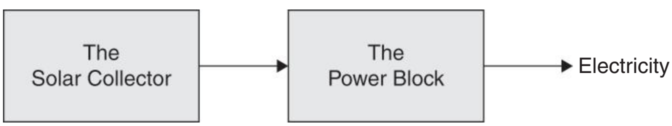
According to guidelines issued by the Central Electricity Regulatory Commission (CERC), India, investments in renewable energy plants such as solar, wind and biomass, will get a pre-tax return of 19% per year for the first 10 years and 24% per year from the 11th year onwards. The CERC has also come out with norms for investments as follows: ₹45 per watt for biomass plants, ₹50 per watt for small hydro projects, ₹51.50 per watt for wind projects and ₹170 per watt for solar projects (also see Table 4.3). The costs are for the year 2010 and will be reset every year.

(4) Concentrated Solar Power (CSP) Systems: While the efficiency of PV panels is only about 15%, it is relatively higher at 24% for Concentrated Solar systems using parabolic mirrors. Much of the experience comes from Spanish and US applications. Presently, 1400 MW is operational and another 6,400 MW is under construction. Rajasthan is reputed to be setting up India's first unit of 400 MW capacity.

Large-sized plants for supplying electricity to urban areas are presently coming up in a few parts of the world to demonstrate various technologies. Experience has shown through the development of special large-sized units called *solar concentrators* for power generation in Spain, USA and elsewhere that it is possible to generate power on a large scale but there are a few problems yet involved in development of solar power and its storage for cities or large consumers.

Land is one problem. Remember that solar energy is plentiful in nature but available on the earth in 'dilute' form. Hence more land is needed (about 10,000 acres for a 1,000 MW plant, the land alone costing around ₹100–200 crores). Land requirement may become a serious problem. Cheaper land would perhaps be available in a place like the Rajasthan desert.

CSP systems convert the infra-red part of solar radiation into high temperature heat using parabolic mirrors. The large parabolic mirrors are shaped as ultra-long troughs and aligned North–South and slowly rotated as the sun moves from East to West daily. This is done to concentrate sunlight on to a long tube containing oil or molten salts that store heat (400°C). The salts are actually a mixture of two fertilisers, sodium nitrate and potassium nitrate. This heat is then used in a conventional thermal power plant to produce steam and operate steam turbines to give electricity at about ₹4 per unit. Thus, there are two major parts to a CSP: The solar collector and the power block.



The capital cost is estimated to be about ₹11–13 crores per MW (see Table 4.1) It is hoped that, with further research and improvements in future, the *concentrated solar power (CSP)* system costs may become competitive with conventional power and larger-sized units could be developed. There are already signs that costs are sure to come down for both CSP and photovoltaic panels.

Land availability may, however, become a problem in India as experience in Singur, West Bengal, has shown. Even though desert lands can be brought into use without affecting agriculture, often, even what is classified as wasteland by the government is considered valuable by villagers who use the land for grazing, collecting minor timber, and as transport corridors. Villagers have also spurned joint ventures with corporate bodies out of mistrust. Hence, land can become a serious problem in India.

Moreover, water is also needed to wash off dust from the solar mirrors. This water may be scarce in wasteland areas and need expensive reuse techniques to make it possible. Use of solar energy is, thus, not so simple a problem as it may seem. One of the major problems is how to store heat produced during the day for later use. The first commercial solar plant with heat storage was opened in 2008 in Guadix, Spain, east of Granada. During the day, the molten salts are heated, while in the evening they give back heat to make more steam. A Spanish company is now building a plant in Arizona, USA, for Phoenix and Tucson cities which will generate 280 MW in late 2012.

CSP in Desert Areas

A fantastic project is being conceived using the large and barren *Sahara Desert* area in the north of Africa to develop a *CSP* device to generate enough electric power to meet 18% of the energy needs of Europe. The energy generated would also enable desalination of sea water needed for humidification to grow crops in greenhouses located in the Sahara Desert. It is an excellent example of synergy between CSP, sea water and greenhouses. Land is available, solar energy is available, generation of power is possible, but the conveyance and distribution of power from the desert to various European locations would pose enormous problems and involve large costs. Of course, no greenhouse gases would be produced.

In India, the deserts of Rajasthan and Thar might hopefully be developed one day on similar lines as the Sahara though several other areas are also likely to be used. IOC is reported to be considering setting up in association with Bharat Heavy Electricals Ltd. (BHEL) a solar power plant worth about ₹100 crore in Barmer, Rajasthan, based on the PV panel technology. The government hopes that, by 2022, solar power installation in India will reach 20,000 MW. It also hopes that 9,000 villages will benefit from soft loan schemes which will be refinanced by the Indian Renewable Development Agency Limited. Rooftop solar power will be promoted by providing incentives for self-use. To enhance human resources, the technology institutes are being asked to develop suitable training courses.

4.4.3 Hybrid Systems: Wind–Solar Integrated Systems

Hybrid systems are used where solar and wind-operated systems are both required to complement one another. Solar systems would not be available at night or in cloudy weather, while wind-driven systems would not work at no-wind times. Thus, the two could be made to complement one another to keep power supply available for longer time of day and night without too much use of storage batteries.

Cost Comparison

A cost comparison (presumably based on US data) for producing power by different methods has been given by *DNA Newspaper*, India (17.11.09), and runs as follows:

	Coal-fired	Nuclear	Solar Power	Wind Farm
Capital cost/net output 1 MW, $Mil	1.44	4.6	5.33	7.11
Cost per unit (kWh) of power gen ($)	0.16	0.26	0.05	0.14

The reader is referred to Fig. 4.1 for cost figures based on Indian data.

World Status

Germany and Spain have invested heavily in solar power. Germany, which gets relatively as little sunshine as any other North European country, is the world's largest producer of photovoltaic power from solar energy—22 GW or roughly the output of 20 nuclear power plants (Bill Clinton, 2012). Electricity generated from solar energy (in 2006) in gigawatt-hours is reported to be: Germany 2220, USA 565, South Africa 532, Spain 125, China 105, Australia 31, South Korea 31, Italy, Netherlands, Switzerland, 20–30 each, Canada 21, India 19, Mexico 10.

One megawatt of renewable energy saves around 7,000 tonnes of coal annually and 6,000 tonnes of CO_2 besides \$1 million in foreign exchange. The Government of India issues RECs since April 2011, which can be traded like the UN/CERs. It is felt that the pace at which the gap between solar power tariff and the landed cost of power will be bridged will determine the pace at which solar power will take off. Whatever the situation, one thing is clear. More investment in renewables will come if government policies are encouraging and consistent. Clean or green energy has for long been mislabeled as expensive and unwieldy. In the USA, it has been growing at 8.3%, more than twice the US economy. India would be well advised to spend its huge subsidies rather towards encouraging more renewable energy sources than in importing petrol and diesel oil from other countries.

To enhance human resources, the technology institutes are being asked to develop suitable training courses. As people see more and more installations of wind and solar energy for 'distributed generation' of electricity, a culture of energy conservation and environmental responsibility will hopefully develop. The general feeling is that a critical mass of business firms does not as yet exist in India. A larger number of business firms has to come into this field for prices to go down and expertise to become abundant. Development of training programs will be a step in the right direction.

4.4.4 Biofuels

Agriculturally cultivated oil-bearing plants called 'biofuels' appear to be other equally interesting sources of power, especially for transport. Biofuels are promising alternative green technologies. There are several biofuels obtained from natural sources such as agricultural plants, algae, corn, sugarcane, etc. Their use has been suggested mainly as additives to the existing petroleum products. Their cultivation would also help uplift rural India, and save India some foreign exchange on buying oil.

- **'Jetropha'** an oil-bearing plant that can be readily cultivated in India and whose oil can be used as additive with petrol or diesel.
- **'Ethanol'** is ethyl alcohol (C_2H_6O) commonly known as drinking alcohol. It can be obtained through chemical conversion of agricultural products such as corn or sugarcane and can be used as an additive or as an alternate fuel. Corn is used

in colder countries, and sugarcane in warmer countries such as India and Brazil. In Thailand, Cassava (root or chips) is cultivated and exported to China for making biofuel.

The earliest demonstration was apparently given in the year 1900 when Rudolf Diesel displayed an engine that worked on peanut oil. Years later, Brazil has shown us that a mix of 5–10% biofuel like ethanol along with regular petrol can be used for cars without any changes to their mechanism. At 5% blending, a country like India is estimated to need about 600 million litres per year and at 10% blending it would need double this quantity.

In India, Ethanol, made from sugarcane has been used widely as an additive to blend petrol up to 5–10%. Cost-wise, it is slightly cheaper than petrol, but also slightly less 'powerful'. Thus, mileage given by a car may reduce 3–4% with use of ethanol as 10% additive. Brazil and USA are also making flexi-fuel cars and cars capable of running on 85% blend of ethanol and gasoline giving proportionately less mileage. Sweden is also exploring the conversion of biomass from forest products into fuel-grade methanol. In Iceland, renewable methanol is being manufactured from waste carbon dioxide at a geothermal power station.

However, use of biofuels has been somewhat controversial. Their use appears acceptable where *sugarcane* is the source and the climate is tropical like Brazil and India as the energy balance is of the order of 8:1 there which is favourable. In colder countries where the biofuel is made from *corn*, the energy balance is considered not so favourable when one considers all inputs like water, fertilisers, gasoline and transport for cultivating corn. India and Brazil, fortunately, grow sugarcane.

'Methanol' is another biofuel. It is methyl alcohol (CH_3OH). Commonly known as non-drinking alcohol since it is toxic. Methanol has only 1 carbon ion and four H ions which makes it a good fuel for mixing in petrol, or if slightly modified, it can be used alone in modern petrol engines. Methanol can also be easily transformed into bio-diesel and used. It can also be used in fuel cells and be burnt in power generation plants. Methanol can be used to produce many other things, e.g., plastics. It almost seems like the friendliest chemical one can get. From paints and plastics, furniture and carpeting, to car parts and windshield wash fluid, methanol is a chemical building block used in making hundreds of products that touch our daily lives. Methanol is also an emerging energy fuel for running our cars, trucks, buses, and even electric power turbines. Methanol, also known as methyl alcohol, can be made from virtually anything that is, or ever was, a plant. This includes common fossil fuels—like natural gas and coal—and renewable resources like biomass, landfill gas, and even power plant emissions and CO_2 from the atmosphere. Methanol has been one of the world's most widely used industrial chemicals since the 1800s.

The problem in a populous country like India is that the area available for food cultivation and water cannot be diverted to make way for biofuels instead of food. Here, the Jatropha plant comes to our rescue. Jatropha is regarded as a better alternative to sugarcane as it needs much less water (even wastewater will do) and can be grown on land considered 'wasteland' for other purposes. Recently, fear has been expressed that Jatropha grown without the use of enough water leads to growth of a seedless variety. This claim has to be further investigated as one of the principal advantages of Jatropha is that it can be grown on poor soil and with little water. Indian agricultural institutes have a problem cut out for them.

With diesel engines, Jatropha can be used unblended on 100% basis also. Jetropha has performed well even on high mountain and sub-zero temperatures. India needs a large-scale effort to grow and market suitable biofuels to make them easily available at every petrol station in the country so that their use is promoted. This involves a very large-scale, countrywide effort at cultivation, storage, distribution, pricing, etc., for the biofuel on the same lines as is being done by government agencies for marketing petrol and diesel. The use of Jatropha oil for fuelling aircraft has tempting possibilities but needs to be proved through more trials.

Miscellaneous Biofuels

There are several other miscellaneous biofuels which are being developed out of local materials. Thailand produces the starchy cassava root, Europe produces the rapeseed, and Spain is experimenting with algae where the algae is mixed with CO_2 from a cement factory to 'kill two birds at one stroke' by reducing the carbon and producing oil from algae as nature does over millions of years. Shell and Exxon are reputed to be also experimenting with algae as a source of oil. Algae grow quickly, extracting carbon from air or water, and can give an oil that can be processed to give a biofuel.

Biofuels from Microalgae

The production of various biofuels from microalgae has the potential of providing a sustainable technology for addressing the growing global energy need while partially mitigating the global warming by capturing carbon dioxide from the atmosphere through photosynthesis. While several land-based crops, e.g., corn, sugar cane, soybeans, canola, can be used as sources of biofuels, they suffer many disadvantages compared to aquatic microalgae, including much higher need for water and fertilizers, much less capability of capturing carbon dioxide for the same amount of energy production, and potentially causing food scarcity, as shown below (Groom, *et al.*, 2008). Furthermore, the land requirement to produce the same amount of energy is extremely small for microalgae compared to other fuel sources.

Currently, the major drawback for wide-use application of microalgae as fuel source is high economic cost of the conventional processes used for growth and harvesting of microalgae, and the extraction of lipids from the cells for biodiesel production. Hence, over the last few years about 3 billion dollars have been spent on R&D activities in many parts of the world, including S. Korea, USA, France, European Union and Israel, to bring down the cost.

The use of wastewater for growth of microalgae maybe preferred to satisfy the need of microalgae for nitrogen, phosphorus and trace metals and simultaneously provide treatment of wastewaters, and thus to reduce the undesirable effects of wastewater discharges on receiving waters while saving on costs of fertilizers and clean water. A research project being conducted by Prof. Mirat D. Gurol at Gebze Insitute of Technology in Turkey and supported by the Scientific and Technological Research Council of Turkey (TUBİTAK) aims to accomplish this by growing indigenous microalgae mixed cultures in secondary effluent of a domestic wastewater treatment plant. This way, advanced treatment of the effluent for N and P removal is avoided. The organisms are then subjected to ultrasound and hydraulic cavitation for harvesting and for extraction of lipids from the cells. The extracted lipids are then subjected to esterification for production of biodiesel. The remaining biomass is further treated by fermentation to produce bioethanol. The algal biomass can also be gasified or liquefied, or converted to biogas in anaerobic digesters.

Carbon–neutral

It is necessary to clarify that both fossil fuels and biofuels produce CO_2 when burnt. In the case of fossil fuels like coal or oil, carbon sequestered in it millions of years ago is released in its combustion. In case of biofuels, CO_2 is released from the carbon contained due to photosynthesis which generated the plant. The latter is, therefore, regarded as carbon–neutral, while the former is not.

Fuel Sources

Crop	Used to Produce	Greenhouse Gas Emissions*	Use of Resources During Growing, Harvesting and Refining of Fuel				Percent of Existing U.S. Crop Land Needed to Produce Enough Fuel to Meet Half of U.S. Demand (%)	Pros and Cons
			Water	Fertilizer	Pesticide	Energy		
Corn	Ethanol	81–85	High	High	High	High	157–262	Technology ready and relatively cheap, reduces food supply
Sugar cane	Ethanol	4–12	High	High	Medium	Medium	46–57	Technology ready, limited as to where will grow
Switch grass	Ethanol	–24	Medium–low	Low	Low	Low	60–108	Won't complete with food crops, technology not ready
Wood residue	Ethanol, biodiesel	N/A	Medium	Low	Low	Low	150–250	User timber waste and other debris, technology not fully ready
Soybeans	Biodiesel	49	High	Low–med	Medium	Medium–low	180–240	Technology ready, reduces food supply
Rapeseed, canola	Biodiesel	37	High	Medium	Medium	Medium–low	30	Technology ready, reduces food supply
Algae	Biodiesel	–183	Medium	Low	Low	High	1–2	Potential for huge production levels, technology not ready

*Kilograms of carbon dioxide created per mega joule of energy produced

The IOC is reputed to have made a welcome beginning along with the Chhattisgarh Renewable Energy Development Agency in cultivating Jatropha on 600 hectare waste land in Madhya Pradesh. It is hoped that the government will continue to show consistency in its policies for promoting use of bio-additives irrespective of the world price of oil.

Marketing Biofuels

For any biofuel to be used, it has to become available at each and every petrol pump in the country, regardless of which company is the petrol dealer. This becomes a severe marketing problem unless its use as an additive is made mandatory and centrally controlled. The regular use of biofuels would have two distinct advantages:

1. It would start a new industry and give employment to many people, and
2. it would save the country the foreign exchange it spends at present to import oil from the world market. In the author's opinion, the time is overdue for use of biofuels in India.

4.5 Green Technologies Needing some Prior R&D Work

4.5.1 Shale Gas

Shale gas is a natural gas found in rock formations and requires specialised production techniques. No gas is exactly a green technology because some carbon is produced in its combustion. However, much lesser carbon is produced than with oil or coal. The USA first produced shale gas in 1989 by using normal drilling methods which proved expensive as each well gave little gas. The USA is then reported to have later developed a new and easier method of extracting gas from shale deposits, a common sedimentary rock found across the world. In 2009, shale gas accounted for as much as 13% of total energy consumption of the USA. Shale gas exploration entails what is now called 'fracking' or vertical drilling followed by horizontal drilling using chemicals, explosives and millions of gallons of water to create tiny fractures in the shale formations underground. Shale gas is found in tight reservoirs that have poor permeability. Shale gas requires large number of wells as the volume per well is small.

A downside of hydraulic fracturing ('fracking') is the enormous water requirement and the water pollution problem it causes. The wastewater contains hydrocarbons, heavy metals, scalants, salts and microbes in the flow-back water from shale gas wells. This requires treatment comparable to the worst industrial wastewaters—a wastewater treatment challenge! France and Bulgaria are already reported to have forbidden the use of 'fracking' techniques. Moreover, in Europe, the law gives the right to minerals found underground to the government, and not the landowner above. In the USA, the mineral wealth belongs to the landowner—and the oil company has to negotiate with the private landowner before drilling or fracking. The USA is reported to have developed a treatment process to be able to reuse fracking water.

Almost all states in the USA have reserves of shale. The USA is estimated to carry 24.4 trillion cu metres of shale gas. Argentina is estimated to have 21.9 trillion cu metres while Europe has 18.1 trillion cu metres of which large reserves have been found in Poland and Bulgaria. China has large deposits estimated to be around 36.1 trillion cu metres and is getting into the act now. Australia is reported to carry 11.2 trillion cu metres of the gas.

India also has massive shale deposits and, thus, there is good scope for use of this gas. Potentially, every rock formation can have shale gas and shale gas promises to become the fuel of the future. Reliance India in the private sector as well as ONGC in the public sector are reported to be tying up with US companies in order to benefit from their knowledge of techniques. Gas from shale deposits will become available all over the Gangetic plain, Gujarat, Rajasthan, NE Assam, and some coastal regions. New gas deposits are being constantly found offshore. Their development will, to some extent, depend on availability of underground water for 'fracking' which may become a serious problem in its development.

Gas extracted from shale deposits is definitely likely to benefit India. India, however, has a strange restriction at present against harnessing non-conventional sources. Firms are allowed to produce conventional oil and gas, but they have to keep their hands off coal gas, methane and shale gas even if they discover them in their exploration blocks. Since gas can be a cheaper and cleaner alternative to oil, a policy change is urgently required to allow exploitation of shale gas and methane without delay.

Besides shale gas, large quantities of natural gas are already available in India from the Krishna–Godavari offshore basin. It would appear that this gas will be used first before any attempt is made to develop shale gas.

4.5.2 Wave Energy—A Promising Source of Energy

Other important forms of renewable energy are wave energy and geothermal energy. Scope exists for their usage in India wherever they are possible to use. Not much research work, however, appears to have been done as yet in India with these systems.

Wave energy would appear to be most promising for use in India. The wave potential is said to be around 1,000 times more than the wind potential. Waves are a stable and predictable source of power, taking into consideration diurnal and seasonal variations. Wave energy results in a substantial quantum of power generation since the energy generated varies according to the square of wave height (as compared to wind power which varies according to cube of air speed). In addition, water is some 850 times denser than air. Moreover, infrastructure requirements are said to be much less, since wave energy needs only 1/200 of the land area of wind energy. Generating wave energy entails lower infrastructure costs.

According to an UNFCCC update (EB 51), four different technologies are under development in USA and elsewhere. Among the mature ones is the 'Terminator' installed near shore in California and is able to produce electricity at about 10 cents/kWh (₹5–6 per kWh). In India, the cost would hopefully be lower. The principle is illustrated below in Fig. 4.5. Portugal and Philippines are also reported to be working on these devices.

No project on wave energy harnessing yet appears to have been set up in India in spite of its long coastline. The presence of important ports and cities on India's coasts would indicate a great scope for use of such devices to convert wave energy into electricity at reasonable cost. Every city is hungry for more electricity. In the author's opinion, India must pay very serious attention to this source of renewable energy. Its cost seems affordable, its technology not very difficult and India has a long coastline with major cities such as Mumbai, Chennai and Kolkata on the coast. Mumbai especially is thinking of creating new islands out of the sea.

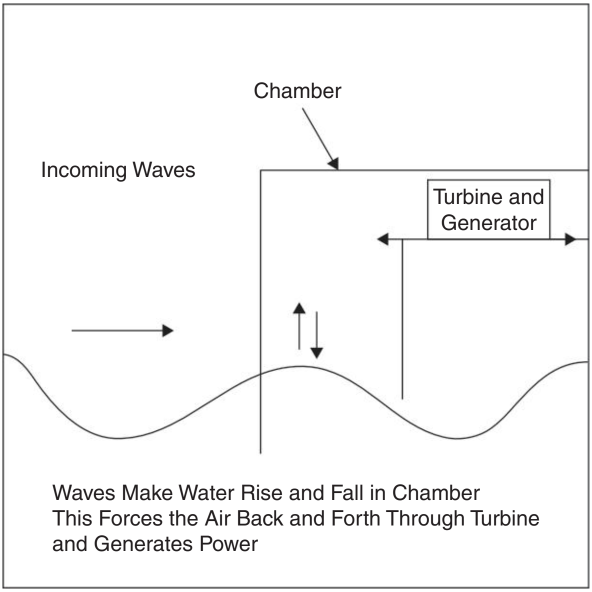


Figure 4.5 *A turbine device used to generate electric power from wave energy.*

4.5.3 Geothermal Energy

Geothermal energy is available in certain parts of the world e.g., Iceland and around southern Russia and can be used in the form of hot or lukewarm water in homes or public baths, welcome in a cold country. It is reported that 25% of Hawaiian electricity is geothermal. In Iceland, nearly 80% of all homes are heated by geothermal energy. Iceland also claims that 318,000 new jobs are created per MW of electricity provided.

Naturally available hot water from a groundwater source can be, for example, piped and supplied city-wide through a network of pipes laid in tunnels, built to facilitate their maintenance. The Chinese city of 5 million people, Xiang Yang, is hoping to set up one of the world's largest urban geothermal heating systems.

India is supposed to have a large scope for setting up geothermal energy projects (10,000 MW) but not much progress yet seems to have taken place in this direction. A beginning has to be made with proper mapping to indicate where the greatest scope lies. Thermax in Pune, India, has tied up with Iceland's Reykjavik Geothermal for a joint venture to find sites for development in Maharashtra.

CHAPTER

5

Green Technologies for Personal and Citywide Application

Few people care to know how our daily activities generate carbon. Concern for the environment gives them a virtuous feeling but often nothing else happens thereafter.

Unfortunately, what we have to do ourselves we tend to put off.

5.1 Let's Paint the Town Green

Q: Why paint the town green? Why should we think 'green' in everything we do? We are a poor country.

A: Precisely because we are a poor country, we should think 'green' without waiting for any other country to think that way first. Thinking 'green' saves us money, and may help us earn some money too! In fact, as seen earlier, green could become an acceptable acronym for 'Growth with Resources, Environment Enhancement and Nature'.

Thinking 'green' helps us to

- conserve our precious resources such as fossil fuels, water, forests, etc.

- reduce our expenditure on use of costly electricity by using it more efficiently
- generate less pollution (including less greenhouse gas emissions) from various activities.

We have to think 'green' at *every* level. Hence, in this chapter we start with things we should ourselves be doing, relatively easily, in order to reduce emissions and use our resources wisely. Early inventories of emission sources show that electric power generation in India is mostly done using a polluting fossil fuel like coal and to some extent oil. Oil and petroleum products for transport are also mostly imported. Thus, we have an emission problem and a resource problem. Another problem is that new forestation is slow while deforestation is unfortunately brisk. We seem to know what is to be done but do not seem to do it.

To recapitulate from Chapter 3, the crux of our approach has always to be the following:

1. Use *less* fossil fuels (coal, oil, etc.) for generating energy for running our cities, industries and transport
2. Focus on carbon emission reductions through lifestyle changes, increased efficiency of equipment and processes employed for various commercial and industrial activities and in other possible ways.
3. Use 'cleaner technologies', make process changes or product changes to reduce carbon emissions from its manufacture, transport and waste disposal
4. Research and develop new methods to treat and reduce carbon emissions at source and in the atmosphere
5. Save existing forests, trees, grasslands, water bodies, etc., and plant more trees so as to get more photosynthesis and carbon fixation.
6. Reduce water consumption at every stage to conserve water resources and reduce pumping costs. Reuse wastewater as far as possible without adding to GHGs.

In this chapter, some suggestions have been given for carbon emission reduction at two levels: the personal and community levels, i.e., where the decision depends on the individual concerned and on the community. Sometimes the two categories may not be very distinguishable from each other.

5.2 Carbon Emission Reduction at Personal Level

There are many possible ways in which carbon reduction can be achieved at the personal level, such as in travel, in the use of electricity at home, in avoiding imports and in dietary habits. However, in most cases, the reduction generally achieved is relatively small in magnitude and to some it may even seem unpalatable compared to other alternatives. What we have to do ourselves, we tend to put off. A few words of advice and a few examples are given in the following:

On a global basis, as seen earlier, emissions due to travel (by air and cars) are responsible for 14.5% of the world's emission of carbon. Both car travel and air travel have to be reduced.

Travel: Walk if walkable, share transport otherwise. Use public transport. Emissions vary per passenger per km travelled with the mode of travel, being maximum for air travel, lesser for cars, still less for buses, least for trains and zero if you walk. Hence, one is always advised to walk to a nearby (walkable distance) destination rather than go by car. If it is not a 'walkable' distance, see if you can go by public transport rather than by your private car. Send children to school either by school bus or public bus rather than by your private car. If you must send by car, carry a few more children/people in the same car. Car-pooling is always a good idea as it reduces the fuel consumed per person.

India is fortunately full of small- or medium-sized cars. Larger cars and SUVs are, however, increasing their share. The larger the car, the greater the emissions. **Appendix 1** gives some emission values. The story is complicated because as the number of cars increase, the people drive fewer kilometres per car. Also, the more the cars, the slower the traffic moves and greater the emissions per km travelled. Fortunately, as the traffic gets slower, demand for public transport (metros) increases.

The advice for car owners is to use small or medium-sized cars, drive fewer kilometres per year and use low emission fuels, blended with biofuels if available. Use LPG or CNG as fuel if it is cheaper, permissible and possible. In India, CNG gas is preferred as a clean and cheaper fuel. 55,000 taxis in Bombay have switched over to CNG in recent times. Also, pay some attention to your driving style. Avoid high speeds and start-and-stop driving.

Be prepared for electric cars. They are coming with better batteries. They can be used as needed during the day and charged from the building's solar energy system when the car is parked for the night. Truly renewable. No petrol, no diesel. No emissions.

For business visits to nearby cities (like from Mumbai to Pune), do not go by plane or car if it is a single person, but rather use the bus or train. It gives much less carbon emissions per person.

Video Conferencing: For a single person, avoid long distance business visits by air. Use 'video conferencing' instead of air travel. It is immensely cheaper and often just as effective.

Holiday Travel by Air: It would be meaningless to find various ways of reducing emissions in our daily lives if just one holiday by air to a long-distance country can cancel out all that gain. This is what actually happens in some cases and cheaper air travel is worsening the situation. The only way of meeting this problem seems to be either to forgo the travel or change the fuel of the aircraft—use bio-fuels instead of kerosene.

The latest AIRBUS-380 carrying 800 passengers is said to use a little less than 3 L of kerosene per passenger per 100 km. Many modern aircraft use 3.5 L per passenger per 100 km. Also, a modern hybrid car like the Toyota Prius uses more or less the same amount of fuel, namely, 3.8 L per 100 km when driven by 1 passenger. By comparison, in 1985, an average commercial aircraft consumed about 8L per passenger per 100 km.

A rule of thumb says that a plane and a car both emit more or less the same amount of CO_2 on per passenger per km basis, but air journeys are considerably longer than car journeys and air travel also releases some moisture and nitrous oxides along with carbon emissions which increase the warming potential of CO_2 by 2–3 times. The CO_2-equiv value is, therefore, high.

Example 5.1

For covering a flight distance of 1,000 km (approx., Mumbai–Delhi) by a modern aircraft carrying 180 passengers, the fuel required at the rate of 3.5 L per person per 100 km is $3.5 \times 180 \times 1000/100 =$ 6,300 L. The CO_2 produced can be estimated from the C content of the fuel. Alternatively, the CO_2 emitted can be estimated at the rate of172 g/person km = $172 \times 180 \times 1000/1000 = 30{,}960$ kg. Assuming the warming potential as 3.0, the effective emission is 92.88 tonnes of CO_2-equiv (in just a one-way journey).

The Directorate General of Civil Aviation, India, has decided to commission a study to determine actual carbon dioxide emissions from aircraft flying in India. As a thumb rule, almost 10% of the fuel used in a flight is consumed in landing and take-off, both of which happen at city airports, thus adding to the city's carbon footprint. The percentage is higher for short-distance flights.

Food and Flower Travel: An unbelievably large amount of CO_2 is produced because food and flower items go by air from one country to another daily. Air travel is generally required to keep them fresh. The world buys pineapples, fruits and flowers from tropical countries. Good for them, but bad for the world's environment. Buy local is the buzz word to counteract this trend.

The 'buy local' request is also applicable to various building materials, fittings and fixtures and a whole lot of commercially traded items. People seek exotic items from distant countries forgetting the damage they cause to local trade and the general environment. Delhi's new airport (Terminal 3) must have added millions of tonnes of CO_2 to the atmosphere as a result of the heavy amount of imports made for its construction and set-up.

Change from Fossil Fuel to Biofuel: One of the best innovations anyone can make to retard global warming is to develop the use of biofuels which can be safely used by aircraft all over the world. A beginning has, in fact, been made by conducting one or two successful flights on biofuel only. Similarly, the use of biofuels instead of diesel oil in tractors, cars and water pumps and as additives to petrol for other vehicles is possible. A whole new industry is likely to develop someday soon with it (provided the traditional fuel suppliers will allow it to happen) when the global warming problem will be somewhat reduced. Till that time, 'buy local' and 'travel less by air and car' are the refrains to use (also see Biofuels in Chapter 4).

Avoid Imports, Prefer Local Products, Local Labour: Preferably, use locally available items of construction materials, and industrial products, in preference over imported items since imports generally require air transport which generates high amounts of carbon emissions.

Forget Stand-by, It Is Not Enough: Shut off all TVs, electronic devices at the wall plug instead of keeping on stand-by mode with a red light on, as the latter consumes some electricity. Stand-by losses can amount to as much as 400 kWh/year. Apart from carbon saving there is also a fire-hazard in leaving these devices on the red light.

Dietary Aspects, ***Become more than a Vegetarian, Become a Vegan!*** One kilogram of meat is said to require 8 times the energy to produce it compared to 1 kg of tofu protein. A 2006 UN Report says that livestock is one of the most significant contributor to global warming. As stated earlier, cows give a lot of methane during their lifetime due to enteric fermentation which leads to belching. Up to a point, however, they help the ecosystem by giving milk for food. After they stop giving milk, their emission continues as long as they live.

It is clear that in a country like India which venerates the cow, it keeps giving off a large amount of equivalent CO_2 till the animal dies of natural causes as the animal is never slaughtered for its beef even after it stops giving milk. In countries where beef is normally eaten, the cow is generally slaughtered for its meat after it stops giving milk—and there ends the enteric emission too! Yet in a country like France, the total methane emissions from herbivores reported in 1997 amount to 2000 million cu metres per year of which 91% are from cattle. One of the ways of reducing global warming would be to avoid eating meat and milk altogether (become a 'vegan'). The lesser the number of cows and buffaloes, the better it will be for the world. Chicken are better for the ecosystem as they give eggs and are eventually eaten (no CO_2 is given off).

The food industry is notorious for its carbon emission problem at every stage right from agriculture to collection to processing, packaging and transporting to the consuming public. The best advice that can be given as regards food is concerned would be: 'buy organic and local, avoid processed and packaged items and become a vegan if possible.'

5.3 Carbon Emission Reduction at Local Authority and Citywide Level

Electric consumption in a community is much affected by:

1. **Presence of Industries:** The extent of electricity consumed by a community depends on the level of industrialization within that community. Industry and commerce are often the biggest consumers of electricity, and often no benchmarks exist with which comparisons can be made. Nonetheless, this is one area where managements are most receptive to suggestions for economy as they have considerable effect on the company's bottom line.

A company like Infosys in Bangalore says that 'in the last 12 months we reduced our electric consumption as a way of reducing our carbon footprint; now we find it saves us nearly $7 million'. What a welcome addition to the company's bottom line!

2. **Residential Consumption:** The extent of electricity consumed by residencies in a community depends on the lifestyle of the people and the efficiency of its fittings and fixtures used. Here, the type of bulbs and whether air conditioning is used or not make a difference. The average electric consumption of a family of average size 2.3 persons in different countries varies from 4,000 kWh/year in the USA to as little as 426 kWh/year in Denmark. In India also, a study carried out by NEERI in Mumbai has shown that consumption in slum areas is very low whereas in more affluent districts it is almost comparable to UK's average.

Appliance	Rating (Watts)
Incandescent bulb	40, 60 or 100
CFL bulbs	10–15
Fans	60
Air coolers	175
Air Conditioners	1500
Refrigerators	225
Water heater	3,000
TV	100

A water heater consumes the maximum wattage, but is operated for only a short time. Nonetheless, it would be a clever idea in India to replace an electric heater by a solar thermal heater to let nature do the job and help save electricity, especially if it is a large family or a hotel or hospital or a student hostel.

Use CFL (compact fluorescent light) bulbs for all domestic, commercial and industrial lighting. Avoid old-style incandescent bulbs which consume 5 times more power for the same illumination because much power is lost as heat. CFL bulbs are more expensive to buy, but their longer life and the savings obtained on the electric bill can be substantial and pay for itself. Disposal of old CFL bulbs needs some care since mercury is used in their making.

Similarly, use power-saving and long-life LED (light emitting diode) type fixtures if possible as they consume even lesser power (one-third less than CFL). Their cost is even higher than CFL at present. However, their high initial cost is recoupable from savings in electricity.

A CDM approved project 'Bijli Bachat Yojna' has commenced in Maharashtra from April 2010 under which a CFL bulb costing about ₹180 is sold at ₹15 per piece in return for one incandescent bulb in *working* condition.

The biggest power-consuming gadgets in affluent domestic residences are A/Cs, refrigerators, dishwashers, clothes washers and dryers, etc. Electric lighting is not always the biggest consumer. Of course, the poorer the family, the greater is the proportion of electric lighting cost to the total cost.

3. **General Lighting:** General lighting covers various uses such as:
   (i) traffic lights,
   (ii) street lights,
   (iii) advertisement hoardings,
   (iv) lighting for open air marriages and other functions and
   (v) public purpose TV's, etc.

   In Indian cities, one sees very bright lighting at open air functions/weddings and for illuminating all advertisement hoardings. LED lighting could be made mandatory for such purposes. (3,000 billboards in Mumbai alone are estimated to consume 15,000 kWh/day). In some countries, the manufacture of 100W or higher incandescent bulbs is now forbidden.

Punjab is the first state in India to use LED street lights in five cities. Such applications may even qualify for support under CDM's certified emission reductions. High-end motor cars have started to use LED bulbs on their head and tail lights. Halogen bulbs are of the incandescent type and are not recommended for the same reason.

It has been estimated that a state of the size and population of Maharashtra has the potential to save around 2,000 MW of power if it switched over fully to CFL/LED instead of the conventional incandescent bulbs. To generate 2,000 MW, the state would need an enormous investment of about ₹14,000 crores, besides a copious supply of fossil fuels to run the plants (and have unwanted co-generation of CO_2!).

Timer Switches: Fix timer switches on electric lights in common usage areas such as staircases and passages. They will also pay for themselves from electricity saved.

Use Certified Fittings/Fixtures: Use fixtures and fittings certified by the Bureau of Energy Efficiency (BEE). Avoid cheap and uncertified products which consume more electricity for the same service given.

Provide Solar Water Heaters: Adopt solar water heaters for hot water in all hotels, hostels, guesthouses, clubs, industrial kitchens, etc., where water consumption is high enough to give a reasonable return period of 2-4 years on investment. Solar radiation can bring up the water temperature to the desired level. A 60°C temperature seems adequate for shower baths.

A policy announcement from government would help as this is one of the easy and profitable ways of bringing down the carbon emissions. Remember, even in a cold and chilly country like the UK, over 100,000 houses are reported to have some form of solar hot water heating. One wonders if in a tropical country like India where the sun shines at its most powerful, one can boast of half as many houses with solar heaters. We must make a beginning with large volume users such as clubs, hostels, hotels and industrial kitchens at the soonest.

Cooking Fuel: It is always recommended that cooking be done using gas rather than electricity. Pressure cookers are recommended for use. Solar cookers are especially recommended where mass cooking has to be done for many persons at a time. Microwaves are best for heating pre-cooked food. Industrial kitchens need much hot water for washing of utensils, etc., and solar heaters are generally recommended for use.

Economic Air Conditioning: Just as heating is essential in colder countries, air-conditioning is needed in warmer countries.

Air conditioning is not considered a luxury any more in warm climates. Most important buildings and offices have air conditioning provided in them. However, air conditioning is one of the highest consumers of electricity. Hence, maximum attention should be paid to it right from the design stage to installation and operation:

- Cooling is required for countering the heat generated indoors, partly due to sunlight penetration (solar heat) and partly due to people inhabiting the area (metabolic heat). Other sources of heat should obviously be eliminated.

- The design of the building to be air-conditioned should take into account the use of cavity walls (hollow blocks for walls of rooms) and the provision of sun breakers and double-glazed window panes as far as possible. Effort has to be made to reduce sunlight penetration into the interiors while allowing daylight to come in.
- Prepare the rooms to be air-conditioned. Use thermostats/ sensors on A/C areas, if possible, to save on electricity. Just as insulation is important in case of home heating, the same way insulation is important for air-conditioned spaces.
- Wherever possible, use water-cooled A/Cs which are more efficient than window-type, air-cooled A/Cs.
- Set A/Cs to kick-in at 26°C rather than at usual 22 or 23°C. It will make the area comfortable and save on electricity.

In hot-dry areas, use coolers instead of air conditioners. They are more efficient in hot-dry climates. For larger installations, consider using the TERI-style air-conditioning arrangement with blowers instead of compressors (explained in Chapter 6) which save on power.

Again, a large company like Infosys says that they have two buildings in Hyderabad. One is cooled in the traditional way with air conditioning for 1100 people. The other building which is identical has ambient cooling and uses 50% less electricity. Both are equally cool and comfortable.

Heat pumps have just not been used in India. Use heat pumps wherever possible to put waste heat to use. They will pay for themselves in a short time.

Miscellaneous Sources of Carbon Emission: Among miscellaneous sources, one must include computers and mobile phones, cattle and other animals.

Computers: The manufacture of a single *desktop computer* is reported to produce nearly ½ tonne of CO_2 per unit. How many units do we produce per year? The 2-gram microchip contained in each computer produces 4,000 g of CO_2 in its manufacture. A liquid crystal display (LCD) monitor consumes much less power than one with a cathode ray tube (CRT). A desk-top computer uses 60–120 W of power when active. A laptop uses only 15 W.

Mobile Phones: A mobile phone contains copper, gold, silver and a small amount of platinum. As these are precious metals consuming much power in their refining, they should be recycled. India does not yet collect old mobile phones for recycle. In fact, collection of all forms of e-waste is starting in India, with Bangalore having taken the lead.

Cattle and Other Animals: In India, 70% of the rural population owns livestock. Livestock includes cattle, buffaloes, horses, sheep, goats, donkeys, camels, poultry and many more. It also includes their dung.

As shown in Appendix 1, belching (enteric emissions) gives 600 L of methane gas per day per cow. (In terms of equivalent CO_2 it is an enormous amount of about 15,000 L of gas expressed as CO_2-equivalent per cow.)

The media reports that a medium-sized dog eats 164 kg of meat and 95 kg of cereals per year. By calculating that it takes 43 sq metres of land to produce 1 kg of chicken, one could say that it takes 0.84 hectares of land to feed the dog. A large dog (e.g., Alsatian) needs about 1.1 hectare—a large carbon footprint indeed!

We are Often Just Plain Stupid: We give importance to small things and neglect the major ones. We switch off TVs properly but neglect fixing thermostats to our old air-conditioners and neglect timer switches to our staircase lights. We don't care to know what a heat pump is. Our dear child goes to school alone in our family SUV.

We fret and fume that deforestation is rampant in our country but do not stop to think about all the paper we use. Use less paper and paper products and use recycled paper or non-wood based paper (e.g., bagasse) to avoid deforestation. Discourage over-packaging of goods for the same reason.

Recycled paper uses much less water and energy in making paper. 'Live Earth' gives an interesting bit of statistics in its book on Global Warming that if we recycle 3.8 million kilograms of newspaper, we would thereby save enough trees to be able to absorb a million kilograms of CO_2 per year. Paper can actually be recycled 3–5 times before fibre breakdown occurs. Forests can be saved by recycling paper at least twice if not more!

Greening your terraces would be another way of helping the city to stay cool. A garden on your terrace would be ideal in many ways. A bustling city like Chicago in the USA is reputed to be having over 200,000 vegetated roofs. A green roof can reduce up to 50% cooling costs for a building and reduce CO_2 emissions too.

5.4 Carbon Emissions from Imports

This topic has been included in this chapter as imports are generally due to personal preferences and curbing imports mainly depends on people. Carbon emission due to imports can be quite substantial but have been taken for granted. Some may take imports as good for international trade. Others may consider the emission as a problem of the country from which imports come. It doesn't matter from which country the imports come, the global atmosphere is one and the same. We are all in the same boat.

Carbon emissions from imports are two-fold as they are due to two separate activities: first, the manufacture of the product causes emission in its original country and then its inter-country transport (generally by air) which may produce even more emissions spread over several countries.

Every time a Britisher buys mangoes from India or an Indian buys cloth manufactured in a Lancashire textile mill, it may certainly be good for international trade but not for carbon in the global atmosphere. For trade reason, any embargo on either would be frowned upon by the World Trade Organization and the respective trade organizations in the two countries would make it difficult to enforce such an embargo. In UK where the people are known for their preference for local products, the carbon emissions due to imports are estimated to be as high as 33% of the total emissions per person. A similar figure for India is not available, but it should be somewhat lower as poverty makes the Indian public more price-sensitive.

Delhi Terminal 3

Delhi's spanking new air terminal No. 3 is a good example to quote. It is replete with imported items. It is simply modern European. No thought seems to have gone into the carbon emissions this air terminal must have caused. This happens on other occasions too. Use of local materials and local labour is always recommended (even to the disappointment of some people) not only from the carbon viewpoint but also from the employment angle. Even the USA is now frowning upon 'outsourcing' from the employment viewpoint.

CHAPTER

6

Green Technologies for Specific Applications

This chapter shows how many different stakeholders are there and how wide a variety of work is involved. However, the principles remain the same.

6.1 Promotion of 'Green' Buildings

Green buildings can save a community some good money and a lot of carbon emissions. Green buildings focus on health, environment and resources. Green buildings reduce exposure to toxic material and other substances that may have health impacts. Green buildings help conserve resources such as fossil fuels, water, etc. use local building materials as far as possible, and recycle waste and wastewater.

Moreover, green buildings reduce a building's carbon footprint forever afterwards and reduce its demand on a country's natural resources. The scope for reducing carbon emissions is high because buildings, in general, are said to account for 40% of all energy used in this world today and energy demand is expected to increase by 30% within the next 10 years. Urbanisation is so rapid that 60% of the world population is expected to be living in cities in the next 15 years. So, green buildings and green infrastructure seem a must.

Promotion of 'green' buildings and area planning begins with sensitising professionals such as architects, engineers and builders through the medium of seminars/talks, etc. held along with professional organisations such as The Indian Institute of Architects, The Institution of Engineers, etc. to the philosophy of energy-saving and environmental protection measures enumerated in LEEDS (Leadership in Energy and Environmental Development Systems), GRIHA (Green Rating for Integrated Habitat Assessment) and other such guidance documents to produce what are called 'green buildings'.

These concepts could be extended to apply to new area development projects such as special economic zones(SEZs) or specific areas within a city or regions within a state or country for reducing carbon emissions and adherence to LEEDS/GRIHA philosophy. The government is also reported to be giving a 10-year tax break to those investing in infrastructure.

First and Second Generation Green Buildings

The author would like to make a further distinction by referring to green buildings as first generation or second generation according to the extent of electric power used and produced in the building. *First generation* green buildings are those which use various architectural and engineering devices in planning and constructing the building so as to minimise electric power and other resources consumed, but do not generate any power of their own, whereas *second generation* green buildings not only minimise use of power and resources needed to operate the building but also generate some or all of their power requirements at the building site itself.

There are first generation green buildings that have reduced power and water consumption by as much as 40%–60%, and there are second generation green buildings that have reduced consumption and also generate power (from renewable sources such as wind or solar or hybrid, etc.) at the building itself to meet a part or all of their requirements, and even give back some power to the grid. When the entire power needs of the building are met from local generation, the building is often referred to as 'zero-energy building'. The next step eventually perhaps will be zero-energy cities.

Green Buildings in India

It is true that 'green' buildings might cost 5–10% more in capital cost, but it is certainly less expensive in operating cost. Thus, overall it becomes a more economic proposition and the additional capital expenditure (CAPEX) is made good in a few years through savings in operating expenses (OPEX). However, there are some who point out that where the builder is not the ultimate owner, the higher capital cost is incurred by the builder while the beneficiary is the ultimate owner. Of course, there are others who point out that the additional cost incurred by the builder is anyway recovered from the final owners. Nonetheless, the idea of green buildings has caught the imagination of Indian architects and builders. The Indian green building movement is now so widespread that there would be no going back on it. The country already has over 1.2 billion sq feet (from over 500 buildings) under LEEDS certification and another 105 million sq feet under GRIHA. Urbanisation is rapid all over the world. In India, certification is likely to reach 80 billion, making green buildings 20% of the total by 2030 says the Indian Green Building Council (IGBC).

New cities coming up in India, e.g., in the Delhi–Mumbai industrial corridor would have a high component of green buildings in them. NOIDA's development already shows a higher proportion of green buildings. The government has also mandated that SEZ areas conform to green requirements. Today, there are at least 140 registered SEZs in India. A 100 new airports are coming up. The new Hyderabad airport has secured silver rating under LEEDS. Information Technology firms are most willing to go in for green buildings. The government is also now going in for green buildings. Here, justification is easier since both the capital and operating expenses are borne by the same authority.

Excellent business opportunities exist for architects, builders, engineers, plumbers and other professionals conversant with green building guidelines and practices and ECBC codes. At the same time, the benefit this bestows on the resources situation (water, fossil fuels, etc.) of India is certainly very high. It makes people conscious of the need to always look over the shoulder and keep an eye on the resource position. Thirdly, people get exposed to the need for a low-carbon lifestyle.

To have what we call a 'green' building in India, one has to pay attention either to the guidelines set by LEEDS, or GRIHA developed jointly by TERI (The Energy Research Institute) New Delhi, and the Government of India. GRIHA is said to be more suited to Indian conditions and approved by the Government of India. Many private architects seem to prefer the LEEDS guidelines whereas government architects prefer the GRIHA system.

Other organisations in the world have also prepared similar guidelines for their use. It is hoped that one day all countries will follow one international system the world over. Essentially, all these guidelines help to develop a stronger sensitivity towards use of electrical energy and other resources, and a greater respect for the environmental impact of the developers' actions. Climate and nature must be respected in everything we do.

For example, it is a well-known fact that owing to latent heat, far greater energy is required in cooling or air-conditioning a space than in heating it. Hence, in a country like India, one has to be extra-careful to avoid aggravating heat by wrong architectural planning and then using more electricity to overcome the situation by air-conditioning. Excessive use of air-conditioning is not good economics and must be avoided by better planning and choice of building materials, etc.

Some guidelines for design of buildings have been available in India since time immemorial when building designers were taught that in India there are two major types of climate situations: hot-humid, as in South India; and hot-dry, as in North India. Building design had to be distinctly different in the two cases. Modern architects sometimes blur these natural distinctions by using air-conditioning lavishly with the same architectural design everywhere. Similarly, designers sometimes provided 'modern' features without ascertaining first whether the required infrastructure exists or not. Waterless urinals, for example, cannot be provided where power failures often happen.

6.2 The Leeds Rating System Guidelines

The LEEDS guideline can be used to cover various aspects of a project design starting with the building construction site itself and proceeding up to the various planning modules and aspects as listed in the following including 'social relevance' without which it would be an empty effort. The LEEDS guidelines certainly promote environment-friendly acts but suffer from the fact that no negative marking is given for an environment-unfriendly act committed by a developer. All new 'green' buildings are required to comply with the guidelines suggested for each of the following aspects of a project:

1. The building construction site
2. Environmental concerns in architectural planning
3. Energy conservation and its better management
4. Water conservation
5. Waste management
6. Social relevance

Some larger, old buildings under major renovation could also be included, if desired. The guidelines are really based on commonsense matters and, if followed, would help to make life better, cheaper and in line with modern environmental concepts. The following text summarises in brief what can be done under each item:

1. The building construction site

- Design with minimum disruption to the site; minimise soil displacement indiscriminate leveling. At the same time, minimise soil erosion, if necessary
- Preserve and reuse nutrient-rich top soil for landscaping
- Reduce micro-climate temperature rise by planting shady trees, etc.
- Minimise pumping; let drainage follow existing slopes/contours; facilitate easy maintenance.
- Preserve biodiversity, compensate by reforestation and replanting if necessary
- Facilitate groundwater recharge; restrict rainwater run-off by constructing small bunds as necessary to promote groundwater recharge. Avoid local flooding problems

2. Environmental concern through choice of materials and architectural planning: The following measures are recommended to keep a building more cool and comfortable and reduce power costs in air-conditioning:

- Achieve thermal comfort (e.g., use hollow blocks for walls to keep house cool and cut down on use of A/Cs in tropical climates). Use of hollow blocks, double-wall construction and other methods should be preferred rather than use of ordinary bricks, from an insulation viewpoint in India.

- Avoid use of glass facades especially on sunnysides as they greatly increase the load on electricity for air-conditioning. (e.g., glass is fine on the north side in Mumbai). Many buildings unfortunately use architecturally attractive full-length glass panels on the side facing the road (even if it happens to be on the sunnyside). This places a higher load on the air-conditioning system of the building and, hence, on power consumption.
- Achieve visual comfort (through choice of colors, materials, etc. as necessary).
- Prevent heat gain (through use of larger roof overhangs to extend shade for longer hours).
- Use of concrete or stone 'jalli' with a lightly flowing water fountain has been a very effective device used in the hot and dry climates of North India since hundreds of years.
- Where a sloping roof is provided, use double-roofing for heat insulation (e.g., a sloping concrete roof may be covered with Mangalore or Spanish tiles to protect the concrete from the heat of the fierce sun).
- Where roofing is in the form of a terrace, a roof garden may be provided to keep heat away from the floor below and keep it relatively more comfortable. Special treatment of the terrace floor before laying the earthwork is necessary to prevent later leakages.
- Scientifically designed vertical and horizontal fins (sun-breakers) could be provided in some cases. Double-glazed window panes would reduce heat transfer.
- Ensure entry of adequate daylight inside the house to avoid use of electric lights during day time (important to use sky-lights, transparent sheets, etc., which would admit natural daylight and save electric power).

3. Energy conservation and better management: Heating, ventilation and air-conditioning (HVAC) are usually the three heaviest users of electricity. Thus, some attention needs to be paid to the efficient use of electrical energy by them. Of course, the original architectural planning of the building greatly determines their power consumption and thus the previous section needs to be given careful attention.

Choice of equipment: Normally, air-cooled window air-conditioners are said to use more electricity per tonne of refrigeration capacity than equally large units with re-circulating waters. For air-cooled units, the electrical consumption is said to vary from 1.6 to 1.8 kW per tonne of refrigeration. The coefficient of performance for water-cooled chillers varies from 0.72 to 1.0 kW per tonne. Their maintenance cost is further reduced by providing double-glazed window panes, sun-breakers, etc. and ensuring thermostat control of temperature.

Conventional chillers or air-conditioning plants generate chilled glycol at sub-zero temperatures during the night when power demand is low. The chilled glycol can be stored and then circulated throughout the office area during the day with the help of blowers complete with air-handling units (AHUs) and fan-cooled units (FCUs). This saves power.

Use 'CFL' or LED-type bulbs (and other similarly efficient lights). Also shut off all electrical fixtures from wall plugs. Some energy is consumed when kept on 'stand-by' position.

Use timers and other control devices on staircases and other common areas to turn off lights when not needed.

Landscape for energy efficiency. Develop shaded areas in the vicinity of building.

Use solar water heaters (not electric devices) to meet hot water requirements.

Use 'heat pumps' to recover heat which would otherwise be lost in wastewater or waste air. (For example, a relatively large volume of waste air exhausted from an air-conditioned roomal ways carries some quantum of heat extracted from the room. Normally, such heat is lost in the exhaust. But, a heat pump can be used to capture back that heat, and use it elsewhere)

Use renewable sources of energy such as wind energy and/or solar energy for power generation wherever possible. Solar panels are nowadays available in a wide variety of shapes and textures (see Chapter 5).

LEEDS recommends to restrict light power density to 7.5 W/sq m or less, as far as possible in a green building.

The stepwise approach generally followed in the case of energy conservation is as follows:

- Use architectural features and materials as suggested earlierto reduce air-conditioning and lighting demands as far as possible.

- Adopt power conserving devices (thermostats, etc.) as described earlier*.
- Adopt more advanced waste heat recovery devices such as heat pumps to recover heat from warm effluents/air discharged after use.
- Supplement conventional energy sources by renewable energy sources (wind and solar energy) if possible. Use biogas.

4. Water conservation:

- Minimise use of *public* water supplies. Conserve water. Reuse wherever possible.
- Provide for rainwater harvesting and groundwater recharge to minimise use of water from public water supplies. Effort should be made to add more water to the site (through rainwater harvesting) than what the building and its garden consume. Become water-positive, if possible.
- Provide low-flow fixtures, orifices in pipes and dual-flushing tanks to minimise use of water.
- Provide waterless urinals where power supply is dependable.
- Reuse grey/black waters after suitable treatment either for flushing in toilets or for gardening.
- In garden, plant species which inherently require less water.

5. Waste management: Use a 'natural' method of treatment such as a lagoon, pond or constructed wetland or land irrigation which avoids use of electric power for aeration in wastewater treatment, pumping, etc.

Reuse wastewater as far as possible for gardening, crop irrigation, groundwater recharge and other uses at site, after minimal treatment

Reuse solid wastes after segregation (i) to recover re-usable materials and (ii) use the wet waste to prepare compost from the organic wastes and recover biogas and manure for use.

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*(TERI, New Delhi, has demonstrated how use of electric power for air-conditioning can be saved by providing air tunnels of a certain dimension at 4 meter depth through which air is blown. At that depth in Delhi, the air is literally uniform throughout the year, and so the air blown through it either picks up heat or discharges heat depending on the season. As everybody knows, a blower consumes much less power than the compressor of an air-conditioner. Moreover, the reduced power is met from a renewable energy source. Hence, the building consumes about one-third power of what a conventional building would consume) in Delhi.

6. Social relevance: Ultimately, whatever is done must have social relevance and be good for the local people. We must use affordable, durable and low-maintenance building materials which are *locally* available, need locally available skills and management systems to maintain and avoid use of fuel for transport of men and materials from distant countries. It should also reduce consumption of all resources, promote reuse of water and avoid wastage of materials and production of wastes.

Use green plants to keep up air quality (e.g., areca palm, a living room plant which helps oxygenate during day time and *Sansvieria trifasciata* which helps oxygenate during night time).

Home loan financing bodies would be well advised to give preferential financing for 'green' projects and develop supportive micro-enterprises.

Environmental sustainability is improved through the following tangible benefits:

- Energy savings (20–30%, more likely),
- Water savings (30–50% likely).

Even tall buildings in cities like Mumbai and Pune now boast of such advantages as solar energy for common areas, rainwater harvesting so as to make the building water-neutral, large windows to improve natural lighting, wastewater treatment for reuse in gardening and solid wastes composting and reuse. All these claims are to be welcomed. They also make it easier for builders to find buyers for their flats.

Other likely benefits of an intangible nature are improved air quality, improved day-lighting, improved health and well-being, conservation of scarce national resources and better project marketability.

6.3 The 'Griha' Rating System Guidelines

As stated earlier, TERI, New Delhi, has developed an Indian version of LEEDS called GRIHA which is said to be more suited to Indian conditions and approved after some modifications by the Government of India. Actually, the essential principles remain the same in both cases. Government-funded buildings in India are generally required to meet GRIHA guidelines.

- A green building depletes the natural resources to the minimum during its construction and operation. The aim of a green building is to maximise the use of efficient building materials and construction practices, and optimise the use of on-site sources and sinks by bio-climatic architectural practices.
- A green building uses minimum energy to power itself; uses efficient equipment to meet its lighting, air-conditioning, and other needs; maximises the use of renewable sources of energy.
- It uses efficient waste and water management practices; and provides comfortable and hygienic indoor working conditions.
- In sum, the following aspects of the building design are looked into in an integrated way in a green building.
  - Site planning
  - Building envelope design
  - Building system design ((HVAC) heating ventilation and air-conditioning, lighting, electrical and water heating)
  - Integration of renewable energy sources to generate energy onsite.
  - Water and waste management
  - Selection of ecologically sustainable materials (with high recycled content, rapidly renewable resources with low emission potential, etc.)
  - Indoor environmental quality (maintain indoor thermal and visual comfort, and air quality)

It is interesting to note that the intention of both systems (LEEDS and GRIHA) is to respect the local climate and situation and to minimise consumption of all resources, including fossil fuels. In case of the GRIHA system, the objective of each criterion is as follows.

GRIHA—The Green Building Rating System

The Context

Internationally, voluntary building rating systems have been instrumental in raising awareness and popularising green design. However, most of the internationally devised rating systems have been tailored to suit the building industry of the country where they were developed. The US-based LEED rating system is more meant for energy efficiency measures in A/C buildings.

Keeping in view the Indian agro-climatic conditions and in particular the preponderance of non-AC buildings, a National Rating System—GRIHA—has been developed which is suitable for all kinds of buildings in different climatic zones of India. The system was initially conceived and developed by TERI as TERI-GRIHA, which has been modified to GRIHA as National Rating System after incorporating various modifications suggested by a group of architects and experts.

It takes into account the provisions of the National Building Code 2005, the Energy Conservation Building Code (ECBC) 2007 announced by BEE and other IS codes, local bye-laws, and other local standards and laws. It works on the commonsense prescription that 'what gets measured, gets managed'.

The system, by its qualitative and quantitative assessment criteria, would be able to 'rate' a building on the degree of its 'greenness'. The rating would be applied to new and existing building stock of varied functions—commercial, institutional and residential.

GRIHA guidelines also cover various aspects of a project design starting with the building site itself and proceeding up to the various planning modules and aspects as listed in the following. This improves its social relevance and marketability:

List of Criteria	
Criteria 1:	Site Selection: Conform to master plan of area. Avoid destruction of natural environment in name of development.
Criteria 2:	Preserve and protect landscape during construction/compensatory depository forestation. Avoid denuding soil to cause erosion, flash flooding, etc.
Criteria 3:	Soil conservation (post construction): Save top-soil for later reuse
Criteria 4:	Design to include existing site features: Consider local context, do not just copy western designs
Criteria 5:	Reduce hard paving on site: Hard paving not to exceed 25% of site. Let rainwater percolate in
Criteria 6:	Enhance outdoor lighting system efficiency: Lighting has to serve a purpose. Avoid reckless use of energy to floodlight everything Provide at least 15% of outdoor lighting through renewables
Criteria 7:	Plan utilities efficiently and optimise on site circulation efficiency
Criteria 8:	Provide, at least, minimum level of sanitation/safety facilities for construction workers during construction
Criteria 9:	Minimise air and noise pollution during construction
Criteria 10:	Reduce landscape water requirement. Use drip and sprinkler systems. Minimise use of lawns. They need 5 L/m^2/day to keep up

Criteria 11:	Reduce building water use. Use efficient plumbing fixtures, sensors, auto-control and pressure reducing valves. Dual flush tanks. Toilets need 2–3 L per flush and urinals 0.4 L per flush
Criteria 12:	Efficient water use during construction. Also avoid mosquito growth
Criteria 13:	Optimise building design to reduce conventional energy demand
Criteria 14:	Optimise energy performance of building within specified comfort. Use less glass on sunny sides
Criteria 15:	Utilisation of fly-ash in building structure
Criteria 16:	Reduce volume, weight and time of construction by adopting efficient technology (e.g., pre-cast systems, ready-mix concrete, etc.)
Criteria 17:	Use low-energy material in interiors
Criteria 18:	Renewable energy utilisation can easily be considered
Criteria 19:	Renewable energy based hot-water system is a must
Criteria 20:	Waste water treatment using natural methods as far as possible
Criteria 21:	Water recycle and reuse (including rainwater)
Criteria 22:	Reduction in waste during construction
Criteria 23:	Efficient solid waste segregation
Criteria 24:	Storage and disposal of waste
Criteria 25:	Resource recovery from waste
Criteria 26:	Use of low-VOC paints/adhesives/sealants.
Criteria 27:	Minimise use of ozone depleting substances
Criteria 28:	Ensure water quality
Criteria 29:	Acceptable outdoor and indoor noise levels
Criteria 30:	Tobacco and smoke control
Criteria 31:	Universal accessibility
Criteria 32:	Energy audit and validation
Criteria 33:	Provide operations and maintenance protocol for electrical and mechanical equipment

The earlier criteria are rated and total ratings (points) are converted to stars as follows:

- Points from 51 to 60 are given 1 star
- from 61to 70 are given 2 stars
- from 71 to 80 are given 3 stars
- from 81 to 90 are given 4 stars
- from 91 to 100 are given 5 stars

All new buildings in a city can be required to comply with the guidelines. Some larger, old buildings desired to be renovated could also be included, if desired. The guidelines are really based on commonsense requirements and, if followed, would help to make life better, cheaper and in line with modern environmental and global warming concepts.

The Mumbai Municipal Corporation is introducing a welcome inducement by reducing the Property Tax on green buildings.

6.4 The Energy Conservation Building Code (ECBC)

Most commercial buildings in India have an electrical performance index (EPI) of 200–400 kWh/sq m/year whereas similar buildings in Europe and USA have an EPI of 150–200. A good design in India can reduce the EPI to 100–150 but Indian builders fear that they would have to bear the increased capital costs which would jack up the sale price while the buyers (tenants) perhaps reducing their marketability to some extent. On the other hand, they would benefit the tenants from lower operating costs.

Most of the electrical consumption in a building (over 55%) occurs in heating, ventilation and air-conditioning (HVAC). The remaining is consumed in lighting (14%), electronics (24%) and miscellaneous uses (4% or more). ECBC has, therefore, prepared guidelines covering

- Building envelope (walls, roofs, windows)
- Lighting (indoor, outdoor)
- HVAC
- Solar water heating
- Electrical systems

While the benchmark is 180 kWh/m^2/year, ECBC compliant buildings average 110 kWh/m^2/year. The benefit of reduced electrical consumption is now being obtained by my buildings in India, some with the assistance of consulting companies.

In 2001, the Government of India enacted the Energy Conservation Act under which it prescribed the energy conservation building code (ECBC) for efficient use of energy in non-residential buildings. Presently, it is applicable to buildings with a demand in excess of 500 kW or connected load in excess of 600 kVA. All GRIHA buildings are ECBC compliant.

Under this Code, the Bureau of Energy Efficiency (BEE), India, has a rating system for green buildings ranging from one-star to five-star The rating system recognises that there are two major climatic conditions prevalent in India, the hot-humid and hot-dry. Accordingly, depending on the climate in which the building is located, a range of power consumption is listed against each rating concerned.

The Bureau (BEE) recommends the following range of electric power consumption for a building which is *more* than 50% air-conditioned and is located under a given climatic condition, as follows:

Rating Hot and Humid Hot and Dry	(kWh/sq m/year)	
1-star	200 – 175	180 – 155
2-star	175 – 150	155 – 130
3-star	150 – 125	130 – 105
4-star	125 – 100	105 – 80
5-star	Below 100	

For buildings that are *less* than 50% air-conditioned, the rating is as follows:

Rating Power Consumption	(kWh/sq m/year)	Hot and Humid Hot and Dry
5-star	below 45	below 35

Some Outstanding Indian Examples

The first building in India to be certified as 'platinum' under LEEDS system has been the CII-Sohrab Godrej Green Business Centre at Hyderabad. Several other buildings have earned similar ratings from LEEDS and GRIHA. These ratings are being extended to cover different types of buildings (hotels, hospitals, IT Parks, malls, etc.) and in different climatic conditions.

Appendix 2(3) gives an interesting example of a 'green' building designed in Gurgaon, New Delhi, according to the Energy Conservation Building Code (ECBC).

Appendix 2(5) gives the example of the Gujarat Pollution Control Board's new office building in Gandhigram, Ahmedabad, where a solar PV installation costing in about ₹1 crore for 80 kW capacity 2011–2012, i.e., ₹1.25 lakhs per kW including cost of inverter, metering, cables, etc.and maintenance for 10 years, for supplying the electrical need of the building and feed-in of the excess into the grid.

The panels have been fixed on the building's terrace and, hence, no additional land cost was incurred. It is the first 100% solar building in Gujarat. As the excess electricity is fed into the town's grid, no storage batteries are required. During non-sunshine hours, the building's electricity requirement is met from the grid. The grid serves for balancing the demand and supply. More and more buildings are considering this kind of arrangement as batteries are avoided and grids are happy to benefit from the feed-in.

It is evident that the feed-in occurs mostly on Saturdays, Sundays and holidays when offices are closed. The grids want consumers at that time. Hence, industries are needed as they generally work on holidays and weekends.

Appendix 2(5) gives another example of an ownership residence building in Pune where a solar + wind energy (hybrid) system was set up in the year 2007 for part supply of free electricity to the members of the cooperative society. Here also the building's terrace was used. But no electricity is given to the grid. It is used within the building. Giving some free electricity to the tenants seems like a great marketing idea for hastening the sale of flats on ownership basis. Perhaps it is a better idea to attract flat buyers than providing a gymnasium or something else for free use by the tenants. However, the installation cost is increased by 20–30% owing to the need for storage of electricity. Batteries also need to be replaced every few years.

Sustainability is Improved

A benefit arising from the adoption of green buildings is that sustainability improves. A building that consumes less power, less resources like water, less building materials and less labour for its maintenance is more assured of its sustainability over a longer period of time. A first generation green building is likely to have the following features:

- An open atrium bringing natural daylight into working areas
- Construction in hollow block walls
- Interior gardens
- A Green roof garden as an amenity and way of keeping the floor just below, cool
- Solar heaters for hot water
- Light fixtures adjustable according to occupancy
- Water efficient fixtures
- Reuse of wastewater to reduce fresh water use, especially in garden

- Garbage conversion to compost for reuse in garden
- All construction materials. Fixtures and fittings locally sourced
- Boreholes/ponds to store water and supplement rainwater harvesting

Besides the previously mentioned features, a second generation green building would also generate all or some of its power requirement by a wind, solar or hybrid system installed at the building.

Greening of Old Existing Buildings

Although several new green buildings have come up, thanks to a few enthusiastic architects and builders, they still constitute less than 1% of the total building stock in India. There are yet many old, existing buildings in every city that need to be brought into this green category to whatever extent is possible. Only then will our effort make a sizeable impact.

To begin this approach, one has to start with testing/benchmarking the facilities provided by existing buildings and follow by retrofitting and upgrading work as necessary. The relatively short pay-back period for such costs should encourage better response. Siemens and McGraw Hill Construction (MHC) undertook studies in the USA covering three sets of buildings: commercial, healthcare and educational. Their findings are that only about ¼ of the existing buildings could be rated as high-performance buildings. Another ¼ were low-performance units. The middle ½ ranged from low to high. Their report should be made required reading for all planners as it contains many interesting observations. In the USA, 78% of respondents planned energy efficiency upgrades from own resources (company profits).

If such a study were done on Indian buildings, the author's guess would be that all buildings would probably turn out to be low-performance units (except the new green buildings). We have had no benchmarks about performance except until now. Performance of old buildings can be rated in many different ways, but is generally rated in terms of:

- Energy and water requirements
- Environmental impact, and
- Comfort and well-being of the occupants.

Upgrading activity is relatively low in India because of several reasons such as access to funding, insufficient incentives and general lack of interest. Buildings in India generally respond to upgrading suggestions by doing the following (not necessarily in the same order):

- Issue circulars to tenants to conserve electricity usage in building
- Change over to CFL and LED bulbs when buying new replacements
- Seek switch over to cheaper rate of electric supply for bulk consumption
- Install timer switches and thermostats to reduce electric consumption
- Air-conditioned areas keep increasing
- Install low water consuming fittings and fixtures
- No changes to building envelope are possible to undertake at this stage
- No terrace garden is attempted as leakages are feared
- No plantations or changes are possible on site as the site is already crowded
- Meanwhile building inmates keep increasing and toilet and other facilities are overcrowded
- Any switch over to 'renewable energy' (wind or solar) is put off as expensive
- Automation systems are considered unaffordable

The net result is that energy and water requirements are out of sync with the needs of inmates, the building's unfavourable environmental impact hardly changes (although some minor decrease in carbon emissions may result) and the comfort and well-being of the people tend to diminish. Occupant satisfaction diminishes. All talk of any increase in lease rent has to be put off. The situation just goes from bad to worse in most cases. Municipal infrastructure also remains unchanged and deteriorates for the same reason.

At present, India is greatly enthusiastic about new green buildings. India's interest in retrofitting and renovating existing buildings is still in a relatively dormant state. However, it is picking up speed, and activity in this direction will surely increase rapidly in the coming days.

Some hopeful signs are visible (from US experience) in case of commercial buildings, hospitals and large educational universities, first. Hopeful signs are mostly found in cases where the builder is also the eventual owner because the builder is more assured of returns on his/her investment. This is true of government-funded buildings too. Increasing number of private companies are also opting for renewables and net-zero energy buildings.

6.5 Green Hotels and Hospitals

Green hotels are invariably designed as 'green' buildings first, along with green services to their guests. Hotels present an even greater scope for saving power, water, etc. than green buildings do. One such world-wide chain, for example, is the 'Ecotel'. In fact, the hotels use this information to increase their 'brand' value as these aspects appeal to environment-friendly guests.

Hotels try to become *'water positive'*, i.e., they try to generate more fresh water than they use. (This is done by rainwater harvesting and reuse of wastewater after treatment for gardening and non-potable uses.) Hotels also try to become '*Carbon positive*' (through afforestation and minimum use of fossil fuels) and try to have '*zero solid wastes*' (through salvaging, recycling and composting).

These hotels use several energy saving devices (CFL bulbs, efficient pumps, timer switches, etc.). Their door keys are smart cards which are also used to operate room lights and air-conditioners by the customers.

They save water by using dual flushing tanks, pressure reducing devices, dual-plumbing, etc. They save power through solar water heating equipment for rooms as well as hotel kitchens and laundry, etc. The hotels also make extensive use of wastewater after treatment to meet cooling, gardening and other needs and ensure solid waste segregation and reuse, composting, use of recycled paper, use of less water consuming plants in their gardens, etc. Some hotels are also beneficiaries of carbon credits under CER schemes.

Two examples come to mind. The Orchid Hotel near the Mumbai Santa Cruz Airport where every detail on the above lines has been looked into as it should be with a hotel which uses the 'Ecotel' brand name. Others are the chain of ITC Hotels in India and Hotel Gardenia in Bangalore whose various features including a wind-funnel shaped atrium requiring no air-conditioning, and a drip-fed vertical wall garden economising on water, have helped it being awarded the LEEDS Platinum rating. A few other hotels also practice the similar commonsense but valuable principles.

Green Hospitals

Green hospitals is a relatively new concept, but in fact, not so new since it is based on concepts already known to us, namely, green buildings, green hotels and green technologies for municipal services (water supply, solid wastes disposal, etc.). Green hospitals are only an application of all the mentioned concepts. They incorporate all the devices which a green hotel would. They also incorporate all the devices which different municipal services would incorporate (see following text).

A key to their successful operation lies in proper segregation of infectious waste from municipal waste, and its proper disposal. Hospitals must also ensure that used needles and sharps do not find their way back to the market. They must be broken before disposal to make reuse impossible. With infectious wastes, 'no-burn' technologies (such as autoclaves, hydroclaves, etc.) must be used instead of incineration. Burning at lower than a certain temperature may produce the toxic dioxine. Radioactive wastes and cytotoxic drugs need separate disposal as per their own guidelines. Body parts are generally sent to local crematoria for incineration.

6.6 Green Technologies for Transport

There are many different forms of transport to serve a city and they all have varying forms of greenness among them. For example, for inland cities, there are the usual motor cycles, motor cars, SUVs, rickshaws, buses, trucks and tempos, using different fuels. The different transport facilities serving a coastal city include motorboats, launches, ferries, catamarans, and ships, all using different fuels and having different emissions. Airplanes serve all types of cities and use their special ATF fuel.

The many varieties of transport just mentioned can all be placed under two broad groups: 'private' modes of transport and 'mass' modes of transport. The reader is referred to Chapter 4 for emission factors for different types of fuels and transport modes.

Private Transport

In greening modes of transport, effort has mainly been directed towards greater use of the following:

- Biofuels
- Use of smaller cars, (eventually hybrid cars, electric vehicles)
- Switch over to CNG or LPG gas
- Facilitation of traffic by providing flyovers, tunnels, wider roads, etc.
- Discouraging of traffic in certain areas by various means
- Mass transport (buses, trains, metros, monorails, etc.)
- Better planning and layout of new towns with walkways, cycle paths, etc., connecting residential and working areas

Biofuels are mainly used as additives up to approximately 10% of petrol. This addition reduces the demand on fossil fuels and, in some cases like India, their use reduces the need for import of petrol and diesel to that extent.

Petrol and diesel-driven motor cars are now being gradually replaced by electric and hybrid vehicles, to some extent. A present-day favourite of the people is to replace petrol and diesel oil with cheaper alternate fuels such as CNG, LPG, etc. where readily available in cities. A small capital cost is involved in adjusting the fuel feeding arrangement to suit the gas proposed to be used. This usage is primarily due to the government's pricing policy and ready availability. It is clear that the 'greening' of any city's transport system is invariably the result of its pricing policy and availability of the fuel for use by the people.

In the Netherlands, electric vehicles are available to use on hire basis in downtown parts of some cities. They help reduce pollution, traffic congestion and carbon emission. In Mumbai, 50,000 taxis have switched over to CNG gas. The transport authorities state that two air-conditioned buses operating on CNG-hybrid system are being tested at present and seem to cost less to operate than similar sized conventional buses. Further results are awaited.

A congestion tax is a way of dealing with an area or district where traffic has to be diminished by charging a premium for entering that area. It has nothing to do with the quality of fuel. For example, a charge of 8 pounds is levied in London on vehicles entering the 'central business district' in order to decongest the area. The device has succeeded in reducing traffic delays by 22%. Incidentally, carbon emissions are also reduced (by 16% through reducing traffic snarls and idling engines) without hurting the local economy. Singapore levies a charge (a penalty) on vehicles entering a certain business area with only one passenger in them. Singapore also keeps its total number of cars down by requiring an expensive permit to be purchased before one can own a car, and the permit is renewable every 10 years. Reduced carbon emissions are an incidental benefit of this policy.

Transport systems are continually being reviewed and R&D efforts are always ongoing. Besides electric versions of vehicles, hybrid cars and fuel-celled cars, cars running on other cleaner fuels are increasingly becoming available in every country.

Mass Transport

In our greening effort, mass transport is our main preference over individual transport as its per capita emissions of carbon dioxide work out to be minimum. It is given as an illustrative example that for 240 persons to travel we would need 120 cars or 6 buses or just 1 train!

Yet, it must be remembered that mass transport is often installed not because of its lower per capita emission, but mainly because the traffic has got built up so enormously that cars begin to crawl, and the city would like to retain its attraction for more and more people to come, live and shop in it. Mass transport is, therefore, often provided for ensuring better traffic conditions so that business is not affected.

14 Indian cities are reported to be either building or considering metros at the present time.

Blessed are the old world's cities that installed mass transport systems (underground railways, tubes, metros, etc.) in the good old days when costs were low and cities were not so built up. Today the costs are much higher, the cities are more built up and traffic is heavy. Yet, we have to include mass transport in our planning because individual transport and city roads have their limits, and newer technologies make mass transport more feasible, and in some cases the only way out. Again, reduced carbon emissions are an incidental benefit.

Mumbai Transport

Transport has always remained a large source of emission in Mumbai. It has also been a large source of air pollution in Mumbai, and for this reason alone it has attracted much public attention in the past.

A big improvement in air quality occurred after Mumbai taxis (numbering over 50,000 cars) and BEST buses switched over from conventional fuels (diesel and petrol) to using CNG gas. The reduced smoke pollution has made a tremendous improvement concerning air pollution for the local citizens, and reduction in carbon emissions too although some emission still occurs.

The use of hybrid cars or electric cars has not yet increased for obvious reasons. However, Mumbai citizens can be advised meanwhile to use smaller cars rather than big SUVs, as their emissions would be in proportion to their engine size.

The city's fascination with flyovers has led to construction of longer elevated roadways which are proving useful in decongesting Mumbai. Other forms of transport such as water transport have much potential but need greater encouragement and support from authorities, especially in the form of better landing facilities.

Mass transport facilities have always existed in Mumbai in the form of electrified local train services which have been extremely useful (though inadequate). New additions are being planned and partly implemented involving use of metros, monorails, etc. and it must be remembered that mass transport facilities will always be ultimately needed in every city (not because of their lower per capita emission) but mainly because there is a limit to the build-up of vehicular traffic that can be handled by any city's roadway system, and every city would like to attract more and more people to come and live in it, and shop in it, for commercial reasons. So, both forms of transport have a great future.

The Delhi Metro and the Indian Railways have been installing more efficient railway systems and signaling so as to qualify for certified emission reductions (CERs) under the Kyoto Protocol. The Delhi Metro has also been awarded ISO 14001 for undertaking extensive noise and pollution control measures, re-locating thousands of trees and disposing soil from tunneling without harming the environment.

Electric Cars

Electric cars are a distinct possibility in the future in all the cities of the world. With the prices of fossil fuels (oil and petroleum) rising each day, countries like India located in the tropics will find that solar energy converted into electric energy at the building level can be used profitably to recharge the car batteries at night. The car's machinery may also be simplified and air pollution at street level may become a thing of the past. The entire motor car industry may undergo a big change. A better battery is first needed.

6.7 Green Roads

India is planning to invest enormous sums of money in infrastructure, starting with roads, railways, bridges, ports, airports, water, sanitation, power, gas, irrigation and telecom. Most of these items will add to roads and highways. The present roadway length is 3.3 million kilometers (second largest in the world). Barely 40% are paved. New paved roads planned are 15,600 kilometers—and a tax exemption for 10 years is again being offered for investments made in infrastructure.

A concept similar to the LEEDS concept is taking shape for providing guidelines for the design of what may be called Green Roads. Green roads exist already in the form of expressways or autobahns which pass through rural and semi-rural territory and carry relatively high-speed intra-city traffic. Their design is mainly affected by need for isolating the expressway section for only high-speed traffic, maintaining relatively easy slopes and curves at all times and providing special care for drainage, telecommunication and lighting in tunnels in mountainous terrain. All intra-city highways have to exclude slow-moving traffic, keep animal movement corridors open at all times and respect the local ecosystem.

On the other hand, inter-city roads and highways have different problems to handle. The roads vary in width from one-lane to several lane-wide roads, and have to cater to multi-speed traffic varying from cars and trucks to bicycles and even pedestrians. Special attention has, therefore, to be paid to crossovers. The city's drainage and other services including water supply, telephones, wastewater, etc. have to be accommodated and maintained, almost on a daily basis.

Thus, green roadways would have to deal with many items listed under at least the following:

- Environment
- Water
- Access, congestion
- Safety
- Construction activity
- Materials
- Technology

The designers/town-planners have to be encouraged to improve sustainability of the roadways and to lessen their environmental impact. The construction process may itself generate large quantity of debris, produce run-off that chokes the sewer system and pollutes the receiving water bodies. The massive traffic may cause its own problems. In the end, if proper precautions are not taken, the society may be left with impervious, heat-holding islands and carbon emitting vehicles.

6.8 Ports and Harbours

Ports and harbours become key points in transport for any city, more so if the city has an international reputation. Therefore, the design of ports and harbours is intimately tied up with design concerning other infrastructure such as roads, railways, bridges, tunnels, waterways, airfields, buildings and their drainage systems. Besides the features listed earlier in regard to green roads, one has to think of the coastal environment and long-term safety. India needs an urgent doubling of cargo handling facilities in its ports.

Sea level rise and climate change are two other factors likely to affect cargo handling facilities of Indian ports.

The New York City Harbour authorities are perhaps the first to conduct a study on climate change and its likely effects on infrastructure over a period of several decades: 2020, 2050, 2080. The study panel found the following:

- **Air temp** would increase from its present annual mean of 12.8 C to as much as15.5 to 17 C in the period
- **Precipitation** would increase from its present annual mean of 118 cm by about 5–10% in the same period.
- **Sea level** would rise from its present mean sea level by 5.1–12.7 cm in 2020, and 17.8–30.5 cm in 2050 and 30.5–58.4 cm in 2080.

- **Coastal storms** with a present return period of 100 years would have a shorter return period of once in every 35–55 years in 2050 and roughly once in every 15–35 years by 2080.
- **Effects of climate change** would include increased flooding, lowered clearances on bridges, increased risk of power failure, etc.

It was also stated that while uncertainty exists about climate data, this should not stand in the way of evaluation of facilities. Risk analysis should be as quantitative as possible so that evaluation is done in a consistent fashion. The cost of an adaptation measure should be weighed against the cost that would be incurred if the facility is lost. Safety is the prime consideration. Infrastructure having a useful life less than 25 years may be omitted from evaluation (such as air-conditioning systems). The reader is referred to the original article for fuller details ('Anticipating climate change' Civil Engineering Magazine of ASCE, April 2011).

6.9 Green Technologies for Industries

Greenhouse gas emission data from various industries in different parts of India have to be 'benchmarked' so as to be able to compare their carbon emissions with those of similar industries in other areas on a national and international basis. Consulting companies specialising in this kind of work are growing in many countries including India.

Actually, industrial groups are beginning to get aware of the need to retrofit themselves to reduce electric power in their factories, more because of its beneficial effect on their company's bottom lines rather than global warming. Water consumption studies were generally undertaken earlier since water shortage has been dogging industries since a long time. Some have undertaken such work out of their sense of corporate social responsibilities (CSRs) more than anything else. Newer technologies are sought whenever new installations are being planned.

Industries often constitute a big part of our so-called 'carbon footprint'. Industries generate carbon emissions right from the start of mining operations for their raw materials to the chemicals and processes used in their manufacture, and continue to emit during transport and use of their products and even during their disposal after their useful life is over. Industries, therefore, produce emissions *from the cradle to the grave!*

Manufacturing Emissions and Secondary Emissions

Emissions occurring from manufacturing operations at the factory site may be called 'manufacturing' emissions while those occurring elsewhere (e.g., on the road during transport, etc.) may be termed 'secondary'. Emissions occurring anywhere must be accounted for as they equally affect global warming. In this section, we refer only to the manufacturing emissions from industries and what can be done to reduce them. For understanding the secondary emissions, the reader must refer to the section on Transport. It is noted that the total emissions from any industry depend on the processes involved, the vintage of the manufacturing plant, the capacity of the unit, the processes used in manufacture, the efficiency of power generation, the nature of fuel used to generate the power and the location of the factory.

It must be noted that Indian industries are generally proactive in regard to climate change and new ones are acquiring environment-friendly technologies and adopting processes and practices that would bring down the need for fossil fuels. As stated elsewhere, India's steady growth rate of 8% has generated a concurrent growth of only 4% in energy consumption. Indian industries are also undertaking other initiatives such as energy labeling, energy audits, and such to conserve energy consumption in manufacture. Through CDM projects, as many as 28 million tonnes of certified CO_2 emission reductions have been claimed.

The CII estimates that there is yet some energy saving potential in Indian industry ranging from 10% in the iron and steel and aluminium industry to 15% in cement to 25% in pulp and paper and textiles. A large group such as Godrej in Mumbai is planning to reduce its energy consumption by about 30% and its water consumption by 50%. Thereby, it hopes to reduce its carbon footprint by nearly 50%.

Role of Consultants

It is generally wise to engage expert consultants to study the specific local situation regarding energy consumption and actual manufacturing processes used and recommend cleaner technologies and best practices in specific cases. Water and wastewater consultants played a very useful role in the past in developing industrial activity while meeting pollution control requirements and reuse of water to keep up production without damaging the environment. Now, they and others, are ready to undertake similar studies to:

1. Minimise electric power consumption in manufacture,
2. Minimise water use,
3. Develop wastewater treatment manageable within available land, manpower and other resources and needing minimum electricity for operation,
4. Advice on taxation and subsidy matters in country use or export, and
5. Review of the manufacturing processes and chemicals/ solvents used.

6.10 Carbon Emissions from Industries in General and Carbon Tax

Carbon emissions from industries depend on several factors such as requirement of electric power for operating its various machinery and manufacturing processes, type of fuel used for generating additional power locally, type of devices which require pumping, compression, pressure build-up, etc. type of solvents and other chemicals used in manufacture.

Industries listed by the CII are many: aluminium, cement, ceramics, electrical systems, engineering, foundry, fertiliser, glass, iron and steel, pulp and paper, sugar. Indian companies are gradually picking up the idea of measuring their carbon emissions. It is true that what you measure, you can control; what you do not measure, you do not know. The following are among the top 10 Indian companies which have started measuring and controlling emissions: The Tata Companies (TCS, Tata Global Beverages, Tata Chemicals, and Tata Power) Wipro, Yes Bank, ACC, Sesa Goa, GVK Power and Infra, ABB and some more.

Organisations are available to measure, report and find ways to reduce carbon emissions from the corporate world. According to one such consulting organisation, ACC has a carbon dioxide reduction target of 27 kg per tonne of cement by 2013. Tata Chemicals is targeting a 20% reduction by 2020 with 2008 as the baseline. Titan industries are targeting a 50% reduction by 2015 with 2010 as the baseline. Infosys, Wipro, Yes Bank, all have Carbon reduction targets of 50% and over.

There are some countries visualising a *carbon tax* to promote use of cleaner fuels in their respective countries. To equalise its effect on goods imported from other countries where a carbon tax does not exist, they wish to levy tariffs calculated to equalise these taxes. In this way, their own country's competitiveness is protected. It is obvious that such levies may have little effect on total emission reductions of a country where imports constitute only a small fraction of their national supplies.

6.11 Carbon Emissions from a Few Selected Industries in India

Among the few selected industries discussed here from GHG emission point of view, cement, steel and brick-making are considered three most widespread industries in India as their products are widely used in construction and manufacture everywhere. Other industries with significant emissions are the various food and fertiliser industries and aluminium manufacture.

Cement Industry

The cement industry has in the past always been associated with a particulate air pollution problem and has needed bag filters and electrostatic precipitators to control them. The industry now has a carbon emission problem too. The total carbon emissions from the world cement industry have been estimated at 160 million Mt per year around the years 1998–2000. They must have at least doubled since then. The average emission factor for the cement industry in India is estimated to be in the range of 0.5190–0.5408 tons of CO_2 per tonne of clinker for large cement manufacturers, for the year 2001–2002. This is comparable to the default IPCC emission factor of 0.5203 tons of CO_2 per tonne of clinker. The total clinker production from larger cement units in India, in 2001–2002, is 82.05 million tons and the emissions are 43.43 million tons of CO_2.

GHG emission from cement plants can arise from both fuel and the feed materials such as limestone and dolomite. Limestone releases carbon dioxide and the fuel, coal, also releases carbon dioxide. ACC is trying to develop renewable energy instead of coal. But, replacing limestone presents a challenge.

Western authors have discussed possible reduction in CO_2 emissions through various measures for improving the energy efficiency of the whole process by, for example, shifting from semi-wet to semi-dry process, and

- By replacing high-carbon fuels by low-carbon fuels,
- By applying a lower cement/clinker ratio,
- By increasing the additives in proportion to the cement,
- By use of blended cements and application of alternative cements (mineral polymers).

They also suggest removal of CO_2 from the flue gases, and greater recycling of cement kiln dust. Much of this might be possible in India, but the cost is not yet known and experience is lacking.

Steel Plants

In steel plants, the coke ovens help convert raw coal into coke of required quality, while producing by-products which become raw materials for other operations. This coke along with limestone and iron ore brought from the mines are fed into blast furnaces (along with air) to make pig iron.

The resulting pig iron from the blast furnaces is treated further in open hearth or electric furnaces for conversion into steel. All the fumes and polluted air are passed through dry and wet scrubbers and electrostatic precipitators for cleaning before disposal to the open atmosphere. The cleaning process traditionally concentrates on particulates, both in air and in water. No attempt is made to remove or treat CO_2 and other GHGs before release. Further, some of the products undergo pickling, galvanising and plating which generate water polluting substances.

Thus, an integrated steel plant may consist of a battery of coke ovens, blast furnaces, steel melting shops, sinter plants and annealing plating plants. Use is made of different solid and gaseous fuels to operate the different units. These fuels of varying qualities give CO_2 and other GHGs in different proportions. Besides, flux such as limestone and dolomite added in the process also contribute (only about 5%) to the emissions. Thus, the emission factors depend much on fuel quality.

A study conducted in an integrated steel plant in Canada reported an emission factor of 1.6 tons of CO_2 per tonne of hot metal from fuel consumption. The emission factor estimated for an Indian integrated steel plant was noted to be 2.04 tons of CO_2 per tonne of hot metal.

An example can be given from the steel industry in India where Tata Steel* is reported to be making efforts to reduce CO_2 emissions from its steel plant at Jamshedpur from 1.8 tonnes to 1.7 tonnes per tonne of liquid steel made by 2012. The global benchmark is 1.5. Tata's Jamshedpur operation also claims to have reduced specific energy consumption by nearly 18% in the past 10 years. Blast furnace 'off' gas is used for generating electricity. Also, 90% of the solid waste generated is reused.

Brick-making

Brick-making is a widely dispersed industry since bricks are made all over India. Brick-making industry is widely associated with the construction industry in India. Bricks are used not only in housing but also in infrastructure construction in the country. Hence, it is fabricated in several parts of the country wherever the soil permits its fabrication and in most cases, extremely simple, rural type of set-up are used, such as brick-kilns fired by locally available fuels including agricultural residues.

The emissions are, therefore, entirely dependent on the fuels used for firing the brick kilns, and must be estimated accordingly. Increasing use of agricultural residues is suggested as a renewable energy source.

Fertilisers

Manufacture of fertilisers is a complex matter as it involves several different types of fertilisers (ammonia, urea, ammonium nitrate, etc.).

For ammonia production, naptha or natural gas is reformed with air and steam resulting in CO_2, N_2 and H_2 which are taken to a methanator for further treatment. Ammonia is used in producing urea. Also, the reaction between ammonia and sulphuric acid gives

*Among other eco-friendly attempts by the house of Tatas, one can list Tata Motors which is developing an electric version of their Indica car which will run on polymer lithium ion batteries. Tata's Indian Hotels is creating energy-efficient mini-bars, organic bed linen and napkins made from recycled paper for their hotels in India.

ammonium sulphate. Phosphate rock or fluorapatite when reacted with sulphuric acid gives phosphoric acid.

As in case of other industries, the emphasis so far has been on water pollution control by taking care of liquid wastes, and to a lesser extent by proper handling of solid wastes. Gaseous wastes such as CO_2 and methane are produced in manufacture and some fugitive releases also take place. The fuel used in manufacture also leads to co-production of CO_2. These emissions have traditionally been neglected. There can, however, be a carbon recovery plant in ammonia manufacture and the soot produced can be sold.

Use of Fertilisers in Agriculture

Fertilisers are used freely in agriculture, and thereby lead to emissions to the atmosphere. Soil contributes much towards N_2O (nitrous oxide) emission to the atmosphere. It is a by-product of nitrification and an intermediate product of denitrification. There are no significant uptake mechanisms or sinks in the soil. Hence, any reduction in N_2O values in the atmosphere must take place in their emissions. This reduction is achievable by, for example, synchronising supply of the nutrient with the growing season when demand is maximum, or by the method of application or by other methods explained elsewhere.

Food, Beverage and Allied Industries

A large number of industries fall in this group such as the following: milk and milk products, meat and poultry, cane sugar, tanneries, beer breweries, wineries, whiskey and rum distilleries, edible oils, and the like.

Hitherto, they have been mainly regarded as water polluting industries and their wastewaters have, therefore, attracted much attention. Their liquid effluents have been subjected to treatment (often anaerobic) before discharge either into water courses or on land for irrigation of food and fodder crops. Treatment has often been in the form of non-mechanised systems such as lagoons, ponds, ditches, wetlands and the like, all of which require relatively large tracts of land. Near urban areas, where land is expensive and/or difficult to acquire, treatment has been done using either trickling filters or activated sludge systems or aerated lagoons which require less land but more power.

Industrial wastes high in organic content have been treated in up flow anaerobic sludge blanket (UASB)-type plants to undergo anaerobic digestion and produce biogas containing CO_2 and methane (CH_4) without use of external power. In these days of concern with global warming, the biogas cannot be just released to the atmosphere like old times. The methane can be used in the industry's boilers as fuel instead of oil or coal and the CO_2 removed by bubbling it through an algal pond. If biogas is available in large enough quantities, it can be supplied to a near-by industry or fed to a dual fuel engine and electricity produced. Formerly a company in India was providing UASB-type plants on BOT basis, but was closed down for various reasons.

In selecting wastewater treatment systems, it must be remembered that aerobic processes require electric power and thus co-generate CO_2, while anaerobic processes also produce CO_2 along with methane (CH_4) and both need to be taken care of from a global warming point of view. This is further explained later under municipal waste treatment (also see Fig. 6.3).

Shops, Offices and Commercial Establishments

The scope for reducing GHGs from shops and offices is similar to the scope for reducing from domestic houses as it primarily depends on reducing electric power consumption. This means economy with A/Cs, use of more efficient equipment and appliances, office and shop lighting (CFL or LED lights), etc. as outlined earlier. Besides these items, some scope lies in economic use of paper and other materials, Xerox and such machines, all matters which often depend on company policies.

Another important source of GHGs depending on company's policies is regarding travel, both daily travel to and fro office and long distance travel by air or car or public transport to meet clients, etc. As stated earlier, video conferencing is often a good substitute for personal meetings involving air travel.

Some Win-win Examples from India

A few win-win examples of successful reductions from industries in India are given in the following:

- The hotel industry in Mumbai has successfully taken various steps to economise their use of electricity and water in their hotels.
- The Tata Iron and Steel Co, Jamshedpur, is reported to be making efforts to reduce CO_2 emissions from 1.8 to 1.7 tonnes per tonne of liquid steel made by 2012. The global benchmark is 1.5.
- The Aditya Birla group's Grasim Industries manufacturing cement aimed to reduce 1% of its carbon dioxide emissions per year. It has earned ₹17 crores so far by selling credits in Europe.
- Hindustan Unilever has just patented a process for soap-making using 'mixers' instead of steam (which requires boilers and fuel). 15,000 carbon credits, 10 years.
- A fluoride manufacturing company in Gujarat has made a process change which earns it nearly $1 mill/year.
- By using low-cost *solar energy* for cooking meals for schools, temples, trusts, hotels, etc.LPG gas worth lakhs per year is saved.
- Several plants manufacturing food products produce wastewater rich in organics. They have set up biogas plants of the UASB-type on BOOT basis to produce methane which they use and save fuel costs by crores of rupees.
- Waste heat to power is a big source of energy in many industries.
- India ranks fifth in terms of wind energy. An Indian industrial group named SUZLON is setting up wind farms in several countries of the world to generate electricity. It is one of the world's well-known companies in the wind energy business, and has considerable experience with large projects.

Regarding development of 'sinks', India does not have much to show. However, an example from Germany can be given. A German industry has dedicated a large forest area for absorbing atmospheric CO_2 through photosynthesis. (A single tree can absorb 1 tonne of CO_2 over its lifetime.) This fetches a good income from the dedicated forest. India has much scope for developing such dedicated forests in its warm climate.

6.12 The Changing Scenario in Cities

In recent times, many cities are undergoing a gradual change in the type of industries based in them. For example, Mumbai has been changing from a textile industry centre to a 'service' centre with consequent reduction in visible smoke and other emissions. The city's 50,000 taxis have also changed over to using CNG gas as fuel. However, no carbon emission data exists from the past, nor are benchmark values available for the present activities with which past data can be compared.

Mumbai's changing industry scenario requires a more detailed study of the new industries for two aspects:

(i) their carbon emissions and
(ii) their water requirements (as water is in short supply).

Both will help establish benchmarks of local utility. Consultants capable of undertaking such studies need to be engaged at the earliest by industries and industry associations.

Several other cities are likewise showing a changing scenario in industries. Also, almost all cities remain power-hungry. As all cities are short of power, generation of green power in second generation green buildings or through solar PV panels or wind turbines or both installed on existing buildings has to be encouraged with the proviso that any surplus power so generated can be fed-in into the city's existing grid at a specially fixed premium price to be paid to the seller by the electric company. Whatever power shortfall is reduced is welcome.

The country as a whole, however, has being doing well in terms of reducing emissions. Over 300 Indian entrepreneurs are reported to have benefitted from awards made under the Kyoto Protocol. China comes next in this respect. Indian industries can continue to obtain financial benefits under CDM and such other programs for CERs now that the Kyoto Protocol has been extended for another 10 years.

6.13 Need for Wider Application to Town Planning and Area Re-Development Projects

It would appear advisable to apply these 'green' concepts more widely than at present. These concepts should become immediately applicable to the planning of all new large buildings in both the public and private sectors, with immediate effect. Besides this,

1. All new SEZs. They should really be the first to demonstrate the applicability of the concepts both to buildings as well as the infrastructure.

2. All new regional development schemes planned for areas within large metropolitan cities.

   In Mumbai, 'green' concepts can be employed to the development of Crawford market area, Dharavi area, Null Bazaar area, etc. and similar other regional development areas in New Mumbai, Maharashtra, and the whole of India. At the time of the Commonwealth games in New Delhi, some telephone kiosks, ATMs, stadia, etc. were operated through solar PV panels to generate the needed electricity.

   The recent 2012 Olympic Games in London gave an opportunity to develop a whole new area for the occasion. Access to the area was only possible either by public transport or cycling or walking. Thousands of trees and wetland plants were planted and looked after. The principles of green buildings were fully adopted to save on water, electricity and other resources in construction.

3. Intra-city roadways like *Delhi–Mumbai industrial corridor* and all the consequent development that will take place in the states through which the corridor/roadway will pass has to be subjected to 'green' principles of planning. 24 futuristic industrial and residential hubs are likely to come up across 6 states.

   The Gujarat Government is bestowing special attention on a new planned city, the City of DHOLERA, which is to become a model city on this corridor and connected to nearby Ahmedabad by a 10-lane highway. Every housing, office and industrial complex will be within 10 minutes walking distance of some form of public transport. The city will rely heavily on solar energy for its power requirements although a 1300 MW conventional power plant has also been planned. Waste will be recycled. All parking will be underground, leaving the surface open for gardens, parks, pedestrians and cyclists.

   From their experiences, we will have a better understanding of the problems and what our priorities should be. Mr Amitabh Kant, CEO and Managing Director of the Delhi–Mumbai Industrial Corridor, says that urbanisation is accompanied by unprecedented natural resources consumption. Cities occupy 3% of the earth's land surface, house half of the human population and account for two-third of all energy and greenhouse gas emission. He continues to state that the fast growing cities of the world all show high areal densities. New York has a gross average density of 9,810 people per sq km. Shanghai has a density of 24,673 and Barcelona has a density as high as 37,600. These cities have demonstrated a high quality of life and livability. The standard practice in all these cities has been to raise the floor space index (FSI) with time. India has been doing the opposite—reducing the FSI with time. In Mumbai, the FSI was brought down from 4.5 to 1.33. People, nevertheless, kept coming and slums developed as a result. To accommodate the migrating population, China is building three Americas. India has to do the same, if not more. But, India with its poor funding has been an extremely reluctant urbaniser. India needs to leapfrog into technology and reforms much faster.

6.14 'Green' Infrastructure for Municipal Services

Green buildings and green industry evidently have to be supported by a 'green infrastructure', otherwise it would be illogical. Both must go together. *Green infrastructure** covering various municipal services refers to a city's entire infrastructure mainly consisting of its

- Water supply distribution network,
- Storm water collection and disposal network,
- Wastewater collection, treatment and disposal system,
- Solid waste collection and disposal system,
- Industrial and hazardous waste collection and disposal system.

In each item, there is much scope for release of greenhouse gases and, therefore, there is equally good scope for some 'greening' to be done as indicated in the following.

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*It must be noted to the credit of the Indian Government that from Feb 2010 onwards, all SEZs in India will be required to adopt 'green' rules of planning and seek renewal every 3 years thereafter. The rules require optimising use of energy and water as also focus on waste management, tree plantation, site preservation, internal transportation and infrastructure.

Water Supply and Distribution

- All water resources in India are depleting. We need more rain water harvesting and groundwater recharge systems, both in urban and rural areas, to replenish the ground water. Creation of more ponds, lakes, check dams, etc. is needed, especially in rural areas. In urban areas, roof-top-type rainwater harvesting arrangements can be made although they may have their own possible health problems, if done haphazardly.
- From the viewpoint of reducing CO_2 emissions, electricity usage must be minimised in water treatment and in water distribution, since the *production of 1 kWh of electricity to operate a pump releases 0.44 kg CO_2 at the power generating station.*

Water policy has to address growing concerns about carbon release from electric power usage. According to Tushar Shah in the *Economic Times* of 19 October 2010, Indian farmers use 75–85 billion kWh of electricity and 3.5–4.0 billion litres of diesel oil per year in pumping groundwater. Deep tube wells in Gujarat, Rajasthan, Punjab and western UP are great power guzzlers. Groundwater irrigation accounts for 4–6% of the country's carbon emissions. A lowering of 1m in groundwater level increases carbon emissions by 4–6% from pumping. An increase of 1% in groundwater irrigated area increases emissions by 2.2%.

A gravity scheme must invariably be preferred rather than a pumping scheme, if a choice exists. Where pumping is involved, pressures in the system must be optimised so as to meet desired pressure criteria without unduly heavy pumping. For the same reason, a 24 × 7 supply would be preferred over an intermittent supply. A method has been developed to optimise water distribution pressures and supplies by modelling the network (Dr S Dahasahasra, Member Secretary, MJP, 2009).

- It is evident that where water resources are tight, one cannot afford to give free electricity to farmers or to allow anybody to abstract groundwater without a permit. Also, there should be no subsidy on water prices. These are policy issues for the government or local body to address and others can only play an 'advocacy' role to ensure it is done. Yet there are instances in India where free electricity is given to farmers as a result of which groundwater is pumped up indiscriminately and groundwater levels are falling fast.

- Water conservation starts with the municipal body and extends to the individual user. The latter's attitude is mainly governed by the price of water. The price of water depends on the policy of the government. So it is a vicious circle. Where water is under-priced, the water authority generally suffers from wastage of water and lack of funds for proper maintenance and timely augmentation of new sources.
- Unaccounted-for-water (UFW) losses from distribution systems in Indian cities are often unacceptably high (>> 20%) and need more serious repair-and-maintenance routines by local body staff. Leakages eventually mean more volume of water has to be pumped.
- Various typical water conservation measures such as avoiding unduly high pressures in distribution systems, installing dual-flushing tanks, pressure reducing devices, promoting reuse, etc. have to be taken by the local body. Corrosion has to be avoided as it leads to leakages and excessive wastage of water. All leakages from the system need to be minimised for obvious reasons. Metering is another possibility but is often limited to small areas of a city's network and penalties for non-payment are not imposed strictly. This does not make metering very beneficial.
- Augmentation of fresh water supply can be done through (i) rainwater harvesting or (ii) through reuse of wastewater after treatment or (iii) through desalination of sea water (if affordable).

Rainwater harvesting in cities often introduces a quality-control problem because two different sources of water supply come into play: public and private, and who is to blame for what. Rainwater harvesting is best for rural areas where water is mainly needed for agriculture.

Reuse is invariably cheaper and less carbon emitting than desalination which consumes much electric power. One way in which reuse can be done is to replenish a lake by using well-treated wastewater to make up for the heavy evaporation losses typical of lakes in tropical climates (as is being done in Hyderabad for the past 10 years). Another way is to do like what Mumbai does, namely, on an individual basis by asking its large water-consuming buildings and industries to reuse their own wastewater after treatment for non-potable purposes. If *desalination* has to be done, though expensive, its power requirement should be met from a renewable energy source as far as possible.

All buildings housing water treatment plants have to be designed as 'green' buildings.

Storm Water Run-off

- With big changes occurring in rainfall pattern and sea levels rising, the functioning of storm water drains is going to be severely impacted in all coastal cities. All storm water drainage systems will need to be reviewed in the light of local rainfall and runoff data every few years and suitable measures taken to provide flap gates, dykes, holding ponds, large volume pumping stations, large canals, locks, etc. almost all of which we did not need all these years. Someday, one may even need to learn from Venice and Holland in this regard. All of these solutions will involve use of electricity and hence lead to increased emission of GHG unless a renewable source of energy is used.

As stated earlier, Mumbai is already setting up its first storm water pumping station at Haji Ali. This will place a demand on the power supply grid when the pumps are operated since a separate renewable source of energy has not been provided. Under changing climatic conditions, the people will need more accurate data on rainfall intensities and corresponding run-off patterns. Better and timely statistical data will be needed all round.

- Increases in sea level will also have to be recorded accurately and informed regularly as it affects drainage system design, especially for low-lying coastal areas.

Wastewater Collection, Treatment and Disposal

In dealing with wastewater, GHG emissions occur in all three of its component systems, namely, the wastewater collection system, the treatment system and the disposal system, i.e., after its disposal to the environment.

Where sewerage systems are provided, carbon emissions have two obvious sources:

(i) wherever electricity is used which is produced by using fossil fuels some co-generation of CO_2 takes place. Electricity is used generally wherever pumping is done and
(ii) carbon is produced when wastewater turns anaerobic leading to production of CO_2 and CH_4 in the environment.

Hence, it would be advisable to avoid pumping wherever it is possible to do things by gravity, and it would be advisable not to discharge untreated wastewater to the environment where it will turn anaerobic in course of time.

Sewerage systems have not yet been provided in many towns of India. In this matter, there is a very large backlog of projects to be undertaken. A relatively progressive state like Maharashtra has many mid-sized towns yet to be provided with modern sewerage systems. Only 28% of Mumbai's sewage is yet treated. The rest goes to the nearby sea through long outfalls to let nature do its job and avoid smell nuisance.

While much work remains to be done in terms of wastewater collection, treatment and disposal, it gives us an opportunity to decide whether we need acentralised or a decentralised sewerage system. In a *centralised* system, a network of laterals, sub-mains and mains are provided with a long outfall leading to a river or water course where the wastewater is finally discharged (as we have been accustomed to in the past). Alternatively, we could have a *decentralised* collection network consisting of several smaller outfalls discharging smaller quantity at each outfall which can be either used for irrigation or soaked underground to conserve water.

With the old-style long outfall, we have to treat a large volume of wastewater at the outfall and hence conventional treatment methods (activated sludge and such) needing electric power for aeration are generally used. These methods of treatment are both unaffordable because of the electric power cost and are more difficult to maintain in working order. They also produce carbon along with power generation. These methods have come to us from the western countries where because of their colder climate 'natural' systems would not work. Natural systems depend on the growth of microbes, algae, etc., which need a warmer climate. What's more, the treated effluent discharged to rivers or nallahs leads to pollution and other problems downstream.

With decentralised collection systems, the volumes to be handled at each outfall are smaller and hence, 'natural' systems of treatment (such as ponds, lagoons, constructed wetlands, irrigation, etc.) become feasible to use. Natural methods do not need electric power which means they become affordable in a warm country like India, and additionally, they do not generate CO_2, which is ideal in these days of global warming. Natural methods also have an important advantage that they help us to conserve our water resources since groundwater recharge or irrigation is the preferred method of final disposal when natural methods are used.

For the purpose of Figs. 6.1 and 6.2, an activated sludge plant to serve 1 lakh people in a typical mid-sized Indian town requires 15 lakhs kWh of electric power per year which releases an enormous quantity of 657 tonnes of CO_2 per year at the power generating stations.

Decentralised systems deal with a number of smaller areas. This requires less pumping. Natural systems also require minimum of building materials and earthwork and conserve water and nutrients through final ground water recharge. Decentralisation of sewerage systems might, in fact, have to be made *mandatory* in India for small and medium-sized towns and for suburban areas of large cities in view of the enormous benefits involved.

If power is required (because adequate extent of land is not available for natural systems to be adopted) the power should be generated locally from biogas. This will force municipalities to use 'natural' methods as far as possible. Only if land is not available

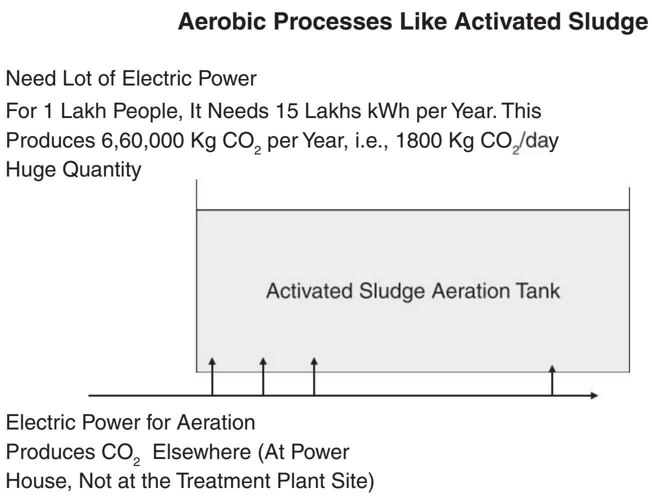


Figure 6.1 *Aeration power and CO_2 emission from the activated sludge process.*

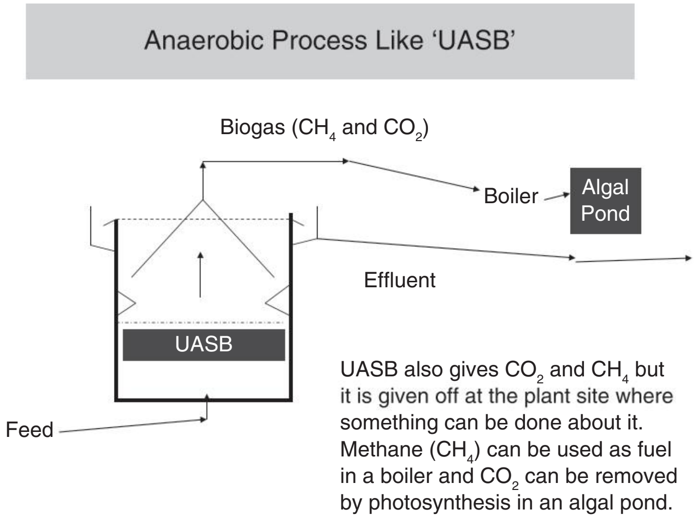


Figure 6.2 *Emission control and power generation from the UASB process.*

and mechanised systems have to be used, the local body should be prepared to generate its own biogas from conventional methods, and from it the required power.

Below are listed a few typical sewage treatment methods and their status with regard to certain global warming parameters such as *direct* emissions of biogas containing CO_2 and/or CH_4, their *indirect* emission of CO_2 due to electric power consumption, and thirdly whether photosynthesis is involved or not. It is hoped these details will help planners in deciding on their suitability:

Treatment Method	Direct Emission of CO_2/CO_4	Indirect Emission Due to Electric Consumption	Carbon Sink Due to Photosynthesis
Aerobic Biological Methods			
Extended aeration	Minimal	Very high	Nil
Activated sludge	Minimal	High	Nil
Trickling filters	Minimal	Medium	Nil
Aerated lagoons	Minimal	High	Nil
Waste stabil ponds	Medium	Nil	High
Constructed wetlands	Nil	Nil	High
Crop irrigation	Nil	Nil	High
Anaerobic Biological Methods			
UASBs	High	Nil	Nil
Sludge digesters	High	High	Nil

Treatment Method	Direct Emission of CO_2/CO_4	Indirect Emission Due to Electric Consumption	Carbon Sink Due to Photosynthesis
Sludge lagoons	High	Nil	Nil
Anaerobic ponds	High	Nil	Nil
Septic tanks	High	Nil	Nil
Physico-chem methods			
Pumps	Nil	As per electric consumption	Nil
Screening and grit removal	Minimal	Low	Nil
Sedimentation tanks	Minimal	Low	Nil
Filter units	Minimal	Medium	Nil
Membrane bio-reactors	Minimal	High	Nil

Selection of processes/operations for treatment of wastewater is normally done on the basis of effluent quality requirements and sludge condition to meet national pollution control standards. The standards so far do not require any attention to be paid to gaseous (GHG) discharges.

From the global warming viewpoint, only a few of the previously mentioned methods qualify. The acceptable methods are those which meet effluent discharge standards without producing carbon dioxide or other greenhouse gases either directly or indirectly. Even more acceptable would be those methods that do not produce greenhouse gases, but at the same time have photosynthesis which absorbs carbon. Thus, the constructed wetland, the waste stabilisation pond and crop irrigation would be the best to use.

In an effort to keep the activated sludge process acceptable from the viewpoint of power consumption, effort has been made over the years to find more economical ways of aerating. From aerating at the bottom of the 3 or 4 metre deep tank (which needed compressors), aeration was done at just 1 metre depth (using blowers which needed less power). A Swedish development now claims that a further saving in energy is possible with their method of aeration. In India's warm climate, aeration is not necessary and can be avoided and reliance placed on so-called 'natural' methods of treatment even though they may need a little more land.

A special word has to be mentioned about the 'up flow anaerobic sludge blanket' (USAB) process. It does not need power. Hence, its use is considered desirable and economic for wastewater treatment. However, because of anaerobic activity, it directly produces CO_2 and CH_4 which are both GHGs. However, carbon dioxide can be removed by bubbling the effluent through an algal pond before discharge. The methane can be used for its fuel value. Hence, both these problems can be sorted out, and the UASB made a very useful process to consider especially as a pre-treatment unit before a pond or lagoon for high BOD wastes.

Finally, the buildings housing the wastewater treatment plants can be designed like typical 'green buildings' using LEEDS or GRIHA recommendations.

By-products Pay for Waste Treatment

An additional benefit of using decentralised sewerage systems and 'natural' treatment methods is that several by-products can be harvested as shown, for example, in Figure 6.3.

Appendix 3(1) gives an example to show how an old-style solution using a mechanised wastewater treatment system was avoided and instead a number of small different decentralised waste disposal systems were developed to serve different areas. Also, the treatment system was toned up to give reusable water. Some reuse of water was possible for industrial purpose. This

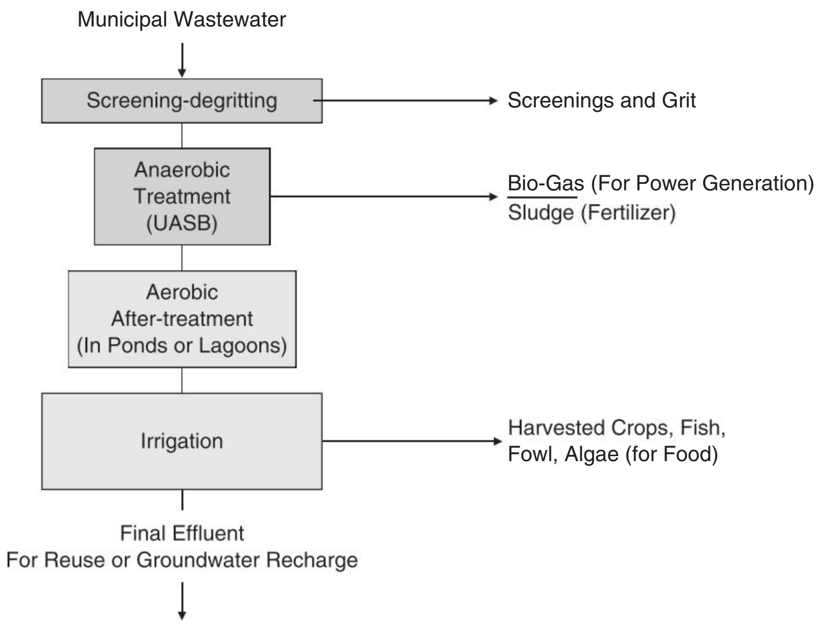


Figure 6.3 *An example of municipal wastewater treatment needing no power and giving resource recovery.*

was a special advantage as otherwise treatment was being almost neglected and the downstream water course was polluted. With reuse in industries, the plant would be more carefully operated and actually would earn some income from the water sold. Thus, it could not be neglected. Moreover, the lake would be replenished with water, no electric power would be needed for the natural treatment plants, water resources would be preserved and treatment simplified. The whole process would be akin to converting a large old money-losing cinema theatre into a profitable multiplex of small cinema houses showing different films, earning money, saving resources and protecting the environment.

Municipal Solid Waste Disposal

Maharashtra is reported to have a coverage of only 20% as far as solid waste collection and disposal is concerned. Since much work has yet to be done, solid waste collection and disposal need not be done in the conventional way, but rather in the following way so that it is more effective and economical, and will also avoid global warming:

Collection Trucks to Run on Renewable Sources of Energy

Collection trucks must operate on renewable sources of energy as pointed out in Appendix 3(3). No fossil fuels like petrol or diesel should be used. If we could do it successfully in the time of the second world war, so why not now? At the most, CNG gas may be used as its carbon emissions are lesser than those of fossil fuels like coal for power generation.

Appendix 3(3) gives the possibilities of operating garbage collection trucks on renewable fuels.

Waste Segregation

Waste segregation in Indian cities must be implemented as it recycles and conserves resources and improves the working condition of the rag-pickers. The wet fraction of the segregated wastes being organic in nature needs to be composted. This can be done ward-wise, in a decentralised system and used locally ward-wise, if area is available. Similarly, organic wastes from selected market-places and large industrial canteens, etc. would go to individual '*waste-to-energy units*' for generating biogas.

Biogas

If, however, the municipal solid wastes are handled in the conventional manner, both the dry (minus salvageable material) and wet fractions would go to a landfill site for disposal. In such cases, a 'sanitary landfill system' is to be preferred and a biogas collection network of pipes has to be embedded into the site to collect the methane, carbon dioxide and other gases produced through anaerobic activity so that their energy value can be used (not done at present) and disposal regulated. Leachate would also need to be treated before disposal.

Biogas released to the atmosphere from a solid waste disposal site located in India is approximately at the rate of 0.42 g/person-day (because of low organic content of the waste). Thus, biogas from, say, 1 million people would be 420 kg/day or 153.3 tonnes per year. As methane is approximately 50% of biogas, its emission = 210 kg/day.

In terms of CO_2-equivalent, it is = 210 × 25 = 5,250 kg/day Thus, total CO_2-equivalent emitted per day = (210 + 5250) × 365 = 1993 tonnes per year. This is a huge quantity from one dump.

Biogas emissions from municipal solid waste (MSW) disposal sites occur continually for up to 20–25 years or more after a waste is freshly deposited. From theoretical considerations, the half life of a landfill is about 23 years. This implies that biogas can be economically pumped out for at least 23 years. The biogas can be collected by a network of pipes buried in the deposited material and connected to a suction pump through a network of laterals and manifolds.

From limited studies by Bhide et al., Indian solid waste dump-sites give a biogas production of 0.263 m^3/kg or 263 m^3/tonne of waste deposited. The fraction of methane gas contained in landfill biogas varies from 0.35 to0.65 of methane (taken as 0.50 on default basis) and can be estimated approximately by using a simplified version of the IPCC default method as follows:

$$\text{Methane (Tons/year)} = \text{Total MSW (Tons/year)} \times \text{MCF} \times (\text{DOC}) \times 0.77 \times \text{F}$$

Where,

MSW = Municipal solid wastes, tons/year
MCF = Methane correction factor = 0.4 for open dumps of shallow depth
DOC = Degradable organic carbon content (determined for each city) = say 0.10 – 0.40
Degradable fraction = 0.77 Conversion to methane assumed as 0.077 (default basis)
F = Fraction of methane in landfill biogas = 0.35 to 0.65 (taken as 0.5 on default basis)

Example 6.1

Estimate the biogas and methane production per year from a municipal solid waste dump site handling about 2740 tonnes per day. Assume from the previous discussions that MCF = 0.4, DOC = 0.3, Degradable fraction = 0.77, conversion to methane = 0.077, and F = 0.5. Thus,

$$\text{Methane produced} = (2740 \times 365)\ \text{T/yr} \times 0.4 \times 0.3 \times 0.077 \times 0.5 = 4620.4\ \text{T/yr}$$

or, $$CO_2 \text{ equivalent} = 4620.4 \times 21 = 97{,}028\ \text{T/yr.}$$

This is no mean contribution to the global warming scenario of a city and warrants the provision of a biogas collection pipe network and earth cover at the waste disposal site to collect and use the gas instead of letting it off to the atmosphere.

Based on a per capita solid waste generation assumed as 450 g/day, the quantity of MSW amounting to 2740 tonnes/day would come from a population of about 6.088 million people. Thus, the methane production of 4620.4 T/yr from the dump site is approximately equal to 0.21 g/person-day or stated as 'CO_2-equivalent' it is = 4.41 g/person-day.

Use of Biogas

Biogas from solid waste disposal landfills is generally a mixture of methane and CO_2 and has a relatively low calorific value compared to natural gas which is 95%+methane. Hence, it is not profitable to compress and bottle the biogas for retail purposes. Biogas is generally either piped and supplied to a nearby industry for use as a fuel for generating steam in their boilers or supplied to the public for domestic use or sent to a dual-fuel engine for producing electricity. The latter is sometimes avoided as it requires a technical skill beyond the scope of ordinary municipal workers.

Finally, when the disposal site is filled up, it must be 'closed' using acceptable procedures, and whatever biogas is still produced for some years should be collected and used, instead of allowing it to escape to the atmosphere.

Appendix 2(7) gives in detail the case of the Gorai solid waste dumpsite where a proper covering was provided after the dumpsite had been exhausted after several years of usage. The covering and reshaping cost the Mumbai municipality over ₹50 crores, while the 'carbon credit' earned by the municipality for avoiding emission of CO_2 to the atmosphere has been nearly ₹70 crores. What's more, the municipality can continue to earn money from sale of the bio-gas which is extracted from the covered site. The biogas would have otherwise gone to the atmosphere.

Appendix 2(8) gives an example from Okhla, New Delhi, where the solid waste is converted aerobically to useful compost (without generating CO_2) and sold to farmers in rural areas. This project was also funded by CDM under 'carbon credit'.

6.15 Bringing up Indian Villages

Last but not the least, we should talk about the villages of India where there is no scope for green buildings, nor major hotels or hospitals coming up nor any infrastructure to talk about. Is there anything we can do for them? India lives in villages. To bring up India, we must bring up its villages.

Earlier, environmental and social scientists suggested that for India to improve, its sanitation had to improve first. But, experience showed that sanitation improved very slowly in a milieu of poverty and neglect. The people needed more money to live before they could have a desire for social improvement. Today, we have a chance to review the situation and use our knowledge of new techniques to bring the village people out of their difficult situation by providing:

- Water
- Electricity, and
- Sanitation

all three together, so that people may come out of the poverty trap. How do we propose to do that ..... in a green way?

More Water in Villages

More water can be brought into the villages and small towns by rainwater harvesting and groundwater recharge so that their wells can give them water for longer duration in the year and they can cultivate two or more crops per year. Today, 60% of India depends on rain and reaps only one crop a year. With rainwater harvesting and groundwater recharge using locally erected check dams and shallow bunds their lives would change. Some NGOs have successfully undertaken such projects in the Thane and Raigad districts. Persons like Anna Hazare have changed the face of villages like Ralegaon Siddhi (80 km from Pune) because of more water having been made available by these methods. Dr Kirtibhai Vaidya has worked wonders in Gujarat's villages. More water has given the people more money.

Electricity in Villages

However, our observation is that money alone does not mean much if there is no electricity in the villages and no business except farming. Many villages lack electricity. Money only sharpens their attraction for migrating to the cities. Electricity is necessary to come to the village if migration is to be discouraged. With some initiative, education and business can follow. But, in today's world, electricity has to come from renewable sources such as wind or solar, NOT from fossil fuels such as oil or coal, since we do not want to add to carbon in the atmosphere and hasten climate change. Small solar photovoltaic (PV) panels now make it possible to provide solar lights (like TERIs, for example) so that the young people can study and read and educate themselves. They can also entertain themselves with TVs at the end of the day. Slowly, electricity begets small businesses and even small repair shops and simple industries to the villages and increases employment opportunities. In turn, this slows down attraction for migration to cities.

Sanitation Also Comes in Such a Setting

Sanitation also creeps along more assuredly in such an atmosphere, and health improvement follows gradually. Sanitary toilets and 'gobar gas' plants help with biogas for cooking. Womenfolk do not have to go into the fields for defaecation and for collecting wood for cooking. Many benefits flow from the simple provision of water, electricity and sanitation together in the villages.

Many Benefits

The world will be happy and the Indian people will benefit if we can encourage all three items, namely, rainwater harvesting for more water in the villages, electricity (through renewable sources) and better sanitation in India's villages and small towns. At present, the world is afraid that if we keep growing at 8% and 9% per year our electrical energy demand will grow equally rapidly and carbon emissions will increase rapidly. Already, India is the fourth largest emitter of carbon in the world today. We want India to grow, but not the emissions. We can do this if our new energy comes mainly from renewable sources along with water and sanitation in the country.

A Business Model

The important question is how do we bring in education and some business for the villagers? Most of the villagers cannot afford any capital investment and are dependent on government subsidies. The assistance has, however, to be decided on a case by case basis so that it is contextualised and meets local requirements. For example, the following may possibly be appropriate:

A business model is to be developed for serving villages shown in Fig. 6.4 through a cooperative services unit integrating renewable energy with village-based economy where the investment is

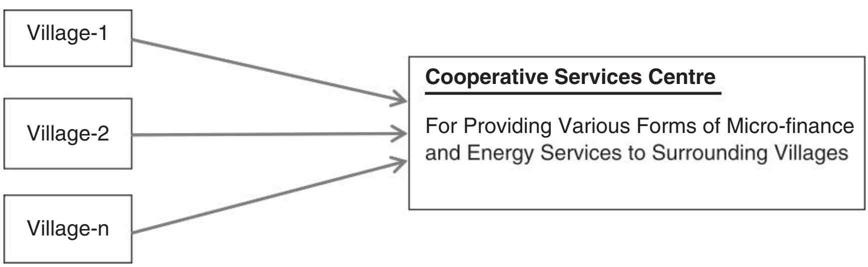


Figure 6.4 *A Cooperative Services Centre to serve a group of villages.*

made by a private business company for establishing a *'common services unit'* on a cooperative basis at a suitable location for producing and supplying to the surrounding villages their electricity, biogas, organic manure and other needs. The cooperative could also provide oil extraction facility for biofuel cultivated by the villagers and brought to it for oil extraction and, if found feasible, a cold storage facility for the farmers' perishable produce, so that the variety of agricultural activity may increase. The cooperative could also provide micro-finance to stimulate women's activities and telemedical facilities. A business model is thus to be developed.

This subject is further discussed in Chapter 8 from Section 8.5 onwards and in **Appendix 3(2).**

6.16 Green Services for Crematoria

Cremation in India is done either with wood or gas. When wood is burnt (as is often done), a considerable amount of deforestation occurs. It has been estimated that for this purpose worldwide, the wood comes from 50 to 60 million trees per year. Burning this much wood is estimated to release 8 million tonnes of CO_2 per year. One may not wish to count the CO_2 released from burning the wood since an equal amount of CO_2 had been consumed earlier in its growth. Cremation of a human body, however, is estimated to give 50 kg of CO_2 whether wood or gas is used.

If the average life span of an Indian is, say, 75 years, it implies an average death rate of $1/75 = 0.01333$ persons per year. India's population (for cremation purposes) being, say, 1.0 billion roughly, the average no. of persons dying per year = 1.0 billion $\times$ 0.01333 = 13.33 million persons per year, i.e., approximately 800,000 tons of CO_2 are produced per year, in addition to the carbon released from burning the wood. What an enormous quantity!

Burial is the other method of choice in some Indian communities where the dead organic matter is consumed by various organisms according to ecosystem principles. This method has also its detractors who say it is not a 'green' method since some land is consumed, methane is emitted and wood or steel is consumed in preparing the caskets.

A UK company suggests that the dead body be immersed in water containing potassium hydroxide to break it down (resomation). However, why pollute water (which is anyway getting scarce)? Some suggest cryomation in which the dead body is freeze-dried and powdered to give dust which may be sprayed on land as compost. The method is reported to need less electricity and give less emission*.

Fortunately, a young Indian is reported to have shown that biogas produced in a gobar gas plant using cow-dung (a renewable source) can be used, and 200 kg of precious wood (deforestation) can be saved per funeral. The gas is transferred to 11 kg cylinders via pumps at 130 degree pressure. It is hoped that deforestation will thus be avoided and a renewable source of energy be used.

6.17 Spreading Message to all Stakeholders

As carbon emission control is a relatively new subject, it is suggested to hold meetings, seminars, workshops, conferences, etc. to spread information on typical topics with various stakeholders such as the following:

Stakeholders	Typical Topics
General public, community organisations, public bodies	Lifestyle changes at personal and community levels
• Architects, engineers, builders consultants, plumbers, etc.	Green buildings and new area development projects
• Manufacturers, dealers, electric supply authority officials, public	Use of efficient appliances, timer switches, power-saving devices, BEE recommendations, etc.
• General	Renewable sources of energy
• General	Transport, biofuels and other alternate fuels, electric and hybrid cars, mass transport

(Continued)

*The originally adopted method of disposal of the dead (by feeding the dead bodies to vultures) is still being followed today by Parsi Zoroastrians, a miniscule community in Mumbai (to which the author belongs). It appears to be the least GHG emitting method though perhaps of doubtful acceptance by the general public, as it involves feeding the bodies to vultures, kites, etc. in open-at-the-top structures called 'towers of silence'. Hence, there is no production of CO_2. When the vulture dies, some other animal (or another vulture) eats it! No burning or cremation takes place at all. The problem in Mumbai is that vultures are scarce nowadays as the use of a chemical called diclofenac is said to have killed them off. Parsees are also increasingly taking to cremation or other methods.

Stakeholders	Typical Topics
Municipal and government staff, town engineers, consultants, etc.	Green infrastructure
Industry associations, engineers, cultivation of biofuels and oil	Green industries, consultants, etc.
Extraction and use at local level	Concerned villagers

Carbon Emissions Caused by Conferences

One may like to know, as a matter of interest, that a conference also has a carbon footprint of its own. First, emission is due to the consumption of electricity for lighting and air-conditioning of the auditorium. Second, emission is due to the paper and other materials handed out to the participants and, third, due to the food and drinks prepared for the occasion. These three major sources alone may give a total equivalent carbon emission of 1.0 – 2.0 tonnes per day per conference depending upon the number of people attending. Additionally, each participant causes some emission in transporting self to and fro the venue.

The environmental professionals and non-professionals already seem to know quite a lot about 'global warming' as a subject, but have not been very proactive in action so far. Perhaps, their hands are full with other matters. Perhaps, they are waiting for clearer/firmer signals from media and other sources. Perhaps, global warming and climate change are yet considered a distant fear, not a certainty. Yet, this is a subject whose time has already come.

There is an American saying that: 'If all you ever do is all you have ever done, then all you will ever get is all you ever got'. We have to re-invent ourselves, set new targets from time to time.

CHAPTER

7

Some High-tech Measures for Reducing Carbon Emissions

As the Minister, Mr Jairam Ramesh once said, our fate has often been something like the following: "Invented in UK; innovated in USA; manufactured in China; known all along in India—'India is slow'." High-tech measures are generally considered last because they are usually expensive and technologically advanced often needing some R&D work at the local level before implementation can be considered.

7.1 Use of Solar Power with Satellite-Based Systems

Large-sized plants for supplying electricity to urban areas are presently coming up in a few parts of the world (Spain, USA, etc.) to demonstrate various technologies. Experience has shown through the development of large-sized units called *solar concentrators* that it is possible to generate power on a large scale but there are a few problems yet involved in development of solar power for cities or large consumers.

While the efficiency of PV panels is only 10–15%, it is relatively higher at 24% for concentrated solar systems using parabolic mirrors and molten salts.

Also, from the experience of Spanish installations, large parabolic mirrors shaped as ultra-long troughs are needed to concentrate sunlight on to a long tube of molten salts that store heat. The heat energy is stored in molten salt (actually a mixture of two fertilisers, sodium nitrate and potassium nitrate). This heat is then used in a conventional thermal power plant to give electricity at about ₹4 per unit. It is hoped that, with further research and improvements in future, the *concentrated solar power (CSP)* system costs may become competitive with conventional power and larger-sized units could be developed. There are already signs that costs are sure to come down for both CSP and photovoltaic panels.

Land Problem

Remember solar energy is plentiful in nature but available on the earth in 'dilute' form. Hence, more land is needed (about 10,000 acres for 1,000 MW plant, the land alone costing around ₹100–200 crores). Cheaper land would be available in a place like the Rajasthan desert. Land availability may, however, become a problem in India as recent experience in Singur, West Bengal, has shown. Even though desert lands can be brought into use without affecting agriculture, often, even what is classified as wasteland by the government, is considered valuable by villagers who use the land for grazing, collecting minor timber and as transport corridors. Villagers have also at times spurned joint ventures with corporate bodies out of mistrust. Hence, land can become a serious problem in India.

Need for Water

Moreover, water is also needed to wash off dust from the solar mirrors. This water may be scarce in wasteland areas and need expensive reuse techniques to make it possible. Use of solar energy is thus not so simple a problem as it may seem. Another problem is how to store heat produced during the day for later use. The first commercial solar plant with heat storage opened in 2008 in Guadix, Spain, east of Granada. During the day the molten salts are heated, while in the evening it gives back heat to make more steam. A Spanish company is now building a plant in Arizona, USA, for Phoenix and Tucson which will generate 280 MW in 2012.

Germany and Spain have invested heavily in solar power. Germany has greater than 5 gigawatts capacity and is the largest producer of photovoltaic power. The electricity generated from solar energy (in 2006) in gigawatt-hours is reported to be: Germany 2220, US 565, South Africa 532, Spain 125, China 105, Australia 31, South Korea 31, Italy, Netherlands, Switzerland, 20–30 each, Canada 21, India 19, Mexico 10.

Satellite-based Solar Power Systems

A relatively high-tech method proposed is the satellite-based solar power system. In this system, it is proposed to capture solar energy at a satellite level so that it is available day and night (without storage in batteries and lock up of valuable land on earth) and then transmit it to the earth by microwave or some such other device.

The biggest advantage of such an arrangement is that no land is required at earth level. Normally, much land is required for solar power projects at usual earth level meant to serve large cities. As land acquisition can be a severe problem in most countries, the solar-satellite system can be a very useful answer there. However, some R&D work is needed before a full-scale project can be implemented. Let us hope that ISRO in India will take up the challenge and work on it.

The land problem is the most serious problem in India both for solar power and nuclear power development. In the case of solar power, the problem could perhaps be avoided to some extent by the recently planned development of *satellite-based solar power systems* under which solar collector panels would be placed in a geo-synchronous orbit in space (to benefit from 24-hour supply) and solar power beamed to earth in laser or other form for subsequent conversion to useful electricity. These technologies are not yet fully ready for commercial exploitation but are mentioned to show the lines on which thinking is going on.

A 24-hour supply and no land problem! This is where the future of solar power lies.

The Sahara CSP Project

A fantastic project is hopefully being conceived using the large and barren *Sahara desert* area in the north of Africa to develop a *concentrated solar power* device to generate enough electric power to meet the entire energy needs of Europe. The energy generated would also enable desalination of sea water needed for humidification to grow crops in greenhouses located in the Sahara Desert. It is an excellent example of synergy between CSP, seawater and greenhouses. Land is available, solar energy is available, generation of power is possible, but the conveyance and distribution of power from the desert to various European countries would pose enormous problems and involve large costs. Of course, no greenhouse gases would be produced.

In India, the deserts of Rajasthan and Thar might hopefully be developed one day on similar lines as the Sahara though several other areas are likely to be used first.

7.2 Use of Carbon Capture and Storage (Sequestration)

India has large coal deposits and, therefore, much power is produced from this source. It is estimated that even by 2030, one-third of India's power will be produced from coal which co-produces much CO_2. Hence, carbon capture and its storage (CCS) in deep geological formations is a possible way of reducing emissions. This is a relatively high-tech method and depends on the local geology of the area and several high-tech factors. The idea seems to have been taken from the successful underground storage provided for storing natural gas during non-peak hours in some US and European cities.

Nature does it effectively when photosynthesis converts atmospheric CO_2 into more trees and forests which eventually fall and get buried in the deep earth and turn into coal or oil after centuries of pressure and heat. This is nature's way of achieving carbon capture and sequestration.

Man tries to do it artificially by capturing the carbon dioxide gas directly at source, liquefying and pushing it underground into selected, deep geological formations for storage for hundreds of years, so that for all practical purposes it is out of circulation in the atmosphere. This is no easy matter and serious problems can arise in implementation and long-term storage. Otherwise, this would be a very comfortable way of 'having our cake and eating it too'!

According to Prof. Sally Benson, Global Climate and Energy Project, Stanford University, California, USA, only 4 relatively small projects are operative at present, two in Norway, one each in Canada and Algeria, handling around 1 tonne of CO_2 gas per year in each case. Evidently, technology is mature for a large-scale demonstration project with cost reduction in mind and development of confidence in its long-term storage.

Elements of a Carbon Capture and Sequestration Scheme (CCS)

A stepwise approach to the planning of a CCS scheme in any country would include the following elements:

- Capturing the CO_2 gas at source
- Compressing it to the required temperature, density and low volume
- Transporting it by pipe to the holding site
- Injecting it underground to the required depth and stratum, and
- Monitoring its performance with regard to regulatory requirements (leakage risks, etc.)

Capturing has been done so far at the post-combustion stage though in some cases separation of CO_2 at pre-combustion stage may be desirable. Anyway, the latter has not yet been demonstrated for power projects.

Storage basins in the form of deep, sedimentary basins have been found suitable for CO_2 storage. California is reputed to have natural ones with alternating layers of sandstone and shale. Options in geological storage generally include the following:

- Use of space released by depleted oil and gas reserves underground
- Use of CO_2 to increase oil and gas outputs from deposits
- Use of deep saline formations (offshore and onshore) for storage
- Use of CO_2 to improve coal-bed methane recovery.

CO_2 is generally injected over 0.8–1.0 km depth at which the volume of gas and its density are both suitable for injection.

Sequestration mechanisms could be either rocks with tiny pore spaces or the CO_2 could be sealed in by low-permeability rocks. Alternatively, the CO_2 may be sealed in by secondary trapping mechanisms such as capillary forces, conversion into solid minerals, adsorption on coal, etc.

Storage is reputed to be safe with over 99% recovery likely even after 1,000 years. Actual experience with CO_2 storage extends over 25+ years, and with natural gas over 100+ years.

Issues Involved in Planning CCS Projects

Several important issues are involved in planning and executing CCS-type projects which, to an environmental engineer, are reminiscent of the type of issues to be faced by those planning 'secure landfills' for hazardous wastes. Both ventures are full of risks and hazards worthy of the most strong-hearted risk-takers and risk insurers. The issues involved are, for example:

- Limited fundamental knowledge of storage and leakage mechanisms
- Limited experience in site characterisation and selection
- Storage engineering
- Safe operation of project
- Monitoring
- Remediation
- Regulatory oversight, and finally
- Financial responsibility

According to CII, the sequestration potential of India is around 572 giga tonnes of CO_2 distributed between various onshore and offshore formations. However, in view of our limited experience with this subject, contracts may be best awarded on 'build–operate–transfer' (BOT) basis to experienced contractors from abroad, valid for 25 or 30 years into the future.

Unfortunately, there are many aspects in which a CCS project could go wrong. The project could damage quality of groundwater or other natural resource, the safety of workers and the general public might be endangered, release to atmosphere could be another problem, and so on. A few issues have yet to be sorted out,

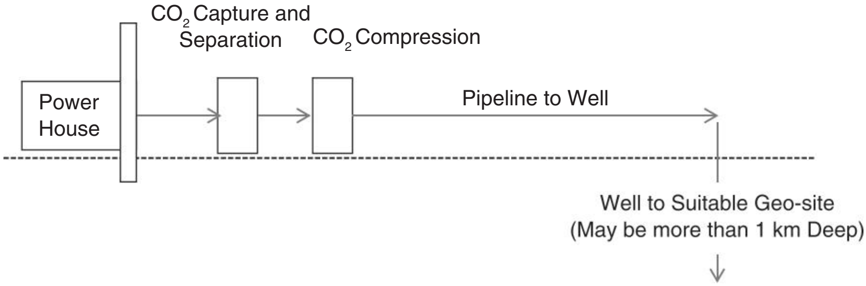


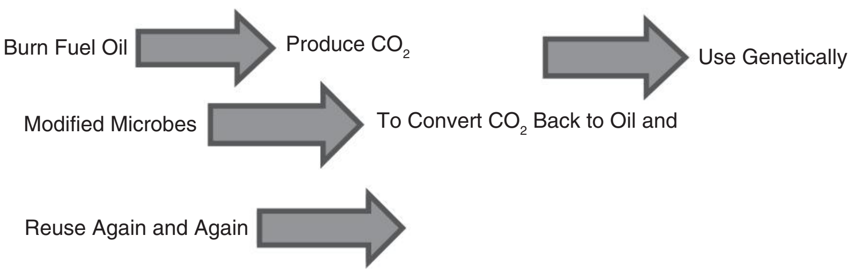
Figure 7.1 *A carbon capture and storage arrangement to reduce carbon emissions from a power-generating station.*

such as long-term liability, general public acceptance, etc., especially in developing countries who may not be ready as yet for such a high-tech method.

A typical layout has been indicated in Fig. 7.1. As stated earlier, large-scale demonstration projects are presently needed, besides practical methods of identification of likely sites from geological observations.

7.3 Genetic Modification of Microorganisms

Another relatively high-tech method is 'genetic modification' of microorganisms as suggested by Dr Craig Venter. Some are most happy with his suggestion to convert CO_2 in the atmosphere back to oil through use of genetically modified microbes which would be excellent if only possible on a global scale. We could then go back to oil and coal with added vigour and not suffer any global warming at all because a new equilibrium would be achieved between carbon sources and carbon sinks.



The proposal is excellent but much R&D work will be needed before a pilot project can be implemented. CO_2 in the atmosphere is in a dilute form. Its capture and concentration is the first problem to be solved. Genetic alteration of microbes is another problem. The third problem would be to put everything together.

Dr Craig Venter who was the first to suggest using genetically modified bacteria to convert CO_2 back to oil has gone ahead and created self-multiplying bacterial cells. The J Craig Venter Institute (JCVI) which is a not-for-profit genomic research organisation based in Rockville and San Diego synthesised the base pair chromosomes of a modified *Mycoplasma mycoides*, a parasite bacteria that live in cattle and goats. The research announced in May 2010 is said to have taken 15 years and cost US $30 million. The genome was designed in a computer, chemically made in the laboratory and transplanted into a recipient cell to produce a new self-replicating cell controlled only by the synthetic genome. Its genome was brought to life through chemical synthesis without using any pieces of natural DNA.

This research brings closer the production of petrol or oil from CO_2 in the air through bacterial activity: bacteria to live on CO_2,bacteria to make biofuels, bacteria to clean up toxic wastes, bacteria to clean up oil spills, etc.

A small British firm (Air Fuel Syndication) has claimed to have synthesised petrol without bacterial intervention, using just air (i.e., CO_2 from air) and electricity (possible from renewable sources). The company uses hydrogen and carbon dioxide to form methanol which in turn is passed through a gasoline fuel reactor creating petrol. No need for genetic modification. This study and the earlier one of Dr Craig Venter show that petrol and diesel will possibly become renewable fuels and be with us for a long time to come.

7.4 A Few Miscellaneous Measures

Various other developments are taking place, almost on a daily basis. Either new methods are being developed or new products are developed or newer applications are being demonstrated for existing products. Some of them have applications which will work wonders. All these must be explored and worked upon in the spirit of R&D. Besides the few methods indicated earlier, a few more instances are given in the following which have business potential:

Electric Vehicles

Among these developments, one must include the electric vehicle (EV) which will transform transportation technologies, and make carbon emissions from vehicles a thing of the past. Many countries are already doing much research in this field. The REVA car in India is well known. Both Tata Motors and Mahindras are now working on EVs. We have presented a diagram earlier in Chapter 4 to show how an EV can be recharged at night (in its own garage) using solar energy to generate the necessary electricity earlier on the building's terrace. It is no use if electricity is taken from the city's grid. Electricity must come at reasonable price from renewable sources. Tatas are also reported to be working on a car that is driven by compressed air.

Depleted Uranium and Thorium

An R&D item of intrigue is the present way of dealing with the uranium. Normally, uranium needs to be 'enriched' to develop power, and has to be enriched still further to make a bomb. What happens to the depleted uranium (some 92% of original) that is left behind? Can it be used to generate power? Or, is it a silly question? Another (silly?) question: Can thorium be used for power generation as it is available in India?

Bacteria that Thrive on Methane

Another example, Indian and UK scientists have found *bacteria that thrive on methane* in the Lonar Lake (an old crater) in Maharashtra, India. Methane bacteria have been found earlier in environments such as wetlands and paddy-fields, but the conditions there are not so extreme as in Lonar Lake which is hyper-alkaline and supersaline. These bacteria may be useful in generating methane as fuel or in breaking down methane.

Biodegradable Plastics

Biodegradable plastics have now been made from plants using organic catalysts instead of petroleum-based plastics made with metal oxide catalysts. They could solve the plastics waste problem.

New Biofuels

A crustacean called Gribble, a marine pest, which bores holes in wooden ships, could be used to make biofuels. Their enzymes can break down cellulose and turn it into energy-rich sugars which could be fermented into alcohol-based fuels and used.

Planes Powered by Renewables

A single-seater plane has been successfully test flown in Zurich, Switzerland, for a 24-hour, day and night flight, after it received its charge of solar energy during the day. A round the world trip is now being planned. Planes working on biofuels are also being developed and have been test-flown successfully.

Wind Power Assistance

A 160 sq m kite hoisted on Germany's largest fishing vessel will help it with its wind power to sail to South America with 30% saving in fuel.

7.5 A Quick SWOT Analysis

If we carry out a serious analysis of our strengths, weaknesses, opportunities and threats (SWOT analysis) we would find that we have a very good chance of success in spite of all our weaknesses and threats facing us:

- **Strengths:** Many good, young and educated people capable of doing a variety of things ranging from R&D to manufacturing, marketing, etc.
- **Weaknesses:** Local prejudices (caste, creed, colour)
- **Opportunities:** Plenty
- **Threats:** Slow starters. Poor funding and facilities

CHAPTER

8

Recommended Plan of Action

The world is afraid that our per capita emission rate, which is low at present, will not remain once we start growing at 8 and 9 percent per year. Around the world, development is always accompanied by an increase in emissions due to increase in demand for more energy, more transport and more land (which means more deforestation).

8.1 How Soon will India's National Action Plan Take Us to a Low-Carbon Path?

In Chapter 2, India's National Action Plan (NAP) as developed by the Ministry of Environment and Forests was given. The NAP was devised in the form of eight different 'missions' to cover the concerned topics and charged with certain objectives and targets to be achieved by certain dates. However, in retrospect, they seem to be more for the purpose of understanding the problem, generating awareness in the public, testing out a few possible remedies and developing the political will for taking more concerted action in future. While India's NAP is certainly good, it is not exactly an action plan, but a means to it. The eight missions will certainly be useful in sharpening our ideas and approaches for further action. But, the further action has to be spelt out more sharply and policies so formulated that people can follow up on them and we can all get on the desired low-carbon path soon.

In the author's opinion, the eight missions are not enough for reshaping the Indian economy to work on low-carbon pathways. This will need a more sharply conceived action plan which is more business-driven, less science-driven. We have to mobilise the media and business interests in order to go forward with speed. We have to have a more purposeful second stage with a thrust area clearly defined so that the people can support it strongly. Otherwise, reshaping will only remain a long-term ambition for the future. A clear framework for cooperation has to be developed in which business, government and civil society can all work together to put India on a low-carbon path in a reasonable amount of time.

In trying to approach the target by the best pathway, one has to keep in mind the following three aspects which in a way set the boundaries to our efforts:

1. We are a poor country
2. We have a tropical climate, and
3. We are a country full of very young people.

8.2 The Missions Help Develop Awareness and Political Will

There is no doubt that the eight missions established by the Government of India have been doing exploratory work in relatively unchartered areas and have been successfully developing awareness of the problem in the country. This is the first step in developing the much needed political will within the country.

Developing attitudes and approaches is a continuous effort, not a one time job. One popular method followed is to organise seminars and conferences along with relevant professional organisations to include all the stakeholders, and take the help of media to discuss the pros and cons. Another method is to use 'demonstration projects' like the ones detailed later under 'Some encouraging peeps into the future'. These projects are more expensive but they are tried out on real people to get honest reactions for future planning on a wider scale. Mid-term correction may be done as necessary. A third way is to use outside expertise (Indian and expatriate) to help develop suitable measures. This last method will probably be best for use by large cities to reduce their carbon footprint. From larger cities, the message will pass to smaller cities as well as to teaching and town-planning schools. Government policies will eventually be formulated and action taken accordingly.

In course of time, this will also lead to development of business opportunities. Once business and industry start coming in, there will be a rapid change in attitudes and approaches. Globalisation is progressing at a fast pace all over the world and the Indian economy is clearly entwined in it. Hence, it cannot escape feeling the momentum for controlling global warming and retarding climate change. India's policies are already beginning to reflect this condition. But, we want to hasten it up.

On the positive side, India's demographic status tells us that there is a very good chance of adopting new methods and hastening up because we have a high proportion of young people in our population mix. Our youth will perhaps find some sense in our desire to reduce carbon emissions. They will permanently reshape our economy in the low-carbon direction—and a new way of doing business will gradually come to be established.

As the level of awareness increases and people see the economic benefit of various measures and develop a vested interest in their continuance, gradually the whole Indian economy will begin to reshape towards a low-carbon-emitting, high-carbon-absorbing situation, and as more countries reduce their emissions, hopefully, the climate change threat will diminish. The advantage of reshaping the Indian economy is that even if global warming does not reduce, our country's economy and resource position will improve and our business opportunities will increase. It is not possible to say at this juncture how much time this will take – but, even if things go well, it will surely be a few years down the line.

8.3 Some Demonstration Projects of Various Countries

The following *peeps into the future* are encouraging as they show the reader that many people all over the world are today thinking of reducing global warming in the hope it will stem climate change, and a lot of new thinking is going on in this matter. Hopefully, this will make things happen faster in India than what we expect in normal course. With this purpose in mind, the following is presented:

Attempts are already being made in some countries to establish model cities, townships or areas where demonstration projects are being set up to demonstrate the working of various 'green' systems on a full-size scale so as to learn of their operating requirements and problems, if any. They become a way of assessing (and of affecting) public attitudes and approaches. Much R&D work will also arise from this effort. This shows the seriousness of the countries and will surely hasten the day when carbon emissions will decrease and the local economies will improve.

An Example from Thailand

In Thailand, a beautiful residential house, a so-called 'bio-solar home' (Soontorn 2005) that is designed to be self-sufficient in all respects has been built by an architect. The important difference is that it needs no municipal services such as water supply or electric supply or wastewater disposal or garbage disposal, etc., which is normally needed by city residents and, in fact, it is able to earn a small amount of money by selling surplus electricity through (feed-in) into the local electric grid.

The electricity is secured from solar panels mounted on the sloping roofs of the house. The drinking water supply is obtained by capturing the natural dew. Wastewater treatment is achieved by using 'natural' processes which need no electric power, while garbage disposal is done by composting. The compost and the treated wastewater are used to water a landscape garden around the house. Thus, the house needs no municipal services (except transport roadways) to exist.

Normally, 'green' buildings are not so totally independent of municipal services, but only minimise their dependence on them, as much as possible, especially for electric power and water supply.

A Model Low-carbon City in China

China is building its first model, environment-friendly low-carbon city in Turpan, a small town in Xinjiang province. Spread over 8.8 sq km, solar and wind energy will be used for lighting and hot water supply in the city. It will use geothermal resources for winter heating and summer cooling, as well as employing electric buses and taxis operated on solar batteries with zero pollution from public transport. The number of private cars will be reduced to the least number possible.

A Model Town in Abu Dhabi and Efforts in Kuwait

Abu Dhabi fears it will run out of oil in the next 50–60 years. It is, therefore, setting up a model ‘green’ town called, Masdar, with over 50,000 inhabitants, with zero emissions, as a prelude to a clean-energy economy. Coming from an oil-rich country, it is a sign of their forward-thinking preparing for the day when they will run out of oil in a few years.

Kuwait is another middle-east country which has set up solar PV panels and wind turbines in the desert to generate something upto 10% of its rapidly increasing electrical needs from renewable sources (solar + wind).

A ‘New’ New York

Interesting things are happening in the USA to curb their well-known high CO_2 emissions. As said earlier, some states in the USA are already placing curbs on their emissions. The USA is building its first ‘solar concentrator’ based on Spanish technology. As many as 430 million sq feet of office space has already been built in the USA as per LEEDS guidelines for green buildings. Another 24,000 projects are said to be in the pipeline.

The response from American architects about cities of the future is eye-opening. Next generation skyscrapers will not only save energy—they will generate their own! Wind turbines will help power skyscrapers of the future. Windows will be embedded with photovoltaic crystals to give electricity for the inmates. There will be rainwater harvesting and rooftop gardens. More greens will be created to which one could walk from residence or office. People will move closer to their work and play destinations. Hence, cities will grow; suburbs will shrink. Traffic patterns will improve; transport grids will be re-configured. Smart buildings will be built to control air-conditioning systems and building’s lighting to match the requirements of the season, thus needing minimum outside sources of energy. Their carbon footprints will indeed shrink.

A Town in Japan

Japan is reported to be setting up a hybrid town near Fukuoka where every house will have a hybrid car and the house itself will run on electricity generated by using hydrogen which works out cheaper than using usual fossil fuels. The fuel cell stacks required in such houses cost upward of US $13,000 each which makes subsidies essential at present.

Indian Examples

In India, one of the oldest good examples of town planning is the steel town of Jamshedpur, while another much later has been the Architect Corbusier's Chandigarh township. In modern times, the new habitation developments in Maharashtra of Aamby Valley and of Lavasa near Pune must be mentioned, especially for the excellent way they have handled rainwater harvesting and reuse of wastewater and solid wastes in their own campus.

Another example worthy of mention is from Gujarat where a solar photovoltaic panel-type arrangement has been set up recently (2012) to generate 600 MW of electricity. In fact, the Gujarat state has set up, since 2009, the first climate change department to address growing environmental concerns. Gujarat leads the country in solar power generation. It contributes two-third of the total 900 MW of solar power generated in the country. It also leads in reverse feed-in of electricity into city grids. More such installations are needed in India. Gujarat is also planning a new model city 'DOLERA' near Ahmedabad on green principles.

In India, the newly coming up 'special economic zones' (SEZs) could serve as ideal experimentation grounds for setting up all round 'green' developments, an amalgam of green buildings, green infrastructure, green transport, green industries and commerce, all set up within the designated area, so as to become a 'model' green area of the kind being set up in China and elsewhere.

Young imaginative Indians are getting into the renewables power business (solar, wind, hybrid, etc.). New firms have come up for undertaking such work. Young architects and builders are preferring to go for 'green buildings' and second generation green buildings which also generate their own power. Some examples are given in Appendices 3 and 4.

Young Indians wait for the day when, in many cities of India, transport problems are solved through mass transport systems and better town planning so that work and home are nearby; power problems are increasingly solved by solar- and wind-operated systems feeding-in into city grids; building bye-laws in dry climate states permit more underground construction to benefit from better ambient temperatures there; TERI-type lamps based on solar panels already light up a million villages; metals used in manufacture of cars and other products are replaced with materials made from bio-degradable and agro wastes, and so on.

8.4 Adaptive Measures Essential for Indian People to Cope with Climate Change

As a baby must take its first steps before walking, all countries must take their first steps with *'adaptive measures'* to adjust life to cope with expected climate change at the local level and then take *mitigative measures* to help the world arrest build-up of carbon. However, as time is short, the world expects us to take some 'mitigative measures' along with adaptive measures at the same time. Thus, we have to generate awareness, develop political will and find the money for both groups of measures at the same time.

Adaptive measures were discussed in Chapter 2. Since we may not be able to find the resources for everything at the same time, we would at least want to cover the absolute essentials such as the following:

- Monitoring systems for early warning
- Better communications in the likely to be affected areas
- Rapid response with first aid facilities.

It will be seen that all the three measures mentioned earlier have a business and employment potential, of course, in a good sense. Besides the commonly taken adaptive measures mentioned earlier, one has to cover three specific types of terrains as far as India is concerned:

- Coastal areas,
- Inland areas, and
- Himalayan areas.

Different measures have to be taken to suit each specific terrain. Also, there are substantial differences between the states. Some states are coastal, whereas some are fully inland. The measures, therefore, have to be state-specific and, need to be administered state-wise. These measures have been detailed earlier in Chapter 2.

8.5 Mitigative Measures and Poverty Alleviation—A Suggested Scheme for India

For a country like India, we cannot take mitigative measures alone. Mitigation alone would not be acceptable in India as it would seem out of tune with the needs of the people. As we have to participate with the world in undertaking some mitigation measures, the only sensible way we can spend on mitigative measures is to link them up with poverty alleviation. Mitigative measures must help poverty alleviation at the same time.

For a country like India, any programme for carbon mitigation has to go hand in hand with poverty alleviation. The people of India need poverty alleviation first while the world, no doubt, needs mitigation. The only way people can be sympathetic towards the required measures would be if we were to have both together. Such an effort would be in keeping with the needs of the country (reducing poverty), and would, hopefully, also meet the world's satisfaction as worthwhile measures for carbon abatement would be taken.

The mitigative-cum-poverty-alleviation measures suggested below should be taken. They can be easily fitted in with the work already accomplished so far by the 8 Missions. The measures are proposed to be grouped as shown below:

- **Low cost and easy measures:** Let us start by harvesting the 'easy and low-hanging fruit' first.
- **The principal or thrust programme:** ***'Improving the Indian Economy by uplifting its villages'.*** The highlight of our effort has to be to improve the Indian economy by uplifting its villages. Long ago, Mahatma Gandhi rightly said: 'India cannot prosper if rural India lags behind!'. He continued further

to say 'Rural electrification is the first step towards this'. His words have relevance even today.

- **The support programs:** The 'eight missions' already set up by the government are absolutely necessary to continue in future. They will have to develop the so-called support programmes. Under each program, a number of sub-programs are provided as shown in Fig. 8.2 as they all need a variety of support programmes.

8.6 Low Cost and Easy Measures

Briefly, common sense dictates that we start with the easiest items first. We can make a beginning with those items which do not cost much and will benefit both the country and the world. In other words, we can start by *'gathering the low-hanging fruit first',* early and voluntarily, to the extent possible, by undertaking the following four sub-programmes:

1. Make some lifestyle changes at personal and community levels
2. Use efficient instruments and appliances (as certified by BEE) to save on electricity
3. Promote 'green buildings' and 'green areas'
4. Conserve water resources.

Lifestyles are intimately associated with attitudes and approaches but as everyone knows lifestyle changes are often the most difficult to bring about. In India, changes occur slowly, but surely, at both the personal and community level. Changes at community level are easier to make than at personal level though changes at both levels occur gradually as the people and local bodies start cooperating.

Most of the changes occurring at the personal level are due to the peoples' general desire to cut electricity and other fuel costs, good old money-saving reasons. This is understandable, and happens the world over. The second reason is perhaps that half of India is of a young and impressionable age and willing to change old attitudes and approaches. Whatever the reason, some action is being achieved in the right direction, and that should be welcomed with open arms.

Technological changes are also taking place gradually at the community level, through education and spread of information. For example, people are changing over from incandescent bulbs to compact fluorescent lights (CFLs) and even to the more expensive LED ones, to save on electric bills. Mention may also be made of the 'Bijli Bachat Yojna' started in Maharashtra.

People are becoming more and more conscious of using efficient electrical gadgets such as those certified by the Bureau of Electrical Energy (BEE) so as to save on cost of electricity. Old, relatively inefficient gadgets are gradually getting replaced with new and more efficient ones, thus saving on electric power consumption.

Presently, after many years of deprivation, the Indian public is just beginning to enjoy a period of romance with individual means of transport by scooters and small cars. As soon as public transport becomes more comfortable and manageable, people will switch over from individual transport to mass transport. Education and information are, hopefully, preparing them for the change over.

Similarly, air travel in spite of its problems, is a luxury the Indian people are just beginning to find out in increasing numbers at present. Only a few are beginning to see beyond this stage. For instance, air travellers will soon see the advantages of its substitutes like 'video-conferencing' rather than air travel for certain purposes. Video-conferencing will no doubt increase in the future.

Architects and engineers are increasingly promoting 'green' buildings and green areas with the objective of saving on electric consumption, water, etc., and making life more comfortable for those who live therein. The people have tasted their benefits and want more of them. This means good business.

Similarly, water conservation and reuse have already made their mark on the public mind. We have now to build upon this 'low-hanging fruit' and give the people more of it. Giving free electricity to farmers for pumping groundwater (as is done in some states) is a populist measure which leads to overuse of resources (both electricity and water), and must be withdrawn. On the contrary, we have to augment our water resources by plain water conservation, by rainwater harvesting, groundwater recharge and reuse of wastewater. There are many successful examples already (mostly industry-based) that can be quoted.

This is the 'low-hanging fruit' to be plucked. It must be pointed out that each action will give us more business opportunities in its direction.

8.7 The Principal Thrust Area: To Improve the Indian Economy

This thought has already been discussed in Section 6.14 of Chapter 6. It is developed further here below. To improve the Indian economy and at the same time reduce carbon emissions, the following four thrust areas have to be taken up:

1. At village level, stimulate growth by providing electricity through renewables along with more water and sanitation
2. Also at village level, provide energy and micro-finance services through a community services centre
3. Promote afforestation and control deforestation
4. At urban level, augment electricity through feed-in from privately owned renewable energy sources.

No person or country can dispute India's desire to improve its own economy. In course of time, this thrust area will help kick-start other related areas. Fiscal policies and programs will also be developed by government in order to promote the selected thrust areas. For India, we feel that the best thrust area would be to uplift the country's economy by uplifting its villages. It will improve everything else gradually as momentum builds up. By starting with the villages and small towns, one is taking a wiser bottom-up approach. In India, climate change is not a hot political subject as in Europe or elsewhere, but a subject involving poor finances and an even poorer political will. A bottom-up approach is essential. Moreover, the four thrust areas will not add a single kilogram of carbon to the atmosphere.

If India is to prosper in future, it is obvious that many, many changes will be needed at various levels in urban and rural settings. Since much of India (nearly 70 percent) still lives in villages, the village economy will need a bigger boost, almost a complete change, in the years to come. A few things can be singled out for attention in this respect. They need to be provided as a package in order to optimise the benefits.

Let us look at these measures in greater detail, one by one.

1. At Village Level, Stimulate Growth by Providing Electricity Through Renewables Along with More Water and Sanitation

Electricity

India badly needs electricity at rural level. In the old day's environment, people talked about increasing water and sanitation in the rural areas. But, they were not very successful. The process was very slow. They gave importance to health and social uplift, but electricity was missing. So, there was little money coming in. Electricity helps bring education, industry, employment and business. This brings in money for improvement. Now, with electricity (from renewable sources), we can give them the whole package and bring in more money—which is more meaningful than before. Business and industry bring prosperity to the people.

Earlier we thought we could improve village level facilities by providing better sanitation. This did not work fast enough. Now, we wish to provide electricity, water and sanitation together in the hope they will bring education and small industry at the village level. People will have a better chance at development.

An example of electricity at the rural level is the development of portable solar PV lamps (such as those developed by TERI) for lighting up small villages and homes, shops, etc. These lamps have found a very enthusiastic response. Thousands of such lamps have been sold or gifted for use in villages. With these improvements, the local people will gradually find more small businesses, repair facilities, workshops and industries coming in. The people will also find more educational facilities available as light will make it possible to study at night. The family can also benefit from solar lamps if they are capable of recharging mobile phones and supporting TV for family entertainment in evenings. The solar lamps will also no doubt reduce kerosene usage in the villages. This will change the village economy for the better, and this in turn will also change the whole country's economy for the better. This is our strategy.

Water

The second important requirement for rural upliftment is greater availability of water for various domestic, agricultural and forestry uses by the local people. Rainwater harvesting is a wide subject as the technique depends mainly on the type of soil and geology of the area. The objective is to prevent rainwater run-off from gushing down rivers and water courses to the nearest sea, but rather to make it enter the ground and become groundwater which gets naturally filtered (and purified) in passage through the soil and protected from undue loss by evaporation. Rainwater harvesting also involves the construction of dykes (often using local materials and labour) to block the passage of surface water flowing along water courses and rivulets, and force it to go underground.

This helps increase water levels in wells and raises the water table which makes water available for a longer period in the wells. Often, this makes it possible to cultivate two or more crops in a year instead of just one crop during the rainy season. Agricultural income increases and lifestyle changes begin to occur. Education becomes more affordable and employment opportunities increase. More water should also help maintain more agriculture and forests too.

Sanitation

A third important factor in achieving rural upliftment is to improve the presently used unsanitary excreta disposal systems. In most villages there are no systems at all. People defecate outdoors in agricultural fields. This is difficult for women folk, especially at night and in rainy weather. Hookworm and other infections are rampant. Womenfolk often go into nearby forests for two reasons: it is quieter and they can bring back twigs and sticks for lighting fires in their houses for cooking. This leads to unwanted deforestation and the womenfolk have to walk long distances and use much of their time in this daily chore.

The provision of toilets draining into a gobar gas plant (which is based partly on cowdung from their cattle and partly on their own excreta) greatly improves sanitation and consequently their health. It also gives the womenfolk more time to attend to their families, and the biogas produced improves their household air pollution situation and smoky cooking conditions. Government subsidies are often available for setting up gobar gas installations as they understand the value of such interventions.

Thus, we see that the provision of electricity using a renewable source of energy along with greater availability of water along with improved sanitation and better health has so many advantages and benefits for the country as a whole that it cannot be neglected any more.

Agriculture supports over 600 million people in the country. Sixty percent of India is dry and rain-fed. As more water becomes available with rainwater harvesting and groundwater recharge, the villagers will be able to grow two or more crops instead of one crop per year, and earn more money. This will improve their economy and together with better availability of electricity (through alternative sources of renewable energy at local level) it should gradually change their village economy and lifestyle as well as generate better opportunities for education and employment. Even today, agriculture provides 21% of the country's GDP and accounts for 11% of exports.

The womenfolk will also find a better medium to cook with (biogas) instead of using as fuel the twigs and sticks gathered by them during their outdoor ablution visits every day. Incidental deforestation will stop.

Electricity, water supply and sanitation will all be improved at the village level without adding a single kilogram of CO_2 *to the atmosphere. The fact that we have little oil and most of our requirement has to be imported is a strong incentive for preferring renewable energy to meet our additional needs.*

2. Also at Village Level, Provide Energy and Micro-Finance Services Through a Community Services Centre

The important question is how do we bring in education and some business for the villagers? Most of the villagers cannot afford any capital investment and are dependent on government subsidies. The type of assistance has, however, to be decided on a case-by-case basis so that it is contextualised and meets local requirements. For example, to recapitulate from Section 6.14, the following may possibly be appropriate in some cases:

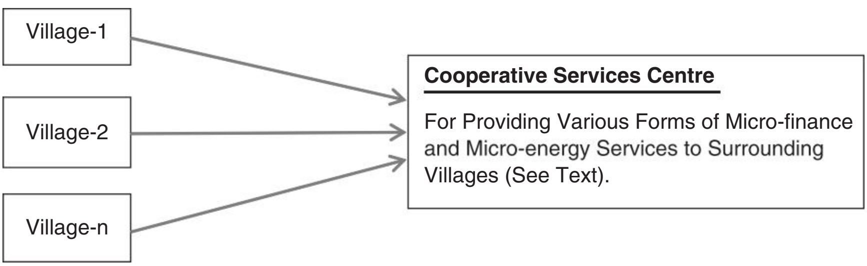


Figure 8.1 *A Cooperative Services Centre to serve a group of villages.*

A Cooperative Services Centre (CSC)

A business model is to be developed for serving villages as shown in Fig. 8.1 through a cooperative services centre (CSC) integrating renewable energy with village-based economy. The initial investment may be made by a private business company for establishing the '*common services unit*' on a cooperative basis, if desired, at a suitable location for producing and supplying to the surrounding villages their

1. Electricity (from a renewable source operated by the CSC)
2. Biogas and manure (from a community-based gobar gas plant operated by the CSC)
3. Oil extraction facility for biofuel cultivated by the villagers and brought to it for oil extraction (operated by the CSC)
4. A cold storage facility (if found feasible) for the farmers' perishable produce, so that the variety of agricultural produce available may increase.

The cooperative (CSC) could also provide the following:

- Micro-finance to stimulate women's activities, sewing, etc.
- A solar PV operated bank ATM and a solar PV operated school for children could also be set up—See **Appendix 2(9)**
- Along with portable solar PV lights used in un-electrified villages in India (TERI-lamps and the like) one could make them capable of also operating a radio, a small TV and mobile phone chargers—**Appendix 2(10)**
- A tele-medicine facility to be able to contact doctors of a selected hospital to advise patients through a tele-facility.
- Mahatma Gandhi depended on his famous 'Charkha-wheel' to stir up the Indian village. We have a much wider based 'CSC' to activate the villages. A business model has to be developed around the CSC. Also see **Appendix 3(2).**

Cultivation of oil-bearing plants is also included as one of our thrust programmes in order to produce bio-fuels which can be used as additives or substitutes for petrol and diesel in automobiles, tractors, water-pumps, etc., at the village and small town level. Cultivation is mainly expected to develop agriculture in rural areas where land would be available and villagers can benefit. Oil extraction from the plants can be done in the various small towns to which the surrounding villages would take their plants for oil extraction. This would in turn increase employment opportunities. The country would benefit from reduced demand on imported petroleum products, Water for cultivation would come through rainwater harvesting and ground water recharge, namely from shallow wells. For it to be successful, the whole operation has to be planned from cultivation to marketing. Employment opportunities would increase at all levels.

Development of biofuels has been promoted by government-led oil and petrol companies in India for blending with petrol and as diesel substitutes for diesel cars, trucks and tractors. The use of biofuels would also greatly help India reduce its foreign exchange spending on fossil fuels as the price of oil increases all the time. Their growth is, however, uncertain as it is feared it might adversely affect food growth in a populous country like India which needs a lot of land for food cultivation too.

Jetropha has the advantage that it can grow on wasteland (not useful for food cultivation) and with wastewater instead of fresh water. Assuming Jetropha is the biofuel of choice, it should be possible to set up Jetropha farms wherever water or wastewater is available in required quantity. It has come to notice that insufficient use of water leads to growth of a seedless variety. Hence, adequate amount of water is essential. Sugarcane based biofuels can also be cultivated.

Another thing necessary for success is oil quality control before it reaches the fuel outlets for use. Biofuels will have a ready market for use in tractors and water pumps in rural areas themselves first. Much greater use of biofuels will really be promoted when it becomes available at every petrol pump in the country. Airlines in other parts of the world are experimentally flying on biofuels as substitutes for aviation turbine fuels. This has happily proved to be successful so far and is expected to increase demand on biofuels.

3. Promote Afforestation and Control Deforestation

As India is a tropical country, promotion of new forests to serve as 'dedicated forests' would have a likelihood of coming up with funding under the international CER Program of Kyoto Protocol. As a result of greater water availability, forests can be cultivated and retained as 'dedicated forests' to serve as carbon 'sinks' thus reducing the carbon concentration in the atmosphere. India being a warm climate country is perfectly well placed to develop new dedicated forests and other plantations to absorb CO_2 through photosynthesis. This is needed to supplement the effort to reduce CO_2 at source since no country can control all its emissions completely at source.

As stated earlier, there is some thought that the criteria used internationally for determining the certified emission reductions (CERs) under the Kyoto Protocol are based on the amount of carbon dioxide absorbed by a tree in its lifetime in *temperate* climates. In the tropics, a tree would be able to absorb relatively more carbon as it grows faster. Some studies are needed at the field level to determine the absorption criterion for tropical climates so that the payment basis may be revised if necessary under the Kyoto Protocol.

Existing forests are sometimes demolished in order to create new land for agriculture or habitation or for mining. This has to be discouraged since it not only demolishes an existing asset (which could have continued absorbing carbon through photosynthesis) but also generates more carbon through burning of the trees cut down for clearing the old forest area.

The REDD program (Reduced Emissions from Deforestation and Degradation) under the UN is an international program for the earlier mentioned purpose. A similar program could be applied at the national level, funded by the country as suggested earlier. Where deforestation is the problem rather than forestation, it is hoped that the REDD programme will bring in additional funds for reducing deforestation at the country or local level. It is felt by some that both CER and REDD programs could also be developed at the *national* level in which the criteria used in evaluating the same could be made less strict so as to encourage greater number of awards at the national level.

4. At Urban Level, Augment Electricity Through Feed-in from Privately Owned Renewable Energy Sources

As we know, India will need a lot more electrical energy at the *urban* level too for development to occur. As India wishes to develop rapidly and at the same time reduce carbon emissions, all forms of renewable energy will have to be encouraged as far as possible (wind, solar, hybrid, biofuels, waste, etc.) along with systems based on fossil fuels. An example of purposeful policy is the availability of government subsidies for wind, solar and hybrid systems installed in India. Such subsidies have so far encouraged installation of renewables where the existing supply is either erratic or unavailable.

India is the proud home of one of the largest Indian wind turbine supply companies operating internationally (SUZLON). They have the know-how and undertake large-sized installations internationally.

In India, a unique event which happened in June 2010 points towards the future in a favourable way. Local villagers of Alibagh village (near Mumbai) offered resistance to the establishment of a new coal-fired electric power station there. The local people wanted a renewable source of energy.

A good example of the use of government policy to achieve this objective at the *urban* level can be given from India where electric supply companies and Boards are presently required to have at least 5–7% of their energy from renewable sources. This is expected to encourage solar PV panel installations (hopefully through private sources of funding) at suitable sites in cities to generate electricity and 'feed-in' into their existing electrical grids at favourable, government designated rates, to make the whole operation attractive. The percentage requirement is likely to increase as time goes. (In Germany today, it is 15%.)

This appears to be one of the best ways of attracting private capital for augmenting electric supply in urban areas which may be facing shortage of electricity (as many cities in India do at present for want of funds). However, it is important for the government to fix the tariff rates adequately and on long-term basis to provide stability to investors so that they are sure of recouping their investment in due time. The price of PV solar panels is reducing rapidly and the cost of producing electricity from solar energy is reaching grid parity which is a sure sign of public interest as one more investment avenue.

In Gujarat, already private parties are willing to invest money on setting up solar energy plants at their own cost provided the building owner will only rent out his/her terrace on long-term basis. Investing in solar energy feed-in systems should become as attractive as investing in mutual funds or government bonds.

It is interesting to note that India has just established its first University level, post-graduate programme to promote better energy management (of oil, solar, wind, hybrid, biomass, natural gas and nuclear energy, etc.) leading to a degree in 'energy management' at the Institute of Energy Management and Research, Gurgaon, near New Delhi. As we said earlier, the days of fossil fuels are numbered. The future belongs to renewable sources of energy. The problem is how to ensure that more of 'green' technologies reach us soon.

Appendix 2(4) gives an example of a building in Pune which generates its own electricity by use of a solar and wind energy (hybrid) system for its tenants.

Appendix 2(5) gives an example of a government building in Gandhigram, Gujarat, built recently with 100% solar energy available for its daily operations, and for feeding-in the surplus electricity to the town grid.

The other way in which solar power can come to urban areas is through the installation of more efficient solar systems for urban areas such as the 'concentrated solar power'(CSP) system being set up in Rajasthan. Such systems have already been set up in Spain, USA, etc., and may involve some foreign expertise—but, it would be only a matter of time that Indian knowhow would be built up. The same would be the case with satellite-based solar power systems in which India has a fair chance of building up the necessary expertise soon, if it wants to.

8.8 Use of 'Missions' to Develop Needed Support Programs

In order to implement smoothly the main thrust program, it is necessary to adopt certain support programs so as to do the right thing at the right time, expedite the whole effort and keep costs down. The eight missions set up by the Government of India have been active since a long time and have begun to develop expertise in their assigned areas. This expert knowledge must be put to use with respect to the main thrust programmes to be undertaken now. Experience will show if any modifications are necessary.

The terms of reference and funds allocated to the missions may need to be reviewed and redrafted in order to enable each mission to participate effectively in the main thrust programme. The plan of action outlined in Fig. 8.2 may need some amendments based on the findings of the various missions from time to time.

The support programs considered essential at the present time are the following:

1. Facilitate land and water availability
2. Facilitate business interests to come in and lead the way forward through
   - (i) Public–private partnerships and media
   - (ii) Stable fiscal and other governmental policies
   - (iii) Innovation, R&D
3. Emphasise sustainability.

The need for additional support programs may become apparent as time goes.

1. Facilitate Land and Water Availability

Land for new development has always remained a serious problem in countries like India. Large chunks of land are required contiguous to each other for development of solar energy, nuclear energy, large hydro-projects, wind farms, dedicated forests and the like. Much of such land is in the hands of farmers and tribals or is public forest land.

Land is also required for the cultivation of oil-bearing plants, extraction and marketing of bio-fuels. As land availability is likely to become a serious bottleneck in the development of low-carbon technologies, its facilitation should be considered from now on. The original Land Acquisition Act of 1894 is not much helpful in today's changed circumstances.

Tribals have always feared land development. Tribals are said to live mainly on three items: the forests, the river and the land, each for four months of the year. They never have a problem because when the output of one is low, the others make up for it. They have enough for themselves between these three resources. For them, development only means exploitation, making them employees and ultimately perishing them. In 1995 the Bhuria Commission in India suggested that for industries in tribal areas, 50% of the ownership must remain with the community, 20% with the landowner and 30% with the investor. Some such formulae have to be worked out from region to region.

Similarly, farmers have also feared development and land acquisition by governmental authorities. Interestingly, politicians have stepped in to fight on their behalf (and have often made matters worse). Magarpatta area, near Pune city, is a good example of how the reluctance of farmers for development was overcome by an arrangement in which ownership continued to remain with them while they formed a 'cooperative' and leased out the land to a group of software companies on long lease. The ownership of the land thus remained with the farmers and a new business could come up on the land. These are examples to show how things have changed.

Water availability, like land, is likely to become another serious bottleneck as population and development increase. Some measures in this direction are needed. Water conservation is an important part of the use of water. The extent to which water conservation is practiced is, however, a matter of government policy and water pricing. One of the best ways of water conservation is to reuse wastewater for irrigation of crops or reuse for various purposes after treatment.

The fresh water resources of a country consist of both surface and ground waters. Both need careful usage. Rising sea levels owing to global warming cause greater ingress of sea water and tend to decrease the usable ground water resources in the coastal areas by turning them brackish. This decreases an important asset. Policies have to be reviewed to encourage conservation.

Desalination of sea water is possible to augment fresh water resource where the sea is nearby and electric power is available and the high cost of desalination is affordable. However, it would be ideal if its power requirement can be met from renewable energy sources, and not through greater use of fossil fuels.

2. Facilitate Business Interests to Come In

It is suggested that business interests should be facilitated to come into this great enterprise and lead the way forward to a low-carbon pathway. It is too big a task for government to do alone. Besides, the beneficiaries of success would be both government and the people. So, both should march in step.

Public–Private Partnerships

Mr Stuart Frazer, Chairman of Policy in the City of London, states, ultimately it is too big a challenge for governments alone. Like other global economies, India's path to future growth and a low-carbon economy will require the active involvement of business and financial investments along with government. It is only by harnessing private sector capital and unleashing the power of the markets to boost investment in green technologies and pollution-reducing projects that the challenges of climate change can be met. For example, India aims to increase its share of grid-connected renewable energy to 10% by 2012. It plans 20 GW of solar power generation by 2022. For undertaking a massive effort as envisaged here, public–private partnerships are necessary to develop.

Media will be a major player in this matter too. Its role will be continuous, not only necessary initially but needed throughout. Media will help to reach all the different players affecting climate change. Not only media, but educational and scientific bodies, professional organisations, industrial associations, NGOs and various other opinion makers will have to be made key partners in organising conferences and seminars on selected topics. People's views have to be treated as valuable and allowed to reflect in the planning and execution of such momentous efforts.

Government's Fiscal and Other Policies

It is evident that government's fiscal and other policies have to be aligned with the thrust program so that they support the country's chosen priorities. Fiscal policies would include a fresh look at subsidies and items available free of cost (such as electricity given free to farmers in certain states for pumping ground water). As much politics is involved with this aspect, the reader is requested to draw his/her own conclusions. It is requested that subsidies be so given as to make the country free from imports in due course of time. On that basis, for example, subsidies should be earmarked more for encouraging renewable sources of energy and R&D work rather than for merely continuing to import traditional fossil fuels.

The policies must also reflect stability in approach without which business and private capital would hesitate to enter.

Promoting Innovation and R&D Work

Good R&D work is possible to do in India. The facilities exist. The manpower exists. The brain power exists. Perhaps what is needed is a sharper focus on the topics of research from the viewpoint of carbon control and climate change.

A typical programme for R&D work can be drawn up from the broad spectrum of topics discussed in Chapters 4–7. Organisations such as TERI, NEERI, CSIR, ARI, ISRO, etc. and many others already have the required expertise and can be consulted. Universities and IITs are also available. Different states of India will, no doubt, have different priorities, as will different countries of the world. An enormous scope arises for R&D work out of the demonstration projects now being set up in different countries (see examples given earlier).

Some work will also be entailed in implementing various improved forms of renewable energy systems for power generation and transport (such as energy generation from sea waves, highly recommended for India with its long coastline).

3. Emphasise Sustainability

The reader is referred to Fig. 8.2 showing the 'carbon-neutral wheel' in which the first three steps show the way to achieve a low-carbon pathway through use of 'cleaner technologies'. The next three steps in the wheel comprise 'social engineering' which is an essential requirement in order to ensure *sustainability* of the just-mentioned approach as explained in the following.

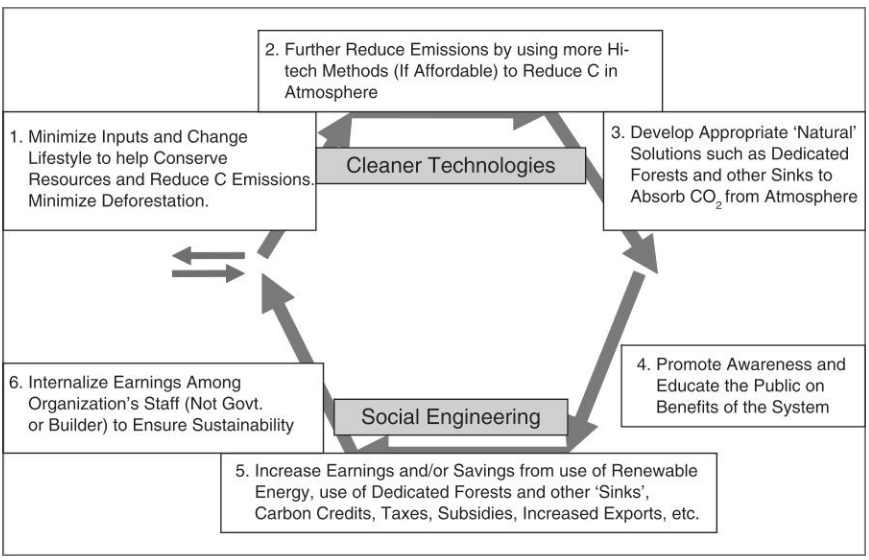


Figure 8.2 *The carbon-neutral wheel.*

The fourth step proposed in the diagram is to promote awareness and education to tell the people that a low-carbon approach is good for them. But, merely knowing that a certain thing is good for one's country does not mean that it will be done. Everything needs motivation. *The author has learnt from his past experiences in controlling pollution from wastewater that motivation is important and motivation comes if some money is earned from the activity by the people concerned, otherwise not! It now looks obvious.*

The people who operate the plant must earn some money from its activities such as sale of renewable energy, use of dedicated forests for absorption of CO_2, levy of taxes, grant of subsidies, realisation of carbon credits, increased generation of exports and expertise. The benefit must be passed on to the people involved (not just the government or municipality) to ensure sustainability and continued public support. The new funds generated by the various earlier-mentioned types of measures must lead to better benefits for the concerned people in the organisation. Only then, sustainability is achieved. Of course, cleaner technologies are essential, but they are not enough by themselves.

8.9 Advantages of the Proposed Plan of Action

The proposed plan of action shown in Fig. 8.3 has many advantages. It does not disturb its eight missions already set up under the MoEF. It merely suggests a sharper focus on certain activities which become the thrust areas. The low-cost and easy measures are identified and taken first. The thrust programme seriously concentrates on improving the Indian economy by uplifting the villages through four clearly defined ways. All the support programmes are handled by the original eight missions and so previous experience is not wasted.

As new electricity needs are met by developing *renewable* sources of energy at the rural level and through a mix of green and conventional sources at the urban levels, carbon dioxide emissions will not be increased much. This is where the greatest effort has to be made. At the same time, the world will see that India is undertaking some serious mitigative efforts.

Biofuel cultivation, extraction and marketing efforts will reduce to some extent our dependence on oil and coal and our out go of foreign exchange. However, India being a developing country, its electric power position has to improve rapidly. India will always

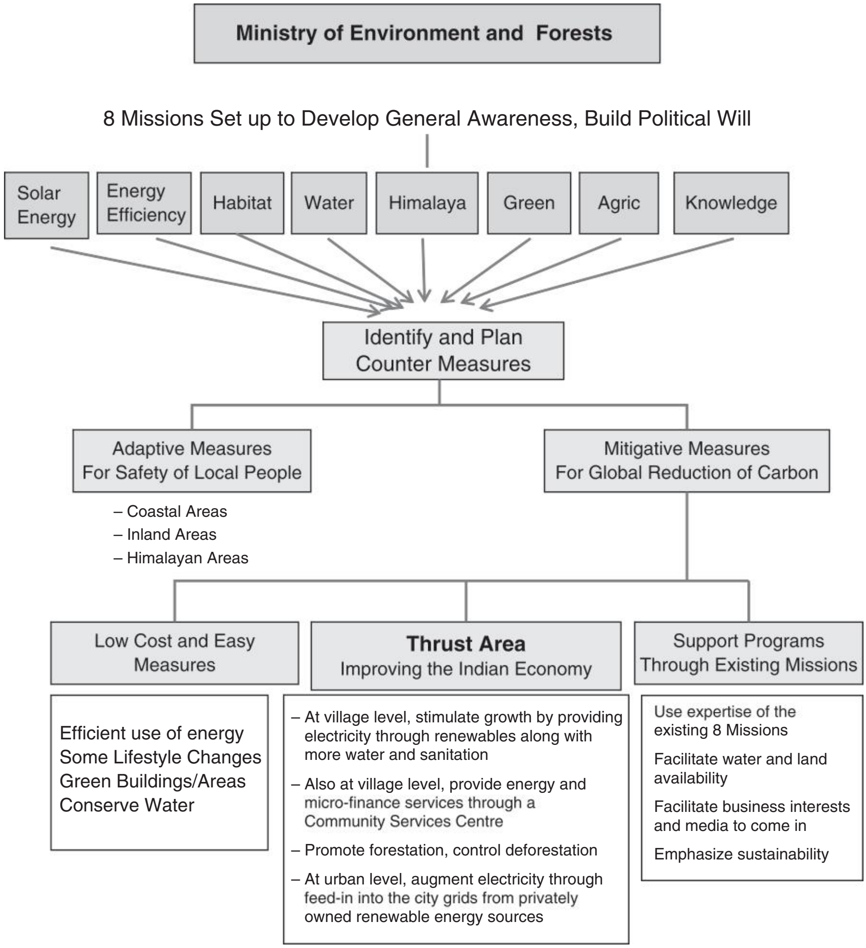


Figure 8.3 *Outline of proposed plan of action.*

need a mix of renewable (green) power and conventional power. The country's economy will be brought up by the new activities and new employment opportunities created by both.

The Benefits of an Improved Economy Through GREEN Technologies

Development of more business and more employment opportunities will be the most obvious beneficial result of our deployment of green technologies. it may be recapitulated that in a generic sense, GREEN signifies the following:

'GROWTH with RESOURCES, ENVIRONMENT ENHANCEMENT and NATURE'.

Green technologies will benefit the manufacturers, the marketers, the shopkeepers, the contractors, the various professionals, the scientists, the managers, and all the people in general. Improving the economy tends to give a fillip to a whole lot of other activities and brings all round prosperity for the country. Some of the related benefits are listed as follows:

1. Business potential is developed at various levels (international, country, state and regional, down to the village level).
2. Wider employment opportunities occur at all levels.
3. Expertise in various renewable energy methods is developed.
4. Biofuels cultivation and marketing (without damaging food production) at local level will be a challenge worth facing. Biofuel cultivation will aid the village farmer too.
5. Development of better educational facilities at village and small town level (schooling) will improve India's future.
6. Expertise in multi-cropping and general agriculture will benefit the farmers and the country and improve the general standard of living.
7. Expertise in rainwater harvesting and groundwater recharge will help the Indian farming community to earn more, and the Indian economy to do better all round. The extra income earned by the people will stimulate the economy.
8. Setting up more dedicated forests under local equivalent of certified emission reductions (CERs) scheme will give the world more 'sinks'.
9. Preventing deforestation and land degradation (under local equivalent of REDD scheme) will add great support to the UN's international effort.
10. All round there will be reduced attraction for migration to cities.

Besides this, the 'carbon-neutral wheel' (Fig. 8.2) lays emphasis on the social engineering steps as they are important to build in sustainability. People must first be motivated through build-up of awareness, but should ultimately benefit monetarily to ensure sustainability and support.

Moreover, such an arrangement would act as a welcome incentive for using land to grow more trees and forests and induce the people to exercise greater vigilance against deforestation. It would also promote conservation of water (and reuse of wastewater) as well as promote rainwater harvesting followed by groundwater recharge since water would be in greater demand than ever before.

Decarbonising the Old Energy System

We have to 'decarbonise' the old energy system. There is money to be earned in doing so, if we do it right. Technology is leapfrogging and time flies. The world in 2050 will look very different. Some of us will still be alive then. However, with the countries bickering, nothing like a major break-through might occur by the time climate change already sets in and may even become irreversible.

We must, therefore, hasten with our *adaptive* measures first to be able to survive the climate changes and sea level rise that will surely occur by then. There is no way out, although it will cost a lot of money to each country.

We will also have to bear the cost of some *mitigative* measures which we will have to take along with the rest of the world to reduce carbon emissions at source. To give a focus to our activities and make then worthwhile for Indian conditions, we have selected *'improving the Indian economy'* mainly through 'village uplift' as our special target because India still lives in its villages.

Our choice, however, comes with a little twist. The twist is that: We would like all our new electrical power requirement to be gradually met from *renewable* energy sources as far as possible. More power, more water and more sanitation will meet the practical needs of Indian villages and we will also be credited for doing something for reducing world emissions. The fact that we have little oil and most of our requirement has to be imported is a strong incentive for preferring renewable energy to meet our additional needs. The world is worried that our per capita CO_2 emissions which are today low will not remain so once India continues developing at 8 or 9 percent per year. This fear will be assuaged by our proposed policy—while at the same time the country will also start to do better.

We will learn much about different forms of renewable energy in the coming decades. It can be said that in spite of having green buildings and green infrastructure, we will have to tap solar energy perhaps for our cities on a 24 × 7 basis by using satellites, and also whatever other forms of renewable energy we can develop by then such as wind, geothermal or wave energy. Wave energy seems to have an edge over other methods for India. Water and land will be our bottlenecks. A lot of R&D work will have to be done, and done quickly, by all to make things happen.

Another item we will have to concentrate on is developing our forests and our other 'sinks' worthy of our tropical climate. Our payment basis seems to need upward revision because of our warmer climate as carbon fixation through photosynthesis happens faster in the tropics. Some feel this aspect will have to be given greater importance, immediately. Incidentally, it will also generate more interest in forestry and deforestation.

Finally, as we said at the start, even if global warming is an uncertain and distant phenomenon, it is good economics to minimise carbon released to the atmosphere because it saves both money and resources. Finally,

The author would like to say what the South Americans would say to express good wishes to somebody: In Spanish they would say 'Salud, Pesetas y Amor y tiempo para guzarlos'. In India, its equivalent would be: 'Good health, Paisa and Love. And the time to enjoy it all'

One might ask: 'What else would you want?'

APPENDIX

1

Emission Factors and Examples to Show How They are Used

In this Appendix, the emission factors commonly used in estimating carbon emissions are given. They are grouped under the following categories to make it easier for the reader to use:

- Fossil fuels and a few others (coal, oil, LPG, kerosene, wood)
- Electricity usage
- Transport sector (scooters, cars, trucks, petrol/diesel, aircraft fuel)
- Industries, commerce and services
- Agriculture and forestry
- Livestock and animals
- Land use
- Community wastes
- Miscellaneous

The emission factors have been extracted from various sources. Some from well-known, stoichiometric and mathematical considerations, some from reports of studies carried out by organisations such as NEERI, Nagpur, and the Automotive Research Association of India, and some from reports and books. In some cases, the default values recommended by the Inter-Governmental Panel on Climate Change (IPCC) have been given. Where the values have been merged or averaged from multiple different sources, no credit to any single source has been given in order to avoid any misstatements.

Another clarification: Emission factors have all been stated as a range of values because the composition of coal, oil and gas all vary somewhat with the source. Carbon must also be distinguished from carbon dioxide. Mol wt of C = 12 whereas Mol wt of CO_2 = 12 + 32 = 44. Thus, CO_2 is 3.666 times heavier than carbon alone.

1. Fossil Fuels and a Few Others (Coal, Oil, LPG, Kerosene, Wood)

Adequate fuel deposits are essential for the development of any country. India has large coal deposits (90,085 million tonnes, 8% of the total world reserves) adequate to sustain a GDP growth of 7% or more per year. Black coal currently provides about 63% of the country's energy requirements. No wonders, the 11th and 12th Five Year Plans count on coal as the principal fuel of India. The methane (CH_4) emissions from coal mining are somewhat complicated by many specialised factors and features of the mining and transport activity.

- Burning *coal* gives 2.00–2.46 kg of CO_2 per kg of coal burnt (depending on type of coal)
- Burning *diesel* oil to generate steam and, hence, electricity gives 2.63–2.97 kg of CO_2 per kg of diesel oil burnt
- Burning 1 kg of kerosene gives 2.518 kg of CO_2
- Burning 1 kg of LPG gas gives 0.15–0.19 kg of CO_2
- Burning 1 kg of wood gives approximately 0.17 kg of CO_2 + some carcinogens from the wood (so beware!)

Fuels derived from oil contain less carbon but more hydrogen (two hydrogen atoms for every one atom of carbon). Because hydrogen produces more heat than carbon when burnt, burning oil releases more heat and less CO_2 per unit used than coal, and in doing so produces only water. Methane has four hydrogen atoms which makes it the fuel of choice for us.

The efficiency of burning a fuel is also a factor in production of CO_2. Burning anthracite to generate electric power results in 67% more CO_2 emission than does burning methane, while brown coal which has more moisture and impurities produces 130% more CO_2. Thus, the kind of fuel used by a country makes a lot of difference to its carbon emissions. Peat and brown coal emit the most carbon, bituminous less, and anthracite lesser still:

Peat → Brown coal → Bituminous coal → Anthracite →→→ Diamond?

Power plant emission rates depend on type of fuel used. Their emission rates in terms of tonnes of CO_2 per MWh of power are: lignite—1.3, coal—1.05, diesel—0.65, naptha—0.64, gas—0.42.

2. Electricity Usage

- Using 1 kWh of *electricity* produces 0.37–0.48 kg of CO_2 depending upon the type of fuel oil used to produce electricity. Thus, as an approximate thumb rule, one could say that using 1 kWh of electricity in the town leads to an approximate emission of 0.43 kg of CO_2 at the power plant. A figure often used for convenience in calculations is 0.5 kg of CO_2 per kWh of electricity used (Chris Goodall, 2009).

Household Electric Consumption in UK and India

A *small* house in UK is reported to use on an average 1650 kWh per year, a *medium* house uses 3,300 kWh per year and a big mansion uses 5,000 units per year. On an average, in UK, a household (of average 2.3 persons) is reported to be using about 4,000 kWh (units) of electricity per year. This produces about 1.0 tonne of CO_2 per person per year (Chris Goodall, 2009).

In Mumbai city, India, NEERI estimates that the CO_2 produced varies from 0.05 tonnes per person per year in the slums of Mumbai to 1.4 tonnes per person per year in high-income group housing (NEERI, Personal Communication). The higher value in the two countries is apparently not very different from each other.

Example A1.1

A family's electricity usage averages only 300 units (kWh) per month (3,600 units per year). Estimate the CO_2 produced per year by the family. Assume the power plant is gas based. Also estimate CO_2 production if the power plant is coal based.

Gas based: CO_2 produced = 300 kWh/month × 12 m/year × 0.43 kg CO_2/unit = 1,548 kg/year

Coal based: CO_2 produced = 300 × 12 × 1.05 = 3,780 kg/year (nearly 2.5 times more)

3A. Transport Sector (Road Vehicles)

The Inter-Governmental Panel on Climate Change (IPCC) gives CO_2 emissions in terms of fuel volume used. The US EPA states that burning carbon (mol wt 12) contained in the fuel produces carbon dioxide (mol wt 44) namely, 44/12 or 3.666 wt for wt. As 1.0 US gallon of *gasoline* contains 2421 grams of carbon, its combustion gives carbon × 44/12 = 8.8 kg of CO_2. Similarly, 1 US gallon of *diesel* gives 2778 grams × 44/12 =10.1 kg of CO_2. Diesel is more polluting than gasoline (Emission Facts, 2009).

For emissions in terms of distance travelled, multiply the average distance travelled by a vehicle by the emission factor for that type of vehicle [as given by the Automobile Research Association of India (ARAI)] and convert to tonnes per year:

Type of Vehicle	ARAI Emission Factor (g/km) (ARAI, 2005)
2-wheeler (Petrol)	45.6
3-wheeler (CNG)	57.71
Motor car (Petrol)	126.5
Truck (Diesel)	166.15

The average western commuter is said to burn 1290 L of fuel a year, and produce 3.4 tonnes of CO_2 per year. Road transport is reported to account for fully a fifth of UK's entire national carbon emissions totalling 33 million tonnes in 2004.

For other modes of travel, namely mass transport systems, the distance travelled per year × the CO_2 emission factor (given in the following from UK data) gives CO_2 emissions in kg/year;

Trains	0.11
Bus	0.09
Underground	0.09
Ferry	0.47

Generally, mass transport systems such as trains and metros give much lesser carbon emissions per person than the motor car, and are to be preferred wherever possible. Among the mass transport means, however, ferries and ships often have relatively higher carbon emissions since they use a heavier (dirtier) variety of oil.

Example A1.2

Estimate the CO_2 produced per year by a 3-wheeler using CNG and a truck using diesel oil, each traveling an average of 100 km/day.

CO_2 produced by 3-wheeler = 100 km/d × 320 d/year × 57.8 g/km × 1/1000 = 1849 kg/year = 1.85 tonnes/year.

CO_2 produced by diesel truck = 100 km/d × 320 d/year × 166.15 g/km × 1/1000 = 5316 kg/year = 5.316 tonnes/year (nearly 3 times more).

■

3B. Transport Sector (Airplanes)

Emissions from aircraft travel are quite high and can be computed on the basis of fuel volume consumed and its carbon content released as carbon dioxide upon combustion. Most aircraft run on kerosene and the bulk of fuel used is kerosene. Gasoline is used only in small piston operated aircraft.

Carbon dioxide emission from air travel, on per passenger, per kilometre travelled basis, is the highest compared to other modes of travel, as shown in the following:

Mode of Travel	CO_2 Emission, g/Passenger km
Air travel	170–175
Car (medium-sized)	130–170
Bus (local)	85–95
Bus (inter-city)	65–75
Train	60–70

The latest AIRBUS-380 carrying 800 passengers is said to use a little less than 3 L of kerosene per passenger per 100 km. Many modern aircraft use 3.5 L per passenger per 100 km. Also, a modern hybrid car like the Toyota Prius uses more or less the same amount of fuel, namely, 3.8 L per 100 km when driven by 1 passenger. By comparison, in 1985, an average commercial aircraft consumed about 8 L per passenger per 100 km (Ref: Internet).

To fly an economy class passenger from Mumbai to Delhi, a distance of 1200 km, an airline emits about 115 kg of CO_2.

A rule of thumb says that a plane and a car both emit more or less the same amount of CO_2 on per passenger per km basis, but air journeys are considerably longer than car journeys and airplanes carry more passengers.

Some forms of transport such as aircraft depend on high-density fuels (ATF). Combustion of kerosene in the presence of oxygen gives carbon dioxide and water:

$$2C_{13}H_{28} + 40O_2 = 26CO_2 + 28H_2O$$

For every molecule of carbon, 13 molecules of CO_2 and 14 molecules of water vapour are produced. Moreover, in case of air travel, the discharge occurs at high altitude and very cold temperature. Actually, three gases are emitted which affect global warming: CO_2, water vapour, and NOx. Thus, in terms of warming potential the CO_2-equivalent is said to be 2.0–5.0 times the CO_2 released (often assumed as 2.7–3.0 times the CO_2 released) (Ref: Internet).

4. Emissions from Industry, Commerce and Services

The emissions from these three sectors vary widely from city to city and need to be determined carefully for each city. The emissions can be estimated only approximately from the amount of different fuels burnt in local power houses as well as in private industries and offices for the purpose.

(UK data gives the CO_2 emissions from industry, commerce and services as widely varying from 600 to 2,000–3,000 kg/person/year.) Such information does not exist for India.

However, for India, the total CO_2-equivalent emission from industries was 412 million tonnes per year in 1997. Nearly 32% was from mineral industries, 28% from metal industries and about 8% from chemical industries and the balance from other industries such as pulp and paper, food and beverage, textiles and leather, mining and quarrying.

Specific emission factors (EFs) applicable to a few industries are given as follows (Ref: Book entitled 'Climate Change and India', Universities Press, 2004):

- *Aluminium:* EF = 1.65 tonnes of CO_2 per tonne Al produced
- *Cement*: EF = 0.5370 tons of CO_2 per tonne of clinker used (estimated in 1994)
- *Iron and steel*: EF = 1.72 tonnes CO_2 per tonne production (OHV)
- *Nitrous oxide (N_2O):* Emission from nitric acid production depends on operating pressures. The mean value of N_2O produced in a medium pressure plant was 10.13 kg per tonne of nitric acid, while in a high pressure plant it was only 2.84 kg per tonne. It could be brought down to as low as 0.4 kg N_2O per tonne of nitric acid by use of a non-selective catalytic reducer.
- *Methanol:* EF = 0.67 tonnes CO_2 per tonne methanol produced. Also, 2.3 kg methane per tonne methanol produced.
- *Ethylene:* EF = 1.73 tonnes CO_2 per tonne of ethylene produced. Also, 3.0 kg methane per tonne ethylene produced.

More values are available from the Ministry of Environment and Forests (MoEF), New Delhi.

5. Agriculture and Soils

Rice Cultivation

Methane (CH_4) is the second most important GHG after CO_2 and according to IPCC, it contributes about 15% to global warming on an overall basis. Moreover, a single molecule of methane is said to trap nearly 21 times as much heat as a molecule of CO_2. Globally, about 500 million tonnes of methane are emitted per year into the atmosphere while about 460 million tonnes are lost in the various sinks (through photochemical oxidation) thus giving a net input of about 40 million tonnes per year.

Out of the 150 million hectares globally available for rice cultivation, India accounts for nearly 44 million ha (about 30%) and is thus an important emitter of methane. In India, rice is cultivated under various water management regimes, depending on the availability of water at the site. In hilly areas, rice is cultivated in terraces along the slopes. In other areas, cultivation is on irrigated or rain-fed lands. The methane (CH_4) emission factors vary roughly from 7.0 to 19 grams/m^2 depending on the water regime used (Climate Change and India, 2004).

Example A1.3

Estimate the methane emission and the equivalent CO_2 emission from a 100 hectare rice plantation field laid out in a terraced area.

$$\text{Methane produced} = 100 \text{ ha} \times 10{,}000 \text{ m}^2/\text{ha} \times 19 \text{ g/m}^2 \times 1/1{,}000{,}000 = 19 \text{ tonnes methane/year}$$

$$\text{Equivalent } CO_2 \text{ produced} = 19 \times 21 = 400 \text{ tonnes of } CO_2\text{-e/year}$$

Emissions from Soils

Out of the total land area of 297 million hectares available in India, only about 4% is pasture land and 2% is forest and wood land. These lands are partly utilised for growing different crops.

Soils are regarded as the major source of nitrous oxide (N_2O). Nitrous oxide emissions from rice–wheat cultivation (including the fallow period) are reported to vary from 0.89 to 1.6 kg per hectare (Climate Change and India, 2004).

Agricultural Residue Burning

CO_2 emissions from biomass burning (e.g., fuel-wood burning and agricultural crop residue burning) contain substantial volumes of CO_2 which is, no doubt, released to the atmosphere, but this production is supposed to be cancelled out by the equivalent consumption of CO_2 which took place earlier during the previous season of growth of this biomass. Hence, relatively quick growing agricultural products are often regarded as 'carbon-neutral'.

Leaving aside CO_2, however, this emission is said to be a significant source of CH_4, CO, N_2O and NOx all of which contribute directly towards global warming. In 1994, the crop residue available for field burning in India was estimated to be 150 million tonnes which gave an emission of 102,000 tonnes of methane alone. A few emission factors from literature (Climate Change and India, 2004) are given in the following:

Residue Burnt	Emission Factor (g of CH_4/kg Residue Burnt)
Rice Husk (wet)	73.0–166.0
Bagasse	61.0
Fuel wood	0.006

6. Enteric Emissions from Livestock

Methane emissions (enteric emissions) from cattle vary with type and their feed. The IPCC default values for dairy cattle are 46 kg CH_4/animal/year while for non-dairy cattle they are half as much. For buffaloes they are around 55 kg/animal/year. Cow belching (enteric emissions) can also be reported in terms of volume @ 600 L of methane gas per day per cow. The methane has, of course, to be converted to equivalent CO_2. 1 tonne of methane is equivalent to 21 tonnes of CO_2 in its global warming power. In terms of equivalent CO_2, cow belching results in an enormous amount of about 15,000 L of gas expressed as CO_2-equivalent per cow.

7. Emissions from Land Use, Land Use Change and Forestry

The term LULUCF signifies land use, land use change and Forestry. This sector is reported to contribute a huge 1.6–1.0 giga tonnes (i.e., 1.6 thousand million tonnes) of carbon emissions per year accounting for about 20 % of the global CO_2 emissions per year. Yet the uncertainties associated with its measurement are many.

The LULUCF pattern for a vast country like India is indeed complicated and the emission pattern is equally complicated. It depends on data regarding changes in forest and other woody biomass stocks, forest and grassland conversion rates and abandonment of managed lands. Data uncertainties are indeed many in these items. GHG inventories in the LULUCF sector suffer from many inherent uncertainties and reliable emission factors cannot easily be given for a specific area. The reader is best referred to the book 'Climate Change and India' (Universities Press, 2004) which discusses the difficulties from carbon emission point of view.

8. Community Wastes

Municipal Solid Waste (MSW) Disposal Sites

Biogas emissions from municipal solid waste (MSW) disposal sites occur continually for up to 20–25 years or more after a waste is freshly deposited. From theoretical considerations, the half-life of a landfill is 23 years. This implies that biogas can be economically pumped out for at least 23 years. The biogas can be collected by a network of pipes buried in the deposited material and connected to a suction pump through a network of laterals and manifolds.

From limited studies (Bhide and Patil, 1985), Indian solid waste dumpsites were found to give a biogas production of 0.263 m^3/kg or 263 m^3/tonne of waste deposited. The fraction of methane gas contained in landfill biogas varies from 0.35 to 0.65 of methane (taken as 0.50 on default basis) and can be estimated approximately by using a simplified version of the method (Ref: IPCC default method) as follows:

$$\text{Methane (tonnes/year)} = \text{Total MSW (tonnes/year)} \times \text{MCF} \times (\text{DOC}) \times 0.77 \times \text{F}$$

where, MSW = Municipal solid wastes, tonnes/year

MCF = Methane correction factor = 0.4 for open dumps less in depth

DOC = Degradable organic carbon (determined for each city) = say 0.10 –0.40

Degradable fraction = 0.77 conversion to methane assumed as 0.077 (default basis)

F = Fraction of methane in landfill biogas = 0.35 to 0.65 (taken as 0.5 on default)

Example A1.4

Estimate the biogas and methane production per year from a municipal solid waste dump site handling about 2740 tonnes per day. Assume from the previous discussion that MCF = 0.4, DOC = 0.3, degradable fraction = 0.77, conversion to methane = 0.077, and F = 0.5. Thus,

$$\text{Methane produced} = (2740 \times 365)\ \text{T/year} \times 0.4 \times 0.3 \times 0.077 \times 0.5 = 4620.4\ \text{T/year}$$

or, CO_2 equivalent = 4620.4 × 21 = 97,028 T/year

This is no mean contribution to the global warming scenario of a city and warrants the provision of a biogas collection pipe-network and earth-cover at the waste disposal site to collect and use the gas instead of letting it off to the atmosphere.

Based on a per capita solid waste generation assumed as 450 g/day, the earlier-mentioned quantity of MSW amounting to 2740 tonnes/day would come from a population of about 6.088 million people. Thus, the methane production of 4620.4 T/year from the dump site is approximately equal to 0.21 g/person-day. This value is comparable to the value given earlier from Bhide and Patil (1985).

9. Miscellaneous Sources

Cremation of a human body is estimated to give 50 kg of CO_2. When wood is burnt at the funeral pyre, one may not count the CO_2 released from burning of the wood since an equal amount of CO_2 had been consumed earlier in its growth. It is actually considered 'carbon-neutral'. We are just playing with the carbon: taking it from the atmosphere, and giving it back to the atmosphere.

However, where wood is used, a considerable amount of deforestation occurs. A question that may be asked is to what use would this wood have been put if it had not been used for cremation? Perhaps it would not have been grown at all if there was no demand for it for crematoria purposes. It is not the type of wood which would be used for furniture-making or house-building. Chapter 6 discusses this subject further.

Computers: The manufacture of a single *desktop computer* is reported to produce nearly ½ tonne of CO_2 per unit. How many units do we produce per year? The 2-gram microchip contained in each computer produces 4,000 g of CO_2 in its manufacture. A desktop computer uses 60–120 W of power when active. A laptop uses only 15 W.

TV: A liquid crystal display (LCD) monitor consumes much less power than one with a cathode ray tube (CRT). A LED TV consumes the least current.

Mobile phones: A mobile phone contains copper, gold, silver and a small amount of platinum. As these are precious metals consuming much power in their refining, they should be recycled. India does not yet collect old mobile phones systematically for recycle. In fact, collection of all forms of e-waste is just starting in India, with Bangalore having taken the lead.

Estimation of Carbon Emissions from a Building in Mumbai

A tall 31-storey building in Mumbai has 120 flats. All flats are equal and consist of 3 bedrooms, hall-dining, kitchen, servant's room, 3 toilets, passages, lofts, etc. Average occupancy is 5 persons per flat (including servants). On an average, 70% flats are with some air-conditioned rooms while another 30% are non-air conditioned. The average electrical consumption of air-conditioned flats is 800 kWh/month while non-AC flats consume only 300 kWh/month on an average.

On an average, each flat uses 1 cylinder of LPG gas per month for cooking. Each flat owner also has one petrol-driven car giving an average of 10 km/L and each flat owner travels about 1000 km per month. 20% owners have 2 or even more cars. Common facilities in building include 4 lifts, 4 water pumps, passage and podium lights, and car park for about 100 cars. Operation of common facilities consumes on an average 11,618 kWh/month. Use emission factors given in Appendix 1.

Estimating the Overall Carbon Footprint

Item	Basis	Total CO_2 Emission (kg/month)
Average electricity non-AC flat @ 300 kWh/month	0.48 kg CO_2/kWh	$36 \times 300 \times 0.48 = 5184$
Average electricity AC flat @ 800 kWh/month	0.48 kg CO_2/kWh	$84 \times 800 \times 0.48 = 32,256$
LPG cylinder used 14.5 kg/month	0.19 kg CO_2/kg gas	$120 \times 14.5 \times 0.19 = 331$
Car travel $120 \times 1.20 \times 1,000$ km/month	126.5 g CO_2/km	$120 \times 1.2 \times 126.5 \times 1000 = 18216$
Power for common items 11,618 kWh	0.48 kg CO_2/kWh	$11,618 \times 0.48 = 5576$
		61,563 kg CO_2/month **738 tonnes CO_2/year**

The bigger sources of emissions are the AC flats in the building and car travel by the building's inmates. As the average occupancy of the building is $120 \times 5 = 600$ persons, the average carbon emission per person = 738/600 = 1.23 tons CO_2/year. This emission does not include the commercial, industrial and other support emissions.

Reducing Power Consumption

For reducing power consumption of the building without sacrificing convenience, the following two things can be done:

1. Common items (lifts, pumps, etc.) could be shifted over to solar energy by installing solar panels, if found economic and affordable
2. All flats could also change over from old-style incandescent bulbs to CFL bulbs. This would give a reduction from 1600 W to 320 W in each flat, i.e., one-fifth electric consumption, without reducing illumination.

Mr Mukesh Ambani's new residence in Mumbai can be used as another illustration because its electric consumption has been given in local newspapers as 6,37,000 kWh (units) per month. On this basis, the corresponding CO2 release @ 0.48 kg/kWh = approximately 3 lakh kg per month = 3,600 tonnes/year. All for 2 people? Even if we assume servants and staff constitute 100 persons, the carbon emission = 36 tonnes per person per year! Fantastic. This is probably due to heavy amount of air conditioning in the building.

APPENDIX 2

A Few Profitable Innovations and Installations in India

Item 2(1)

India's First Award winning Green Building, The CII-Sorabji Godrej Platinum Building, Green Business Centre, Hyderabad

(Chapter 6 gives details of LEEDS guidelines for design of green buildings.)

The CII-Godrej GBC platinum building is located on a 5-acre plot near HITEC City in Hyderabad, AP. It is the first building to be awarded the Platinum Award under LEEDS guidelines for green buildings outside the USA.

1. As much as 80% of the material used in the construction of the building was recycled material.
2. The building discharges zero wastewater as all its used water is reused. Consequently, it consumes about 40% less water than a conventional building due to low water consuming fixtures such as waterless urinals, dual flushing tanks, etc.
3. It has a huge arrangement for the collection of rainwater and groundwater recharge.

4. The building consumes only 1,30,000 kWh electricity per year compared to 2,50,000 kWh of power consumed by a conventional building of the same size.
5. Other notable features of the building are:
   - Minimum site disturbance
   - 55% reduction in energy consumption
   - 100% day lighting
   - 15% power from solar PV panels
   - 60% recycled materials
   - Roof garden covers 60% of built up area
   - Plants confined to non-toxic ones
   - Fly-ash based blocks used
   - Building management system in place

(Source: CII Booklet entitled 'Building a Low Cost Economy', January 2008)

Item 2(2): Kirloskar's Corporate Office, Pune

Another Green Building Awarded Leeds Platinum Rating

The building: The corporate office building of Kirloskar Brothers Ltd. (KBL) called 'Yamuna' was designed by a Bangalore-based architectural company called Venkataramanan Architects. Sanjay Kirloskar, KBL's Chairman and MD, is credited with the decision to build a corporate office meeting the LEEDS requirements because of his earlier association with India's first green building, The Godrej Green Business Centre in Hyderabad.

'Yamuna' located on a plot of 2,00,000 square feet of land in Pune, with a built up area of 1,00,000 sq ft, and housing 500 employees, has a construction footprint of only 40,000 sq ft leaving the rest open for gardens and parking. As a leading water management company, KBL set standards by saving 50% energy and 30% water, all by the use of technology and effective design. It employs solar power generation, eco-friendly cooling systems and rainwater harvesting.

The technology: The structure has photovoltaic panels to generate electricity which meets 2.6% of its power consumption. Maximum use of glass panels is made along walls that allow natural light (not direct sunlight) inside the building thereby saving on electricity and air-conditioning. Most of the lights have economic CFL fixtures. It also employs a water-cooled VRV air conditioning system with sensors for monitoring CO_2 levels and optimising intake of fresh air. There is a dedicated 'reproduction room' with exhaust fans for every floor or wing which houses the printers and photocopiers so that toxic emissions from these do not pollute the general workspace. 'Yamuna' is also a zero-waste building, with as much recycle as possible. Not only is the entire office a 'no smoking' area for obvious reasons, but it is also a 'no food' zone to keep odours away. Tea and coffee are permitted. 3M mats are placed at all entry points to ensure only clean footwear comes into the building.

Water resources: Rainwater harvesting along with groundwater recharge occurs additionally through interlocking pavers in the open areas. All washrooms have sensors installed for the taps and dual flush tanks for WCs to conserve water. The greenery comprises native species of plants which require very little water. Besides, all the water used for gardening is from the sewage treatment plant. The food waste from the cafeteria goes into a vermicompost pit which provides manure for the plants.

Materials: Broken clay bricks are used for waterproofing and Styrofoam for insulation of the top slabs whose finishing is done with china mosaic which reflects sunlight and reduces air conditioning load. The building envelope—glass or brick—is double-walled with a cavity in between. This reduces the heat load much. As far as possible, locally available materials are used and 80% of the site and contours have been left undisturbed. All carpets and false ceilings are made from recycled material. A bio-diesel fuel is used for operating a power backup in case of emergency.

Landscaped terraces, atriums with indoor plants and the use of glass provide a scenic view to the people at work. Staffs are encouraged to form car pools.

Recovery of costs: 'We may have spent a little more in construction' say the owners, 'but we expect to be able to pay-back in about 3 years'. An example of saving money and making good use of resources.

(Source: Inside Outside Magazine, February 2010)

Item 2(3): The Triburg Building, Gurgaon, New Delhi

A First Generation Green Building Following the Energy Conservation Building Code (ECBC) and Saving Money

Owners: Triburg Headquarters Building, Udyog Vihar, Gurgaon, New Delhi
Architect: SPA Design Pvt Ltd., New Delhi
Energy Consultant: TERI (The Energy and Resources Institute) New Delhi
HVAC Consultant: Engineering Services Consultants, New Delhi

Site: Industrial area (Udyog Vihar) in Gurgaon
Plot Area: 7,800 sq m
Built up Area: 10,000 sq m + 4,500 sq m basement

Basic planning: The building gradually increases from 1 to 4 stories as one goes towards the back and is planned around courtyards so as to give daylight to the offices and also increases green cover. Roof gardens, cavity walls and insulation for exterior walls all help reduce the heat load on air-conditioners. Efficient lighting also reduces the load on energy consumption.

The benefit obtained through each ECBC-inspired action is indicated as follows by the reduced value of the electrical energy consumption for lighting and cooling, given in the following.

Feature	kWh/m^2/Annum	Reduction
Basic (without any ECBC-inspired features)	186	–
With envelope optimisation 12% reduction is achieved	165	12%
+ lighting optimisation	120	30%
+ HVAC optimisation	98	47%
+ HVAC controls	92	50%
+ daylight integration	86	54%
ECBC compliant	**86**	

A 54% reduction in energy consumption per year (from 186 to only 86 as shown earlier) is a considerable saving in terms of money.

This is what we have been saying throughout the book. Even if you think global warming and climate change are a distant and uncertain phenomenon, saving electricity (and therefore incidentally reducing carbon emissions) is a good idea. It saves money and fuel resources. Moreover, a 'green' building helps save more things than just electricity and money. It also reduces water consumption and materials used.

(Source: Energy Conservation Building Code (ECBC), Bureau of Energy Efficiency, GOI, R K Puram, New Delhi)

Item 2(4): 'Orange County', Pashan, Pune

A Second Generation Residential Building where Renewable Energy is Supplied Free of Cost to Tenants, Wastewater is Reused After Treatment and Garbage is Composted

Orange County Phase II is a 9-storied residential building at Pashan, Pune, having 36 flats (27-2bhk + 9-3bhk) built in 2007. It is self-sufficient in respect of electricity, water, sewage and garbage processing. It cost the promoters about 2.5–3.5 lakhs extra per flat for the green infrastructure. Electricity works out almost free for the residents. This is what makes it unique!

The Facilities

1. In each flat, electric power is supplied from two sources (the town's grid and the building's green energy). All light, fan, TV and computer points are on 'green' energy as primary source and grid energy as stand-by. Power points are all on grid energy.
2. All flats have solar water heating facility.
3. Common amenities such as lift and water pump, run on 'green' energy.
4. Common lighting in outdoor passage as well as parking areas have T5-28 W tube lights. All these light points have time and motion sensors. At sunset they turn on automatically and then turn off, only to start when there is any motion and turn off again when there is no motion for 1 minute.

5. When all 9 floors are dark, every mid-landing has 3 W LED lights which are on all night. Thus the building practically runs on 9×3 W = 27 W power throughout the night. This saves electricity by 80%. All these lights are on 'green' energy.
6. One of the two lifts works on green energy. Its energy consumption depends on the number of people inside.
7. All flats have to use energy-efficient fixtures and power savers
8. 'Green' power is supplied *free of cost* to every flat holder. To ensure its use within limits, the following restrictions are imposed.
9. Every flat is provided with a blink free changeover (BFC) switch which limits use of current from green energy upto 1.5 Amps. Normally, 3 T5 tube lights, 2 CFL bulbs, 2 fans and 1 TV/computer can be operated within 1.5 Amp limit. If consumption exceeds 1.5 Amps, the system automatically changes over from green to grid supply which has to be paid for as per meter. So people are careful. Each flat is reported to be paying on an average about ₹200 per month for grid electricity.

(If greater comfort is desired to be given, the whole installation would have to be enhanced and greater capital cost incurred.)

The Hybrid Power System (Wind + Solar)

To generate the 'green' power, there are two wind turbines (each 5 kW peak) located on top of the terrace along with 90 solar PV panels (36 of 120 W each and 54 of 144 W each) totalling 12 kW peak. The hybrid installation of wind + solar panels can together give 22 kW peak, i.e., max 60 units (kWh) per day.

The hybrid power collector (HPC) is designed to generate electricity at wind speed as low as 2 m/sec (being hybrid and using boost charging method).

180 number batteries of SMFVRLA type, 2 V 200 Ah, are used. Life span is around 10 years. The batteries can cater to the entire building's needs for 24 hours, without back up.

Solar Water Heating System

In order to avoid unequal distribution of hot water, each flat is provided with a fully programmable solar-grid water heating system. Each flat is served by a tank of 125–150 litres of water (depending on size of flat) with an electric heating coil 3 kW rating and thermostat. Each flat gets fixed quantity of hot water from the solar water heater while the electric heater maintains the minimum reserve level of hot water at any time.

Sewage Treatment and Reuse (Non-mechanised Root Zone Method)

Instead of using conventional sewage treatment by aeration which requires electrical power and maintenance of mechanical equipment, it was decided to use the natural root zone (constructed wetland) method using *Phragmites australis* species of grass. The process is very cost effective and produces 20,000 litres of crystal clear water (BOD 5–8) which is used for gardening, car washing and other non-potable purposes. Being a natural process, it generates no CO_2 and, on the contrary, the plantation helps remove CO_2 from the atmosphere through photosynthesis.

Garbage Disposal

Every floor has a garbage chute outlet separate for dry and wet garbage. The two are collected through separate chutes and further separation is done at ground floor level. From this point, wet garbage is taken to bio-culture pits where it is processed naturally to make manure out of it, which is used for the plantation/organic farming done in the premises. The dry garbage is mostly sold and recycled.

As a result of all the mentioned provisions, the building team has estimated that the total carbon emissions saved = 187 tonnes C per year. As this emission saved is from 36 flats × 5 persons/flat (assumed), the saving is approximately 1 tonne per person per year. *Emission reduction is not the only benefit. The flat-owners save money and the country saves oil and coal resources.* We need more such buildings in every city.

Acknowledgment: The project has been done by 'SCN Realtors'. These successful experiments led to the formation of Orange County Foundation, Pune, a registered organisation working on

various eco-friendly projects. Contact Nos: 9822196473, Mr Amar Chakradeo and 9561354550, Mr Vilas Gogate. Other experts involved are as follows:

- Mr Sandeep Sonigra (Overall), on behalf of the builders
- Mr M D Akole (hot water system) and
- Dr R V Saraf, wastewater and garbage

Item 2(5)

Another Second Generation Green Building in Gandhinagar (Gujarat) Feeding-in Surplus Electricity to the Town Grid

The new building of the Gujarat Pollution Control Board (GPCB) inaugurated in April 2012 has installed a solar energy system to generate the electricity required by the building and to feed-in the surplus to the Gandhinagar town grid.

The building is the first of its kind in Gujarat. It has installed 360 solar PV panels mounted on the building's terrace (about 2000 sq meters area) together with the necessary mounting structures, cabling, inverter for converting DC to AC, 50-cycle and metering the supply sent to the public grid. The installation has cost nearly ₹1 crore including a 10-year maintenance requirement.

The building has 600 fans, about 1,000 CFL tube-lights and 40 air-conditioners for which it needs an 80 kW installation. It produces about 1,16,800 kWh (units) of electricity per year while it consumes about 84,000 kWh (units) per year, the rest being fed-in into the grid. Because it feeds into the grid, no storage of electric power in batteries is needed. This saves initial cost and saves replacement cost also as battery life is generally only 2–4 years. The solar power system is estimated to save 80 tons of CO_2 emission per year.

360 panels × 230 Wp per panel = 82,800 W = 82.8 kW (OK, actually we need 80 kW)

Each panel costs about ₹27,000 including all balance of system items (BoS) and a 10 year maintenance period.

Electricity produced = 1,16,800 units/year = 1,16,800/365
= 320 units/day

= 320/360 = 0.888 units/panel (say, approx. 1 kWh per day per panel)

Electricity consumed = 84,000 units/year. If offices are assumed to work 300 days/year, electricity consumed/day = 84000/300 = 280 units.

The building is a 'zero-energy' building as it consumes no energy from the grid at any time. In fact, on an average working day, only a marginally small quantum of 40 units goes to grid from this building. On Saturdays, Sundays and holidays, much more electricity is fed into the grid and the main power house can use substantially less coal or oil on those days. To make sure there is enough load on holidays, the industries are usually required to take staggered holidays.

(Source: Personal Communication from Member-Secretary, Gujarat Pollution Control Board)

Item 2(6)

Green Energy (Solar Installations) in Gujarat

Gujarat is perhaps the only State in India to have a separate department for 'climate change' and an effective department for promoting solar energy. Solar power initiatives in Gujarat are reported to have attracted ₹49,000 crore investment.

A 214 MW solar park has come up in Charkanka in North Gujarat and is expected to grow into a 600 MW affair.

Another development is the setting up of solar panels along a kilometre stretch of the Narbada canal, on the canal itself so as not to need additional land. No doubt this saving in land cost is offset to some extent by the extra cost of providing a support infrastructure for supporting the solar PV panels over the canal, but an incidental benefit is the reduced evaporation that occurs and the employment it gives to the local people.

As said earlier, in Gujarat, private parties are said to be willing to install solar energy systems *at their own cost and risk in cities* provided the building terrace is leased out to them at a mutually agreed rent for a long enough period. The party gets paid at the official rate fixed by the electric company for feeding-in the electricity into the town grid. In turn, the party pays the building owner

₹3 per kWh fed into the grid as per meter. The relative rates may change in future. In this way, the landlord gets paid for the use of the terrace and for generating electricity without investing a single rupee, the investor has an opportunity to invest profitably and the electric company (and the town) benefits from the electricity fed-in. The business deal is a win-win situation for all.

Gandhinagar already has over 150 installations ranging from 1 kW to 150 kW. The Pandit Deendayal Petroleum University, a large consumer, has installed a solar energy system which is already saving them over ₹4 crore a year.

An obvious requirement of such win-win transactions is that government's policy and pricing must have long-term stability so that the investor may be tempted to invest in such a venture.

(Source: Personal communications from Gujarat Pollution Control Board)

Item 2(7): Gorai the Gold Mine!

Closing the Gorai Municipal Solid Waste Dumpsite Has Been One of BMC's Most Profitable Ventures

Background: Mumbai, spread over an area of 438 sq km with a population of more than 12 million people, generates around 6,500 tons per day (TPD) of municipal solid waste (MSWs) and 2,400 TPD of construction and demolition (C&D) waste. Characterised by high population densities, vast quantities of waste, large slum areas and proximity to sea coast with high humidity levels and tidal inundation, Mumbai poses a unique challenge to the management of MSW. The challenge in the context of Mumbai lies in developing scientific and environmentally compatible MSW processing and landfill facilities while keeping the site-specific constraints in mind.

IL&FS appointed: The Municipal Corporation of Greater Mumbai (MCGM) appointed M/s Infrastructure Leasing and Financial Services (IL&FS) to provide environmental consultancy and project development and advisory services for developing an Integrated Solid Waste Management Plan (ISWM) for the Metropolitan city. The ISWM Project, which includes a comprehensive waste disposal plan, has been developed by M/s IL&FS Ecosmart Limited (a 100% subsidiary of M/s IL&FS) on a public–private partnership (PPP) framework.

The Gorai dumpsite is located in the Western suburbs of Mumbai. It spreads over an area of 19.6 ha and has been operational since 1972. The site is adjacent to Gorai creek and is very close to habitation. About 2.34 million tonnes of waste up to an average height of 26 m is lying at the site.

The existing practice of open dumping that had been followed since 1972 had caused significant environmental damage in neighbourhood adjoining the disposal site. The creek waters had been polluted due to inflow of leachate and the air quality had deteriorated from the frequent burning of garbage at the ground. Public outcry had been occurring.

In view of the severe environmental constraints, including health and safety of residents within the vicinity of the site and since the existing capacity to accommodate additional waste had already been exhausted at Gorai, IL&FS recommended scientific closure of the dumping ground in accordance with international practice and the MSW (M&H) Rules, 2000.

Scientific Closure Plan

The scientific closure plan for Gorai dumping ground included the following components:

- Relocation and reformation of existing waste heap to a moderate slope of 1:3 (1 V to 3 H) for permanent stabilisation.
- Laying of construction and demolition waste and compaction.
- Laying of liner system which consisted of the following six layers:
  (i) Laying of top vegetation layer
  (ii) Laying of 300 mm thick top soil layer
  (iii) Laying of geo-composite layer
  (iv) Laying of 1.5 mm geo-membrane layer
  (v) Laying of 200 gsm and 400 gsm Geotextile
  (vi) Laying of 300 mm thick drainage layer
- Installation of landfill gas eecovery and utilisation system

  A landfill gas recovery system was installed at the site in order to reduce methane (CH_4) emissions in future. Instead of being emitted into the atmosphere, the methane (landfill gas) would be captured using gas wells. For the landfill gas collection and venting, a gas collection and venting manifold comprising of network of landfill gas collection wells and duel wells (gas + leachate) have been installed. The landfill gas thus generated will be brought to a common point and will be used for power generation. The total installed capacity of the power plant shall be 2 MW. The gas that is not used for power generation will be flared in an enclosed flare at a temperature of around 1,200°C.

- Installation of leachate collection system

  A duct to convey the leachate to a collection tank has been installed. The duct is constructed in reinforced cement concrete (RCC) and covered with a cover slab. The leachate is allowed to flow into the duct through perforated pipes located at intervals along the periphery of the fill. The pipes are covered with construction debris to prevent any entry of the fill material and choking of the duct. The leachate from the duct is collected in a leachate collection tank and transported to a sewage treatment plant (operated by MCGM) for treatment.
- Sheet piling on the creek ward side to prevent leachate from entering the creek.
- Surface water drainage for channelling the storm water.
- Construction of bunds, access roads and compound wall on the landward side of the site.
- Peripheral and internal roads and landscaping.

The construction and O&M contract for scientific closure of the Gorai dumping ground was competitively awarded to a consortium led by M/s Van Der Weil Strotgas BV and M/s United Phosphorus Limited (UPL). The construction and O&M contract was designed in a way that preserved the public interest nature of this project with several positive externalities, while bringing in the construction know-how, management and efficiency skills of the private sector.

The construction of the project was completed in 24 months, at a cost of ₹50 crores with the O&M estimated at ₹12 crores for a 15-year period. The total expected revenue generation from the ‘certified emission reduction’ for the Gorai project is ₹72.9 crore. The project has been registered at the UNFCCC as per the Kyoto Protocol.

The capture and combustion of methane gas will result in a substantial reduction of greenhouse emissions and thus has the potential to earn ‘carbon credits’. The project is estimated to reduce greenhouse gases by an estimated 1.2 million tonnes of CO_2 over a 10-year crediting period. M/s IL&FS Ecosmart Limited was instrumental in getting an advance purchase agreement signed with Asian Development Bank. As a result of this effort, *MCGM has received an advance of ₹25 crores* against future delivery of carbon credits from the Asia Carbon Fund of the Asian Development Bank for the Gorai project. The transaction is one of the largest carbon advance transactions in clean development mechanism (CDM) in the world. It includes emission reduction to be generated from the project post-Kyoto protocol, i.e., emissions in 2013–2014 as well.

The Scientific Landfill Closure and Methane capture project at Gorai sets a benchmark in urban rejuvenation. The immediate benefits from the project are significant: the project has created 19 hectares of green space in Mumbai and led to the restoration of mangroves. Other environmental benefits include improvement in public health and hygiene in the neighbourhood; elimination of foul odour, fire and vermin nuisance, an improvement in the quality of creek water and an increase in avian fauna population. Income from sale of biogas will be an additional source of income for the corporation.

The project also demonstrates that the carbon credit finance mechanism can catalyse environmentally sustainable and financially viable closure of existing dumping sites and thus directly eliminating methane and replacing fossil fuel electricity generation to prevent GHG emissions in the atmosphere. The project provides a replicable role model for other municipalities in the country. (We understand that 6 other projects are coming up soon!)

Refund for Failure to Meet Expected Carbon Reductions

It is learnt from a report carried in the *Times of India* dated 22 September 2012 that, upon verification of the claims made earlier, the Mumbai Municipal corporation has been asked by the Asian Development Bank to refund ₹15 crore (about US $2 million) for failure to meet expected carbon emission reductions.

For any queries, readers can contact:

Mr Mahesh Babu, CEO, IL&FS Ecosmart Limited at mahesh.babu@ilfsecosmart.com or Chetan Zaveri, VP and Regional Head, IL&FS Ecosmart Limited at chetan.zaveri@ilfsecosmart.com.

Item 2(8): Okhla Compost Plant

A Model for Municipal Solid Waste Management with Centralised Aerobic Composting

The defunct Okhla compost plant has been revived in public–private partnership between the Municipal Corporation of Delhi (MCD) and the Infrastructure Leasing and Financial Services Ltd. (IL&FS). The project aims to avoid methane emissions generated by anaerobic decomposition of municipal solid waste (MSW) in a dumpsite through revival and upgrading of Okhla compost plant under MCD in New Delhi. The facility provides controlled aerobic composting process of MSW to avoid methane emissions.

Project Background

The old Okhla composting plant was constructed by MCD in 1981 and closed in 2000, as the operation was not cost effective due to insufficient revenues from the sale of compost. After closure, the waste got diverted to the poorly controlled Okhla solid waste dumpsite.

In May 2007, IL&FS signed a concession agreement with MCD to renovate and upgrade the Okhla compost plant with carbon finance support. IL&FS executed the project through its waste management arm, IL&FS Waste Management and Urban Services Ltd.

Project Funding

The capital expenditure (₹8 crores) for setting up the facility was borne by IL&FS and after registration of the project with UNFCCC, an advance was received from them against the projected number of CERs to be generated. The IL&FS has given ₹5 lakhs to MCD as an advance share from this amount. The net CDM revenue sharing between IL&FS and MCD is in 75:25 ratio.

New Upgraded Compost Plant

On an average, 185–200 MT of fresh waste is received per day. The project comprises of designing and rebuilding of a compost plant with capacity suitable for the treatment of organic-rich solid waste. The renovated composting facility became operational by April 2008 with an upgraded capacity to process 200 metric tonnes of municipal solid waste per day. The site occupies an area of about 8 acres.

The fresh solid waste received at the compost plant is subjected to a mechanical pre-sorting step to remove bigger objects and inert matter. The segregated waste is then stabilised though controlled *aerobic* decomposition in a windrow composting process to avoid methane emissions. The composted solid waste is then screened further through a fully mechanised screening plant to remove plastics, inert and other external materials. The free flowing powdery compost is further polished through a gravity separator and magnetic separator to remove silt and small ferrous particles.

About 25–30 MT per day is the average production of compost at Okhla. The facility thus converts approximately 73,000 tonnes of municipal solid waste per year in to about 10,000 MT of compost every year. The compost produced in this facility adheres to the compost quality standards stipulated by FCO (Fertiliser Control Order). The pre-sorting of fresh waste in this project limits the heavy metals to a safer level. The rejects mainly comprise of plastics, rubber, leather, tyres, undigested fibrous packing materials, glass, sand, silt and stones. These items are rejected at different stages of the sorting process, and ultimately sent back to MCD landfill for disposal.

Refined compost is bagged and distributed to farmers through the trade channel network of major chemical fertiliser companies such as Coromandel International Ltd. (CIL), KRIBHCO, FACT, Nagarjuna, Zuari, etc.

Advantages of the Sustainable Model

- Through the controlled aerobic composting process, no CO_2 is produced and no methane. This facility avoids around 1600 tonnes of methane emissions per annum. As per the global warming potential of methane, the emission reduction happening because of this project is equivalent to 34,000 tonnes of CO_2-equivalent per annum.
- Organic waste is converted to compost, which not only recycles available resources but also avoids the emission of greenhouse gases otherwise caused by the production and use of chemical fertilisers.

- Use of compost as an agriculture input increases the soil fertility and makes agriculture an economically and ecologically sustainable activity.

The project got registered for clean development mechanism (CDM) benefits with UNFCCC on June 22, 2009. The additional revenue generated from the emission reduction certificates (CERs) makes this project viable and sustainable. The project contributes to sustainable development through cleaning up of urban landscape, thus improving the health and hygiene and saving precious land at the solid waste dumpsites in New Delhi.

The major hurdle in marketing is the transportation cost of compost from the site to the customer at rural end. Unlike the heavy subsidy available to the chemical fertilisers, there is no subsidy or support for transport of compost from the government. *Receiving support from the government, CDM benefits and sale of compost* together *can make the project viable for widespread adoption.*

For more details, please refer to:

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IL&FS Waste Management and Urban Services Ltd.
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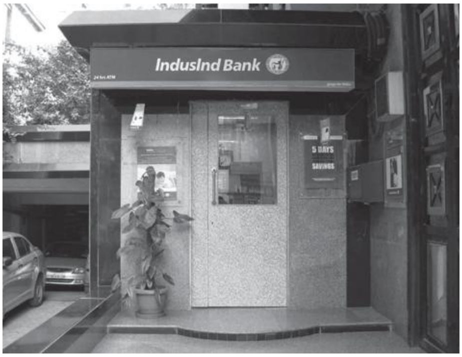
Item 2(9): Green Banking and Schooling on Solar Energy in Rural India

An NGO Promotes Use of Solar Energy in Urban and Rural India

Solar power has two main advantages over fossil fuels. The first is in the fact that it is renewable; it is never going to run out. The second is its negligible effect on the environment. While the burning of fossil fuels introduces many harmful pollutants into the atmosphere and contributes to environmental problems such as global warming and acid rain, solar energy is relatively non-polluting. Additionally, one of the strengths of solar energy is the ease with which it can be generated locally, allowing electricity and energy to be supplied to both urban and rural parts of any country.

The Centre for Environmental Research and Education (CERE) has promoted the use of solar energy in the form of solar photovoltaic electricity in both the mega polis of Mumbai city and in rural Dahanu Taluka, through two unique and successful installations of solar installations described below.

1. Green Banking



In December 2009, as part of the on-going 'Green Office Initiative', CERE in partnership with IndusInd Bank and Autonic Energy Systems Ltd. created India's first fully-automated, micro-processor based solar ATM at IndusInd Bank's Opera House Road Branch in Mumbai City. This ATM is a revolutionary concept in green banking. The Solar UPS replaces the conventional use of fossil fuel in the form of grid-sourced electricity with eco-friendly and renewable solar energy. The solar ATM uses photovoltaic cells mounted on the roof of the building. These cells convert sunlight into electricity and this clean and renewable form of energy is used to power the ATM for a period of 12 hours each day. The system operates on real time and has two levels of operation, namely timer based, which switches to solar UPS on timer operation, and trigger based, where in case of a power failure the system will switch to the UPS.

The Solar UPS generates approximately 5950 watts or 6 units of power each day and saves about 1980 kW hours per annum. Since solar is a renewable form of energy, the solar ATM also results in the reduction of carbon dioxide by 1,912 kg of carbon per year. In terms of economic benefits, the solar ATM saves IndusInd Bank about ₹20,000 a year but more importantly, the savings would be about ₹42,000 in rural areas where ATMs run on diesel generators during periods of load shedding. The payback period for the entire system is less than 6 years while the solar panels are under warranty for 20 years. The solar ATM has been such a grand success that IndusInd Bank is now planning to convert another 100 ATMs to solar over the course of the next year and more and more banks are also exploring the option.

2. Green Schooling

Renewable energy projects in the form of solar-generated electricity are also key in providing energy to those areas which are not connected to the main power grid or where power supply is in extremely short supply. On this premise, CERE also partnered with the Rotary Club of Mumbai Sealand to provide electricity and reading light to school children residing at the Aswali Ashramshala, a tribal residential school, in Dahanu Taluka, Maharashtra.

Note: In this way, the benefits of electricity are brought to Indian villages without waiting for long transmission lines to arrive from distant power houses. The system being renewable, money, materials and other resources such as coal and oil are saved.

For more details, contact:

Dr Rashneh N Pardiwala, Founder and Director, Centre for Environmental Research and Education (CERE) a Mumbai-based non-profit organisation. E-mail: cere_india@yahoo.co.in Website: www.cere-india.org

Item 2(10): Using TERI-Lamps in Un-Electrified Areas

Using TERI-type Lamps with Portable Solar PV Panels in Un-Electrified Villages of India

The Ashramshala suffers long power cuts of approximately 8 hours every single day and children have difficulties in studying due to the lack of regular and uninterrupted electricity supply.

CERE undertook the project to install two solar street lamps and ten portable solar lanterns for use within the remote school premises. The light for the powerful street lamps is provided by an 11 watt CFL bulb and operated by an in-built back-up battery system with a micro-controller. The system works on the dawn to dusk principle, with the street lights automatically switching on as light levels fall below a threshold level. The solar lanterns are equipped to work for 4 hours at a stretch and are charged during the day with the help of roof-mounted solar photovoltaic panels.

The solar street lamps and the portable solar lanterns have made it easier for the students to study at night and safer for them to move around the Ashramshala campus at night.

APPENDIX 3

Some Innovative Ideas Awaiting Implementation

Item 3(1)

Reducing Carbon Emissions by Providing Natural Treatment Instead of Mechanised Treatment

The example shown in Fig. A3.1 illustrates how planning for a typical medium-sized developing town in India can be done in a better way by using a decentralised wastewater collection system together with 'natural' treatment methods which do not need costly electric power for treatment nor emit carbon.

The Old Town and Its Facilities

Firstly, the old part of the town (shown in Fig. A3.1 as dense growth) may be assumed to have a *centralised* sewerage system already existing owing to its relatively high population density. We may assume that an old conventional-type treatment plant exists to treat the waste from this area and discharge the treated effluent to the river.

The town is now developing rapidly around the lake and its surrounding vacant land as it is well served by roads which connect it to other towns nearby.

New Decentralised Facilities Proposed

In the new scheme of things, several newer approaches like a decentralised sewerage system and use of natural treatment methods for water and nutrient conservation are proposed as follows:

1. The wastewater from the old part of town is to be treated to a higher standard than before to make it fit for *reuse in the newly developing industrial area* in the west of the town. In this way, the existing treatment plant would get upgraded and water would be conserved by its reuse. The new plant would also be assured of greater sustainability because of the income generated by reuse and sale of other items from the treatment plant.
2. A new *intercepting sewer* will need to be laid along the upper part of the ring road to divert any wastewater going to the lake and polluting it. All wastewater collected by the intercepting sewer would be carried to the earlier-mentioned treatment plant for reuse while the lake would be protected against pollution.
3. Sewage from the newly developing area in the North-East can be treated by a natural treatment method such as the 'constructed wetland'. This method will provide treatment to a very high degree without any use of electric power. Thus it will save money and avoid any carbon emission.
4. The lake being located in India is estimated to lose about 30–40% of its volume through evaporation. *Replenishment of the lake* with treated wastewater from the constructed wetland would keep the lake topped up even during summer, thus retaining its amenity value for the public and discouraging misuse of lake fringes by encroachment.
5. On the south side of the ring road, for a part of the area, provide wastewater treatment by an *oxidation pond* to make the effluent fit for irrigation. Thus, wastewater will be reused to grow crops.
6. For serving other part of the South-side area, either provide *Ecosan or septic tank* (Ecosan with manual pour-flush or septic tank with cistern flushing depending on water availability). In both cases, final disposal is to land and thus both water and nutrients are conserved. Thus, a mix of different natural treatment systems is proposed to be used.
7. Mechanised treatment plant would be retained, but upgraded for reuse of effluent in surrounding industries. Reuse would benefit in two ways as explained in 1 earlier.

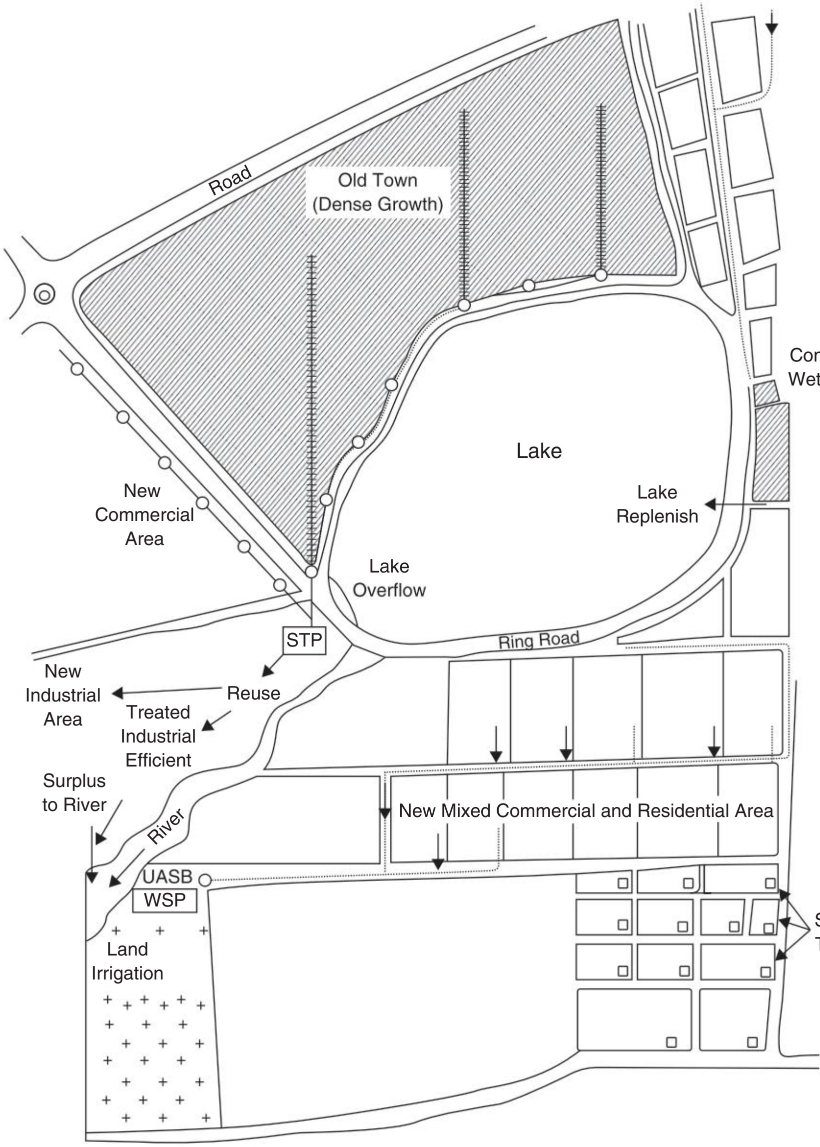


Figure A3.1 *Diagram to illustrate layout of town mentioned in Appendix 3(1).*

Moreover, the overall cost of treatment and carbon emissions would reduce as electric power would not be used by natural treatment methods. The lake would be protected and reusable water would become available for industry.

The whole process would be like what those in the cinema field do: converting an old style single-screen cinema house into a thriving new 5-screen multiplex, better serving different needs and making a profit. This could be called an 'affordable and sensible sanitation for all'.

Item 3(2): Community Service Centres to Provide Energy and Micro-Finance

An Innovative Business Model for Integrating Renewable Energy with Village-Based Agro Systems

Population in India has now reached over 1.2 billion of which some 800 million people live in villages and are in some cases deprived of basic energy needs like electricity required for economic growth of the villages. Although over 70% of the population live in villages, the rural electricity consumption in the country is only 20% of the total consumption. Majority of villages are unelectrified or face extensive power cuts, some of 16 hours per day.

Currently, the major energy source in villages is from conventional fossil fuels. Agro sources and wastes are used individually by a few village households who are able to and can afford to use them. Most of the villagers cannot afford the capital investment and are dependent on government subsidies. Here, a scheme is suggested where the initial investment is to be made by a private business company in the form of a 'common services centre' set up at a suitable location, preferably on a co-operative basis, for producing and supplying electricity, biogas, bio-fuel and organic manure, etc., all on a common basis to the villages around. A business model is thus to be developed. The elements of the proposed 'common services centre' would probably be as follows:

- A solar, wind or hybrid power source of desired capacity to serve surrounding villages their minimum electrical needs.
- An anaerobic digester to process animal and agro-waste to produce biogas and sludge/fertiliser for use by the surrounding villagers.
- A simple oil-extraction plant for seed processing and oil extraction from the biofuel plants cultivated in surrounding villages, and brought to the centre for oil extraction.
- A cold storage unit running on VAM chiller or other principle utilising hot water produced by solar thermal units. The cold

storage unit would help the local farmers to store perishable agro products, but would be installed only if the economics are favourable.

- A micro-financing section particularly for women in villages to encourage small activities such as sewing, cleaning, operating the Charkha, running a children's school, hiring/repairing bicycles, etc.
- Facilities for operating solar lamps on higher basis, also capable of operating small TV and mobile phone chargers.
- A tele-medicine facility to enable the village people to contact experienced doctors in selected hospitals using tele-facilities at the CSC.

A unique partnership is proposed to be set-up with villagers in this business such that the benefits of the venture are shared between the villagers and the company on an on-going basis. Substantial number of local employment jobs will also be created by the business.

(It has been further suggested that a turbo-generator capable of generating power from multiple sources of energy such as solar or biogas or bio-diesel may be developed and used. *For more details on the turbo-generator, please contact Mr Shishir Tamotia, at Tel.: 98198 89972)*

Item 3(3): Operate Garbage Collection Trucks on Renewable Energy or CNG Gas

An intriguing possibility exists of converting all vehicles engaged in solid waste collection to operate on some renewable energy source instead of using fossil fuels such as petrol or diesel which need to be imported into India.

During the II World War, we were innovative enough to use producer gas generated freshly in each truck by burning coal in a stove-like device. Now, we would not want to do that because it gives much CO_2. No fossil fuels should be used. Why not use a renewable source of energy if possible, in any one of the following two ways, or use CNG gas:

1. Convert biogas from waste treatment plants into electricity—and run electric trucks (not diesel ones) to collect and transport garbage to the final disposal site. (In some cities of India, excess biogas is merely flared and $CO_2$is released to the atmosphere.)

2. Run existing diesel trucks on 100% biofuels like Jatropha cultivated in farms located in the suburbs using the city's sewage.
3. Run existing garbage collection trucks on CNG gas which releases much less carbon than fossil fuels.

Item 3(4): Use Roofs to Generate Electricity and 'Feed-in' into City Grids

All city electric supplies are having shortage problems. Presently, government policy favours private parties willing to invest funds in providing 'solar photovoltaic panels' on roofs and other surfaces (so that additional land is not required) to generate electricity which can be fed into the city's electric grid system. The rate offered by the local authorities is attractive so as to make the investment feasible.

As stated in Chapter 6, a recent governmental ruling in India requires all electric supply companies and electric boards to have at least 5–7% of their energy supplied from renewable sources, and pay ₹18.50 per kWh for captive feed-in received by them from private sources. This makes feed-in an attractive proposition. (In Germany, the stipulation is 15% of energy must be from renewable sources.)

This should give a new push to installation of renewable energy systems for feed-in into the existing grids on private initiative in urban areas of power short cities. Incidentally, before feed-in, the electricity must be transformed into an alternating current of the correct voltage of the area using an inverter.

An interesting opportunity appears to present to us: There are many large roofs available:

1. The roofs of all sports stadia can improve our power position considerably. In Mumbai, there are three stadia (CCI, Wankhede and D Y Patil), and in Delhi there are several new ones because of the recent Commonwealth Games. There are so many others elsewhere. They can all be harnessed for a good public cause.
2. There are also large and long roofs over several railway station platforms, bus stations, industrial workshops, storage godowns, etc., which can be used.

If you have the area, but not the money, there are others willing to invest! Ask your friendly, neighbourhood expert or solar PV dealer or your bank to suggest some names. In the past, we had 'land-lords', but now one can become a 'roof-lord' if you have a roof to spare!

Contact: Mr A Contractor, MD, Kiran Energy, Mumbai, at Tel.: 022-23519189.

Item 3(5): Is there Life after Death? Create Some Natural Greenery from an Ugly, Abandoned Stone Quarry

Many 'Dead' Quarries Abound

Prof. Sharad Chaphekar, a renowned botanist–ecologist, says there are many 'dead' or exhausted quarries lying around in every state of India which can be converted into green areas, even forests in due course, helping reduce CO_2 in the atmosphere through photosynthesis, and possibly becoming eligible for earning 'carbon credits' from UN's clean development mechanism.

He has helped restore a 15-acre quarry in Pimpri, near Pune, as first reported in IEA Newsletter of November 1998.

How to Convert Dead Quarries into Living Ecosystems?

The magical requirements for achieving this transformation are just a few common sense items: Landscaping, nutrients, water and care.

Select grasses with creeping habit and spreading roots for holding on to thin soil on rock surfaces and in crevices and cracks. Hydro-seeding (i.e., spraying seeds soaked in nutrient suspensions) either with pumps and hose pipes or pouring a bucketful of seed suspensions on rough rock surfaces from upper rims of pits can give excellent results where other methods of plantation are not possible to use. Legumes mixed with grass swards supply nitrogen normally non-available to other plants.

Once grasses are established on the hostile stratum, other plants slowly follow according to the succession scheme of nature. Alternatively, extensive cultivation of desired plants is also possible, though at a higher cost. Inoculation of roots of plants with suitable strains of bacteria and fungi improve the viability of plants. And, once plants are well established, other members of the ecosystem—worms, insects, reptiles and birds—follow in course of time.

First Decide on End-use

It is necessary to decide first on the end-use of the restored quarry before landscaping can be finalised. The end-use popularly selected is recreational and educational parks. Sometimes, grasslands and pastures are created to suit the terrain. In one case where slate quarries existed, adventure sports facilities were created. A variety of end-uses can be created depending on the extent of area and type of terrain involved. If a dedicated forest can be created, one could perhaps apply for carbon credits under the clean development mechanism after some time.

For more details, contact:
Prof. S Chaphekar, Mumbai at Tel.: 9323243652.

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Finally, the author would like to acknowledge the great help received from time to time from the two newspapers, *The Economic Times* and *The Times of India,* whose daily papers carried several news items and articles of interest on the subject.

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Author's Profile

Professor Soli J. Arceivala pioneered the business of environmental consultancy in India in 1961, long before any legislation for pollution control existed. He founded the first consultancy company in India, called AIC, specializing in water and environmental engineering work. In 1993, the Company was purchased by an Anglo-American group and the name was changed to AIC Watson, then Montgomery Watson and presently, MWH, with Professor Arceivala remaining as Chairman and then Chairman Emeritus until 2001 when he retired.

Professor Arceivala holds a degree from Harvard University, USA, and is a member of several professional bodies. He was the Regional Adviser for Environmental Health with the UN / WHO Regional Office for Europe, and was later the Chief for WHO South East Asia Region, covering 11 countries. Before joining WHO, he was the Director of the National Environmental Engineering Research Institute (NEERI), Nagpur, Government of India.

He is involved in teaching, research and consultancy work. He pioneered water conservation and reuse in India in the mid-sixties and several plants for reuse of water have been built in India and the Middle East based on his designs. Every year, for 20 years, he had been invited to give lectures at IHE, Delft, Holland, on wastewater treatment. In recent years, he has worked on developing reuse of wastewater for augmenting lakes in India for public uses and exploring low-carbon and Green Technologies for environmental protection.

In 1998, he became the first Indian to be awarded, Distinguished Membership of the American Society of Civil Engineers, USA, in honour of his lifetime work in India and overseas. Several Indian organizations have also honoured him with awards. In 1993-94, Professor Arceivala was the President of the Indian Water Works Association and in 1996 he was the President of the Indian Environmental Association.

Professor Arceivala is the author of 6 books on Environmental Engineering and 1 on Global Warming. Out of the 3 books published by the McGraw Hill, one has been translated into Turkish and Iranian languages. His other books have been published by the Indian Water Works Association, The Indian Environment Association and Marcel Dekker, New York.