CUTS Centre for International Trade, Economics & Environment

Discussion Paper

Tapping the Untapped: Renewing the Nation

Focus on renewable sources especially solar energy

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Contents

List of Tables

List of Figures

Preface

Gradual changes in the earth's atmosphere are often the result of natural phenomena. However, human activities have led to a rapid increase in the pace with which these changes take place over the previous century. Over dependence on non-renewable resources, and lack of any check on gaseous and particulate emissions from combustion among many other features of current consumption patterns have disturbed the fine balance characterising the earth's environment and jeopardised its capacity to sustain life.

Two complementary pathways have been suggested, by scientists and environmentalists, to reduce human impact on climate: reduction in magnitudes of human consumption through limits on per capita levels as well as population growth; and a greater reliance on renewable sources at the expense of non-renewable ones. The advisability of the second pathway stems from the relative plenty of renewable sources such as sun and wave and wind power vis-a-vis non-renewable sources. On the one hand, overall human consumption has to reduce, which will require a check on the growing population and its needs. On the other hand, the resource base to provide for human needs can be shifted from non-renewable sources to renewable sources of energy. Renewable sources such as sun, water, tides, and wind are available in plenty but unlike conventional sources, there have not been exploited adequately.

This discussion paper focuses on the mentioned second pathway and addresses various problems caused by the usage of conventional sources of energy i.e. fossil fuels, and the benefits of increasing dependence on non-conventional/renewable sources for our energy requirements. More significantly, with special focus on the Indian economy, the paper evaluates economic viability of alternative sources of energy, especially solar energy and comes up with policy explanations on the basis of sound research and analysis. The argument to have an environmentally friendly resource base is strengthened by analysing the strengths and weaknesses of this sector, especially those of solar energy with respect to India.

Of course, this paper represents a pioneering effort in the field of research on the socio-economic impacts of energy generation for renewable sources. As the technology for such use becomes more efficient and economically viable, interest in such research and its utility is bound to increase. In that sense, this paper can be termed a forward looking exercise.

Jaipur
April 2010

Siddhartha Mitra
Head, CUTS Centre for
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& Environment

Chapter 1
Introduction

The *United Nations Climate Change Conference*, held in Copenhagen, in December 2009, generated high expectations in the months leading up to it. The meeting sought to finalise a new treaty for defining stringent emission reduction targets for the member nations and assume the role of the successor to the Kyoto Protocol. The Kyoto Protocol, an international environmental treaty which enforces legally binding commitments on ratifying nations to reduce greenhouse gas (GHG) emissions, is nearing its expiration in 2012.

The meeting was held with high expectations, but failed to make a significant contribution to climate change mitigation. Instead, in the course of the meeting and later, the world witnessed wide differences in opinion among various nations on related issues. Various groups of countries suggested accords, but none led to propositions that could be agreed upon unanimously.

In an overnight plenary on the last day of the conference, 28 key nations successfully reached what is being termed as the *Copenhagen Accord* and a decision to follow up the progress made in Denmark by meeting again in Mexico in 2010. This accord, which is a statement of political will, is a considerable departure from the earlier protocol and has not yet been accepted by many nations of the world.

A significant increase in use of renewable energy sources is needed to maintain the supply of energy at existing levels. However, initially, these cannot provide absolute replacement to the conventional sources of energy, but can substitute them gradually

Although the world leaders are in the process of finalising their decisions, a critical step taken in this conference is the consent by developed nations to transfer US$100bn by 2020 to developing nations for climate change mitigation. A significant proportion of these funds would be diverted to development of sustainable technologies, such as those utilising renewable sources of energy.

Non-renewable sources of energy have been the main contributors to pollution emissions worldwide. Moreover, the current heavy dependence on these resources enhances the gravity of the situation: enormous reductions are required for environmental sustainability. By the same token, a significant increase in use of renewable energy sources is needed to maintain the supply of energy at existing levels. However, initially, these cannot provide absolute replacement to the conventional sources of energy, but can substitute them gradually.

Among renewable sources such as sun, wind, ocean waves and tides, the sun is an important source of energy, especially in the tropical regions. Solar energy is found indirectly in fossil fuels. It has a vast potential to provide for all our energy needs such as heating, cooking, running automobiles and electricity consumption for domestic as well as industrial purposes.

Initiatives the world over to capture solar energy have been sluggish. Currently, this sector is not witnessing diversion of huge investments for technological development. What can be the possible reasons for leaving solar power untapped? What is still driving the global economy to use polluting fossil fuels when their depletion in the near future can be foreseen?

Specifically for India, which ranks among countries most vulnerable to climate change, the step forward to minimise and mitigate these effects needs extensive debate. Also, since it has a huge potential for solar energy, a moot question is regarding the Indian government's strategy to efficiently utilise this opportunity to develop a clean and sustainable economy.

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This paper attempts to analyse the global energy sector in terms of consumption and source-wise production. It goes on to examine the rationale behind the advocated switch to larger consumption of renewable resources from the current heavy dependence on non-renewable sources. Renewable energy, such as that from water, wind, biogas and the sun, presents a clean alternative and will obviously hold importance for the future trajectory of growth. The paper looks into the potential of these sources and the progress made globally to extract energy from alternative sources.

After studying the global situation, the paper discusses the case of India's energy sector and the strengths and the limitations of the solar energy sector in the country. More importantly, certain policy implications have been listed which are essential for bringing about a clean energy-based economy, with essential characteristics of sustainability and rapid growth.

Chapter 2

History of Resource Use

Natural resources, which refer to all resources owing their existence to natural phenomena, have been used to produce energy in various forms since the dawn of human civilisation. These resources include both renewable resources such as solar energy and water and non-renewable sources such as fossil fuels. Within the former, there are sources which are exhaustible such as groundwater – there is depletion of the resource stock if recharge is exceeded by use, implying possibilities of total exhaustion.

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The pattern of utilisation of the natural resources earlier followed was called the 'Cowboy Economy'. *Kenneth Boulding* coined this term to refer to the belief of conventional economists that the resources on planet earth were unlimited and inexhaustible.

Late 1700s and early 1800s witnessed the beginning of the industrial revolution, which thrived exclusively on use of (non-renewable) fossil fuels such as coal and petrol. In the race to meet the growing needs for industrial products and revolutionise global production and consumption patterns, the constraints arising from limited availability of fossil fuels were ignored. Conventional economists planned development on the belief that economy is an open system, a virtually limitless plane, where there is always some new space to move to[1].

Soon, economists and activists all over the world realised that such a pattern of growth was not sustainable. Boulding came up with the concept of 'Spaceship Earth' to emphasise that there were energy, material and environmental limits to economic growth. This highlighted the limits to growth generated by limited availability of non-renewable resources, which were hitherto heavily relied on for industrial production and direct consumption by households for their energy needs. In a spaceship economy, the focus is on reducing consumption and limiting extraction and pollution and, therefore, on resource stock maintenance[2].

Conventional economists planned development on the belief that economy is an open system, a virtually limitless plane, where there is always some new space to move to

Boulding's proposition was followed by other studies. One of the landmark studies was conducted by the Club of Rome, a group of eminent economists, sociologists, industrialists and scientists, which built a computer model to predict the limits on growth on the basis of high rates of population and economic growth.

These ideas brought about a change in the earlier mindset and heralded a wave of realisation that the resources which the world depends upon are depleting. National leaders have met repeatedly to address the grave situation facing them. They have signed protocols and agreements to contain the depletion of resources and degradation of environment: United Nations Conference on Climate Change, Convention on Biological Diversity, Montreal Protocol and Kyoto Protocol, to name a few, and the event in Copenhagen, Denmark in December 2009.

Chapter 3
Present Energy Scenario

Humans have developed technology to convert renewable and non-renewable resources into consumable energy to support industrial and domestic activities. With increasing industrialisation, overall energy needs have shot up drastically. Between 1996 and 2006, the world's total output of primary energy – from petroleum, natural gas, coal and electric power (hydro, nuclear, geothermal, solar, wind, and wood and waste) – increased at an average annual rate of 2.3 percent.

Table 1: World Marketed Energy Consumption by Country Grouping, 2006-2030

	Quadrillion Btu
Region	**2006**
OECD	241.7
North America	121.3
Europe	81.6
Asia	38.7
Non-OECD	230.8
Europe and Eurasia	50.7
Asia	117.6
Middle East	23.8
Africa	14.5
Central and South America	24.2
Total World	472.4

Source: International Energy Outlook, 2009.

Chapter 4

World Energy Production by Source

Fossil fuels (oil, natural gas and coal) constitute nearly 80 percent of the total commercial and non-commercial energy used in the world. Oil contributes the maximum to the global supply of energy

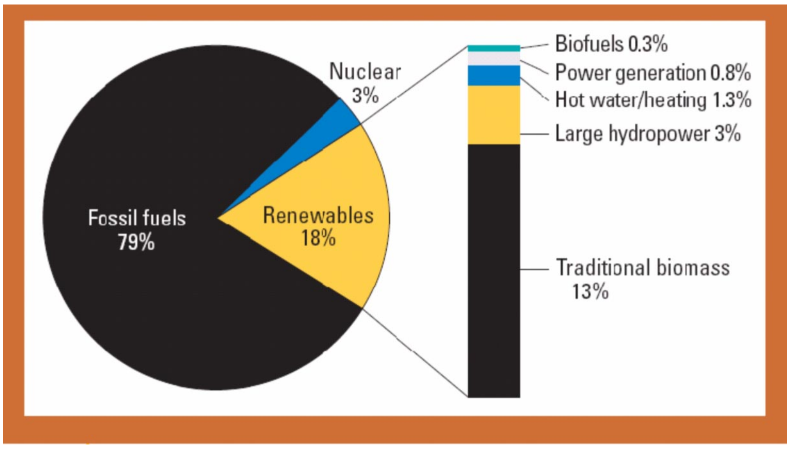
Fossil fuels (oil, natural gas and coal) constitute nearly 80 percent of the total commercial and non-commercial energy used in the world. Oil contributes the maximum to the global supply of energy (IEA, 2006). It alone accounts for 36.9 percent of world's primary energy production. In 2006, daily consumption of liquid fuels was as high as 85 million barrels (173 quadrillion Btu). Although the demand for these fuels has been hit due to global economic recession in 2008 and continued to dip in 2009, the earlier trends in consumption are expected to resume in the long term, as national economies recover.

Coal is the most abundant fossil fuel and is the next highest contributor to the world energy sector. It supplies around 26.5 percent of the world's primary energy supply (Key World Energy Statistics, 2009) and 38 percent of its electricity production. Another important non-renewable source is natural gas. Dependence on this source for the production of primary energy is approximately 21 percent. These three non-renewable resources are the world's significant energy suppliers. Nuclear power contributes 6.3 percent of the world's primary energy supply (Key Energy Statistics 2005).

Coal is the most abundant fossil fuel and is the next highest contributor to the world energy sector

However, some efforts made in the past have encouraged utilisation of renewable resources to meet energy requirements. Figure 1 depicts their position in the final energy consumption.

Figure 1: Renewable Energy Share of Global Final Energy Consumption, 2006



Source: Renewables 2007 Global Status Report.

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Traditional biomass is the largest renewable contributor to global final consumption, with its contribution as high as 13 percent. Large Hydropower, which refers to projects with energy production capacity of more than 25 MW, contributes the next highest share, followed by other sources such as the sun, wind, waves and tides and bio-fuels.

Non-renewable sources of energy are heavily depended upon to fulfil energy requirements arising from production and consumption activities

From the current trends, it can be clearly observed that non-renewable sources of energy are heavily depended upon to fulfil energy requirements arising from production and consumption activities. These resources have also been extracted in mass quantities from the earth to support energy requirements. The natural processes which produce these resources take billions of years and thus these cannot be practically replenished for many generations to come. Given their reckless extraction, prevention of their exhaustion at enormous cost to future generations seems unlikely.

Chapter 5
Why Should We Switch?

To support or oppose the ever growing opinion that non-renewable resources should be replaced by renewable ones, critical examination of the underlying justifications is needed. There are plenty of arguments, backed by scientific studies, which support the discontinuation of dependence on non- renewable resources, or at least its minimisation.

Threats of Depletion

The reserves of non-renewable resources are formed through natural process, in timescales that greatly exceed the length of human existence, in the presence of certain extraordinary geological conditions

Non-renewable sources of energy have evolved over millions of years of natural processes. These sources consist of geochemical concentrations of naturally occurring elements and compounds[3]. The reserves of non-renewable resources are formed through natural process, in timescales that greatly exceed the length of human existence, in the presence of certain extraordinary geological conditions. Thus, these reserves are 'non-renewable' in nature and are unevenly spread throughout the world.

Coal, crude oil and natural gas are the primary fossil fuels used to support human production and consumption activities. The global reserves of these resources are dwindling due to ever-growing demand and the characteristic of non-renewability. The World Coal Institute estimates that at current production levels, proven coal reserves would last 122 years and proven oil and gas reserves around 42 and 60 years, respectively[4]. In 2006, the head of the world's largest oil company, Saudi Aramco, said:

"We are looking at more than four-and-a-half-trillion barrels of potentially recoverable oil. That number translates into 140 years of oil at current rates of consumption, or to put it anther way, the world has only consumed about 18 percent of its conventional oil potential[5]".

The World Coal Institute estimates that at current production levels, proven coal reserves would last 122 years and proven oil and gas reserves around 42 and 60 years, respectively

However, various economists all over the world claim otherwise. American Geophysicist M. King Hubbert's Peak theory predicted that that the global oil production would peak in 1995. This theory proves that after reaching its peak, production will start to decline. But in 1980s, due to a drop in oil consumption due to oil shocks and introduction of fuel efficient cars, this prediction was revised to 2004 by ASPO and then again to 2010. These estimates depend on the 'patterns of consumption' and thus keep changing. At the current rate of world consumption, these would be exhausted in about 36 years[6]. To summarise, the proposition that the world is approaching exhaustion of fossil fuels is not a baseless assumption.

Hazards

The spillover effects of combustion of fossil fuels are enormously high. The effect is worsened because they cannot be limited to geographical boundaries. The effects spread throughout the world, making the high and low domestic emission countries suffer equally. Carbon and other GHG emissions are raising the earth's temperature, melting ice caps, causing holes in the ozone layer and other enormous as well as irrevocable changes in the earth's climate. These effects are global, with strong local indications of worsening living conditions on earth.

Greenhouse Gas Emissions

The most severe impact on global climate change is due to combustion of fossil fuels. In Table 2, the carbon emissions of fossil fuels and that from cement manufacturing and gas flaring have been compared. It shows that though all three processes emit carbon, burning of fossil fuels exhibits the highest contribution and thus is the most important cause of deterioration in the global environment. The trends in table 2 also highlight progressive increase in the use of these fuels over time.

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During the late 1800s and early 1900s, when the industrial revolution spread throughout Europe, UK and North America, the heavy input of fossil fuels to global carbon emissions increased by a factor of ten, i.e. from 54 million metric tonnes in 1850 to 534 million metric tonnes in 1900. In 1929, marked by the beginning of the Great Depression, the level of carbon emissions reached a level which was double that seen in 1900.

1950 onwards, when many third world countries attained their independence and started treading the path of growth, carbon emissions soared to alarming levels within a period of 50 years. Not only have

Table 2: Global Carbon Emissions from Fossil Fuel Burning, Cement Manufacturing and Gas Flaring[7]

		Carbon Emissions				
Year	**Total Carbon Emissions from Fossil-fuels (million mt of C)**	**Consumption**			**Cement Production**	**Gas Flaring**
		Gas fuel	**Liquid fuel**	**Solid fuel**		
1800	8	0	0	8	0	0
1850	54	0	0	54	0	0
1900	534	3	16	515	0	0
1929	1145	28	160	947	10	0
1950	1630	97	423	1070	18	23
1960	2577	235	849	1410	43	39
1970	4076	516	1839	1557	78	87
1980	5332	740	2427	1958	120	86
1990	6144	1026	2525	2397	157	40
2000	6735	1291	2831	2339	226	48
2006	8230	1521	3108	3193	348	59

carbon emissions increased due to the production of goods but also due to consumption by the households, directly as a domestic or vehicular fuel or indirectly due to the use of newer technology to support modern lifestyles. The current emission levels stand at 15 times the carbon emissions at the break of the previous century.

Other activities like cement production and gas flaring also involve carbon emissions. But, their contribution remains insignificantly small, when compared to that of fossil fuels.

Excessive greenhouse emissions can make the earth uninhabitable. Complete combustion of fossils is not a feasible solution for long

Incomplete combustion of conventional fuels leads to air pollution, which destroys the environment. Complete combustion is no lesser an evil. It produces GHGs like CO_2 and water vapours, which trap solar rays and heat earth's atmosphere to more than required temperatures. Excessive greenhouse emissions can make the earth uninhabitable. Thus, as was proposed earlier, complete combustion of fossils is not a feasible solution for long.

To meet target reductions in GHGs, all nations have to change resource usage patterns and rely more on alternative sources of energy. These alternative or renewable sources such as sun, wind, ocean waves and tides are present in nature in virtually unlimited amounts. Geothermal and tidal energies have been present in the nature in unrestricted amounts and are unlikely to be depleted by human consumption.

Climate Change

Over the last few centuries, persistently increasing production and consumption has led to a severe and observable impact on climate. Climate change refers to phenomena such as rising global temperatures, changes in rain pattern leading to floods or famines, melting of glaciers, rising sea levels and depletion of ozone layer. It is the result of emissions of GHGs, carbon and other pollutants above the limit that can be absorbed by the earth's atmosphere. The challenges posed by climate change have reached critical levels.

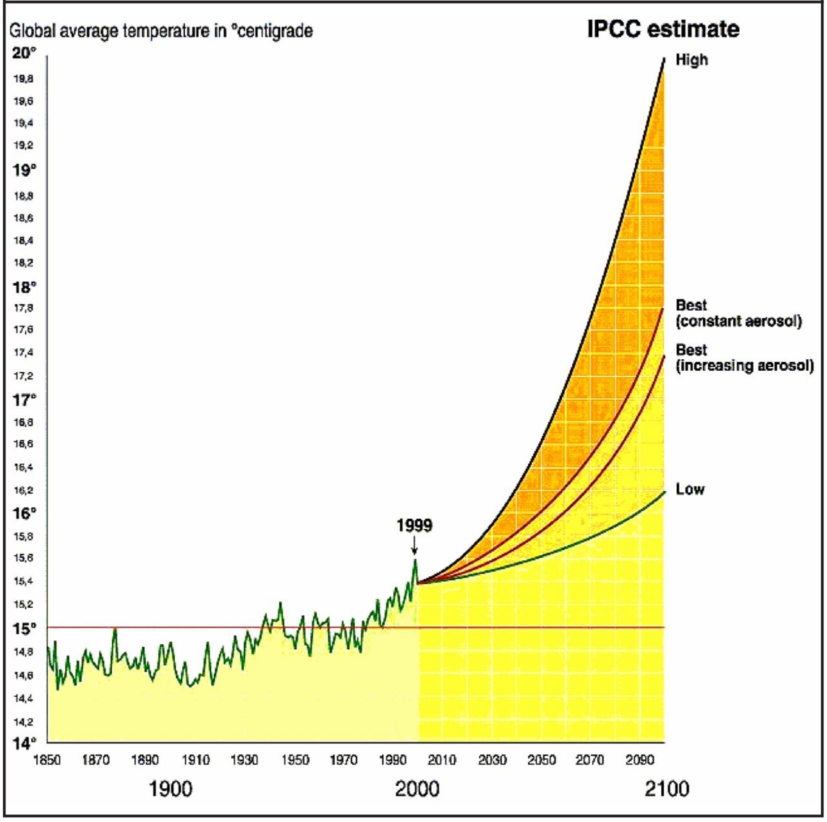
The Organisation for Economic Cooperation and Development (OECD) report states: *"We are facing a policy challenge as urgent, difficult and far-reaching in its implication as any in our history. All major global ecosystems are in decline. Likewise, world scientists published an unprecedented warning to humanity[8]"*

Climate change refers to phenomena such as rising global temperatures, changes in rain pattern leading to floods or famines, melting of glaciers, rising sea levels and depletion of ozone layer

The data collected by Intergovernmental Panel on Climate Change (IPCC) and many other environmental agencies and meteorological departments show a strong case of environmental deterioration through rising global temperatures.

Figure 2 depicts observed changes in global temperature from 1850-2000 and future projections till the turn of the next century. Empirical observations reveal that the global temperature increased by 0.8^{O}C during 1850-2000. The predictions for the future indicate a steeper rise. Climate models calculate that the global mean surface temperature could rise by about 1 to 4.5 ^{O}C by 2100[10]. As mentioned earlier, rising temperatures, leading to rising sea level, increasing wildfires, depleting ecosystems and ozone layer depletion, is exposing the world to extreme danger.

Figure 2: Projected Changes in Global Temperatures[9]



Health Hazards

The earth's climate is an intricate combination of various elements necessary for the survival of humankind. But, this natural balance has been disturbed due to excessive human interference. Reckless use of natural resources has a two-pronged impact – resource extinction and rising health hazards due to pollution. Large scale and global environmental hazards to human health include climate change, stratospheric ozone depletion, loss of biodiversity, changes in hydrological systems and the supplies of freshwater, land degradation and stress on food-producing systems.

Large scale and global environmental hazards to human health include climate change, stratospheric ozone depletion, loss of biodiversity, changes in hydrological systems and the supplies of freshwater, land degradation and stress on food-producing systems

Increased CO_2 in the environment also poses grave health hazards. Respiratory diseases such as hay fever and asthma are feared to increase with the rise in global warming. Also, increased circulation of airborne allergens, such as pollens, due to more abundant growth of plants is expected to cause such ailments. Higher pollutant emissions in industrialised nations have had a substantial impact on people with asthma, chronic bronchitis, allergies and heart conditions.

In developing countries, rising temperatures and humidity have facilitated the spread of many vector-borne infectious diseases, including malaria, dengue and food-borne infections (e.g., salmonellosis) which peak in warmer months. Such diseases impose pressure on the already short supply of health facilities in these nations. Spread of infectious diseases is also hard to curb within the geographical boundary of originating nations because of increased international travel. One such example is the global spread of swine flu.

On the basis of research, the World Health Organisation (WHO) estimates that around 150,000 deaths now occur in low-income countries each year, with young children making up almost 85 percent of these excess deaths, due to the effect climate change has on crop failure and malnutrition, diarrhoeal disease, malaria and flooding[11].

Moreover, the populations exposed to greatest health risks are those living on small-island developing states, mountainous regions, areas with poor access to water, huge cities and coastal areas in developing countries. The poor, especially those lacking access to health services, are among the worst hit.

The usage of non-renewable resources is not only leading to environmental and health problems for the present generation but also carries over a huge burden for future generations

Burden for Future Generations

The usage of non-renewable resources is not only leading to environmental and health problems for the present generation but also carries over a huge burden for future generations. There exists a trade-off between access of present and future generations to conventional sources of energy, i.e. higher extraction in present leaves lower reserves for the future. The rate of extraction needs to be maintained below the maximum sustainable yield to prevent extinction of resource stocks.

Unchecked pollution generated by the current generation would also worsen the environmental conditions enjoyed by future generations. The submergence of land, which is another adverse consequence of increasing global warming, would jeopardise the survival of growing populations.

Chapter 6

Alternative Energy

Owing to the furore raised by environmentalists, activists and concerned citizens on the basis of observations by researchers and scientists regarding severe irrevocable harm to the earth caused by the use of conventional sources of energy, there is a widespread consensus to limit their use and identify alternative sources which can support economic growth, without leading to deteriorating environmental and living conditions.

Renewable sources of energy have been widely available for as long as earth has existed. Solar radiations are responsible for the energy stored in fossil fuels

Renewable sources of energy have been widely available for as long as earth has existed. Sun's rays provide energy for plants and heat for human beings and animals for their survival. Solar radiations are responsible for the energy stored in fossil fuels. The enormous power stored in wind and water becomes evident with the fierceness of tornadoes and cyclones. These sources – some exhaustible such as groundwater, etc., and others inexhaustible such as the sun – are more viable than non-renewable resources and their pollution-free existence implies that their greater use would halt climate change, which would otherwise be inevitable.

But even though renewable and inexhaustible resources are available aplenty, their utilisation for energy production depends upon the economic viability of production processes and distribution. For this purpose, a detailed in-depth analysis of the availability of resources, costs of extraction of the new non-conventional sources of energy and associated benefits is required.

Chapter 7

Potential and Progress

In 2007, more than US$100bn was invested for establishment of manufacturing plants and enhancement of research and development (R&D) in drawing energy from sustainable sources

As discussed earlier, renewable sources of energy exhibit better availability than fossil fuels. Renewable resources contributed approximately 13 percent to the world's total primary energy supply (TPES) in 2007 (Key World Energy Statistics 2009). This share has been growing with increased investments being made for the development of renewable energy. In 2007, more than US$100bn was invested for establishment of manufacturing plants and enhancement of research and development (R&D) in drawing energy from sustainable sources. The annual investment grew to US$120bn in 2008. However, the potential use of renewable sources remains much higher than the current rates of exploitation. Analysis of the potential of individual renewable energy sources has been given below.

Hydro-energy

Hydro-energy is heavily relied upon for electricity generation in many countries across the world. In 2007, around 15.6 percent of electricity was generated globally using hydro-energy. However, it accounted for only 2.2 percent of TPES (IEA 2009). It is the biggest renewable contributor to electricity generation.

Global installed capacity for power generation through large hydropower (individual project capacity higher than 25 MW) is 860 GW and through small hydropower is 85 GW. This was increased by another 25-30 GW in 2008. The gross theoretical capability of the whole world, as reported in 2005, was greater than 41,202 TWh/year. However, with the current technology, only around 17,000 TWh/year is exploitable[12]. This sector witnessed an investment of US$15-20bn in year 2007.

Wind Energy

Wind can provide 12 percent of the world's electricity supplies by 2020, even after providing for the projected rise in world electricity demand by two-third by that year

Wind energy is a significant and powerful resource. It is safe, clean and abundant. According to a study, "Wind Force 2020", conducted by the European Wind Energy Association and Greenpeace, wind can provide 12 percent of the world's electricity supplies by 2020, even after providing for the projected rise in world electricity demand by two-third by that year. This would require installation of 1250 GW of wind power.

This resource has vast reserves. According to one of the estimates, it has the capacity of one million GW for 'total land coverage' (in case of ground mounted solar panels)[13]. If only one percent of the area was utilised, considering the lower load factors of wind plant (15-40 percent), the wind-power so generated could correspond to the total worldwide capacity of all electricity-generating plants[14].

There has been significant progress in the wind energy sector. The technological developments in this field have resulted in wind turbines, which are more modular and easy to install. Modern wind turbines can produce two hundred times more power than its equivalent two decades ago[15]. By 2004, wind energy had reached a global installed capacity of 48 GW. This capacity rose 250 times to 121 GW by 2008. Wind energy also attracted the most investment globally in 2008, i.e. US$51.8bn[16]. But, these account for only around 1.5 percent of global electricity consumption.

Wind energy not only augments the energy supply of the world but also cuts emissions drastically. Global carbon emissions could be cut 10 billion tonnes by 2020 with the use of wind energy

The cost of wind power has also fallen drastically by more than 80 percent over the past 20 years (till 2000)[17]. The cost of producing wind energy depends upon the speed of wind. The cost also goes down with the size of the turbine. The taller the turbine tower and larger the area swept by the blades, the more powerful and productive it is, and thus lower the cost.

Wind energy not only augments the energy supply of the world but also cuts emissions drastically. Global carbon emissions could be cut 10 billion tonnes by 2020 with the use of wind energy[18].

However, wind energy cannot be considered a candidate for becoming the primary substitute for conventional sources of energy as the average intensity of wind currents fluctuate considerably over time and, thus, wind energy cannot be relied upon to produce a significant share of the energy requirement of the country at all times of the year. The same constraint is not faced by solar energy, as the aggregate amount of solar energy received by the country at any time, irrespective of the season of the year, is enough to meet the country's energy requirements. It is only the technology for tapping solar energy which needs improvement so that it becomes economically viable.

Bio-energy

Bio-energy contributes a significant portion to the total primary energy supply of the world. It consists of the energy from vegetable matter and covers a variety of fuels such as wood fuels, biomass, ethanol and bio-diesel. These constitute the category of combustible renewables. Combustible renewable supply contributes approximately 10 percent to total primary energy supply of the world.

Bio-energy contributes a significant portion to the total primary energy supply of the world. It consists of the energy from vegetable matter and covers a variety of fuels such as wood fuels, biomass, ethanol and bio-diesel

It is mainly used as a fuel for final consumption, rather than an intermediate input for producing other forms of energy. This can be inferred from the small share of electricity produced using bio-fuels in total generation, which is just a fraction of the total share of 2.6 percent of renewable sources other than water, whereas biomass (including industrial wastes) accounts for 12.4 percent of the final consumption of fuels.

Investment in this fuel is decreasing every year as against rising trends of investment observed in other renewable sources. The investment in biomass decreased from US$10.6bn in 2007 to US$7.9bn in 2008, which denotes a 25-percent decrease. Similarly, bio-fuels also witnessed negative growth of nine percent in investment.

Solar Energy

Solar energy is the most abundant source of energy. It is available directly in the form of solar heat and indirectly in other forms of energy such as fossil fuels, wind, biomass and hydropower

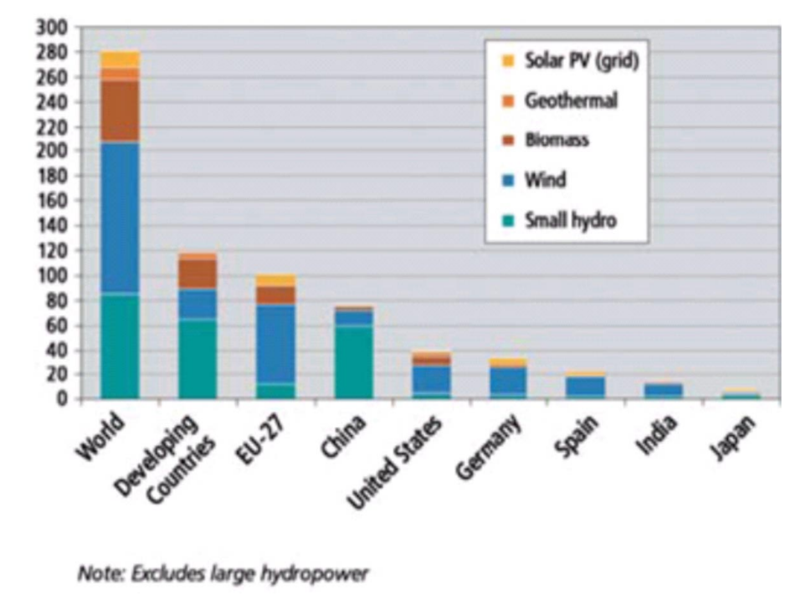
Solar energy is the most abundant source of energy. It is available directly in the form of solar heat and indirectly in other forms of energy such as fossil fuels, wind, biomass and hydropower. According to the World Energy Council Report (2007), the earth annually receives solar radiations which are 7500 times the world's primary energy consumption. As is the case with other sources of energy, availability of solar energy is also skewed, with tropical regions receiving higher radiations. However, useable amounts of solar energy are available virtually in all parts of the world[19].

Presently, solar power contributes only a small fraction of the energy from renewable sources, which itself is a small part of the total energy produced in the world. However, grid connected solar photovoltaic (PV) is the fastest growing power generation technology in the world, with 50 percent annual addition to cumulative installed capacity in 2006, 2007 and 2008. At such a pace, solar energy (both grid connected and off-grid PVs) is expected to account for more than 10 GW by 2010.

Annual installations for solar PVs reached more than 4 GW worldwide in 2008, a fourfold increase from four years earlier, when the solar PV market reached the one GW milestone for the first time. Solar heating, which is done through solar thermal collectors, is also growing as a means of utilising solar energy. The solar hot water capacity in 2006 reached 105 gigawatts-thermal (GWth), which was an increase of 19 percent over the previous year.

An additional investment of US$33.5bn was made in solar energy sector in 2008, which was a 49-percent growth over the previous year. But, this sector needs a higher amount of investment to utilise the immense capacity to generate electricity and provide heating as well as cooling.

Figure 3: Renewable Power Capacities, Developing World, EU and Top Six countries, 2008



Chapter 8
Case Study: India

India's energy requirements have been growing due to the fast pace of its development. In earlier stages of its development, India's energy intensity was as high as twice that of OECD nations, which indicates high inefficiency in conversion of energy to gross domestic product (GDP). However, it has been declining since 1990s, which signifies improvement. It is second (after Brazil) on the list of energy efficient countries among the Brazil, Russia, India and China (BRIC) nations[20].

India's total commercial energy consumption is expected to increase to 7.5 times of 2001 levels. India currently ranks as the world's eleventh-largest energy producer

Along with the improvement in energy efficiency, there has been a continuous growth in demand for energy. The final consumption of electricity in 2006 was 505577 GWth[21]. According to The Energy and Resources Institute (TERI), by 2030, India's total commercial energy consumption is expected to increase to 7.5 times of 2001 levels. India currently ranks as the world's eleventh-largest energy producer, accounting for about 2.4 percent of the world's total annual energy production and as the world's sixth-largest energy consumer, accounting for about 3.3 percent of the world's total annual energy consumption[22].

Energy Base

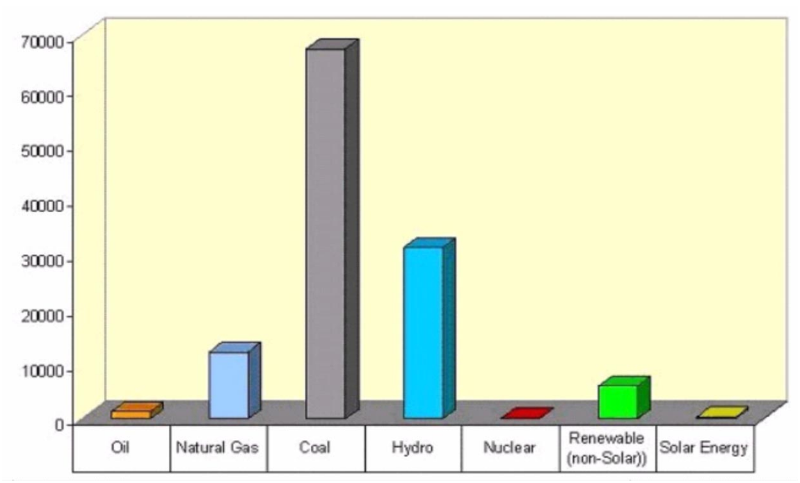
India mainly depends on coal for fulfilling its energy requirements. In 2006, approximately 68 percent of the electricity produced in India was done using coal reserves. India has vast coal reserves, which make it the world's third-largest producer of coal. Till 2005, it was also the third-largest consumer of coal. These figures may be close quantitatively, but the reserves available in the country have a high ash content, which makes it environmentally hazardous, when burnt for domestic and industrial purposes.

In the same year, India was the sixth-largest oil consumer in the world. Even after global recession began and oil prices rose to more than US$140 per barrel, the demand for oil did not fall in the country. Although the consumption of oil has risen, the production of the same has not increased at the same pace. About 30 percent of India's energy needs are met by oil and more than 60 percent of that oil is imported. Huge quantities of oil imports are leading to increasing import bills which are eating away the export earnings of the country.

India mainly depends on coal for fulfilling its energy requirements. India has vast coal reserves, which make it the world's third-largest producer of coal. Till 2005, it was also the third-largest consumer of coal

Natural gas also forms an important constituent of the country's fuel base. Known reserves of natural gas in India are expected to increase due to the efforts of the Government of India in deep-sea exploration and improved viability of extracting natural gas from gas hydrates[23]. Natural gas is consumed in great quantities as an automobile fuel (CNG), as an input for fertiliser production and in the power sector. According to 2005 data, India has nearly 0.5 percent of the world's known natural gas reserves.

Figure 4: Energy Consumption in Power Sector, 2005



Source: Global Energy Network Institute

Renewable Resource Portfolio of India

India, like most of the other nations of the world, depends highly on conventional fossil fuels for meeting its energy requirements. But, it has huge untapped energy potential in the form of renewable resources.

Renewable energy supplied nearly one-third of India's energy needs in 2005, i.e. a total of 3700 MW of energy is being derived from renewable sources. Most of this energy was from traditional biomass and the second-most important source was hydro-power

Table 3: Available Amounts of Renewable Resources in India

Source/System	**Estimated Potential**	**Cumulative installed capacity***
Hydroelectric power+	242,700 MW	1,48,701 MW
Small hydro (up to 25 MW)	15 000 MW	1705.63 MW
Wind power	45 000 MW	3595 MW
Biomass power	16 000 MW	302.53 MW
Biomass gasifiers	—	66.35 MW
Bagasse cogeneration	3500 MW	447.00 MW
Waste to energy		
• Municipal solid waste	1700 MW	17 MW
• Industrial waste	1000 MW	29.50 MW
Solar photovoltaic power plants	—	1566 kWp
Solar water heating systems	140 million m2 of collector area	1 million m2 of collector area

** as on 31 March 2005, data from Centre for Wind energy Technology (C-WET), Chennai*
+ Data from Central Electricity Authority, Ministry of Power, Government of India

Traditional biomass has remained important because of the availability of agricultural and animal wastes in rural areas. India stands second after China in use of biogas plants. Other solid wastes which pose a problem of disposal in urban areas can also be utilised for producing biogas (gasified form of biomass). Biomass provides fuel for cooking in rural homes and can also be converted into biogas to produce clean fuel. The waste from the biogas plants can serve as fertiliser for agricultural fields.

Biomass provides fuel for cooking in rural homes and can also be converted into biogas to produce clean fuel. The waste from the biogas plants can serve as fertiliser for agricultural fields

Moreover, countries are also insisting on production of biomass-derived fuel, ethanol and biodiesel from Jatropha plant seed, as alternative environment-friendly transportation fuels. The Government of India has developed an ambitious National Biodiesel Mission to meet 20 percent of the country's diesel requirements by 2011-2012[24].

Large hydro-power, through the construction of dams, has been identified as a driver of inclusive growth since independence, due to their location in interior areas and benefits such as availability of irrigation channels, flood control, drinking water supply and facilitation of pisciculture. Moreover, generation of hydro-power is non-polluting and more efficient (over 90 percent) than other means such as coal (35 percent) and gas (50 percent). 15.4 percent of domestic electricity is generated through hydro-power plants. In Table 3, it can be observed that India can produce approximately 250000 MW of energy (large, small, mini and micro-hydel schemes combined), but only around 20 percent of such potential has been harnessed so far.

Wind energy has grown impressively in the past decade, with installed capacity rising from 1220 MW in year 2000 to 10242.3 MW as on March 31, 2009[25]. India was the Asian leader in wind energy, but China took over its position for the first time in 2008. India ranks as the world's fifth-largest producer of wind energy, by accounting for 6.57 percent of total wind energy produced in the world[26]. This installed capacity is only 23 percent of the total estimated potential of wind energy in India.

India was the Asian leader in wind energy, but China took over its position for the first time in 2008. India ranks as the world's fifth-largest producer of wind energy

India receives solar energy equivalent of 5,000 trillion kWh per year, i.e. 600 TW, which is far more than the total energy consumed annually. This is also much more than the potential of other renewable and non-renewable resources available in India. Out of this, only a cumulative capacity of 2 MW has been installed till March 2009. Thus, the exploitation of this energy source needs to enable driven investments to reach efficient utilisation levels. Varied uses of solar energy, such as water heating, space heating/cooling, solar cooking and electricity generation, increase its scope and significance. The solar water heating potential of India is about 140 million square metres of collector area of which only 2.30 million m^2 is currently being utilised (2008 MNRE data).

Strengths of Solar Energy

Although all renewable resources have a critical role to play in developing cleaner energy, solar radiations, as a renewable source, become clearly more important due to the following benefits:

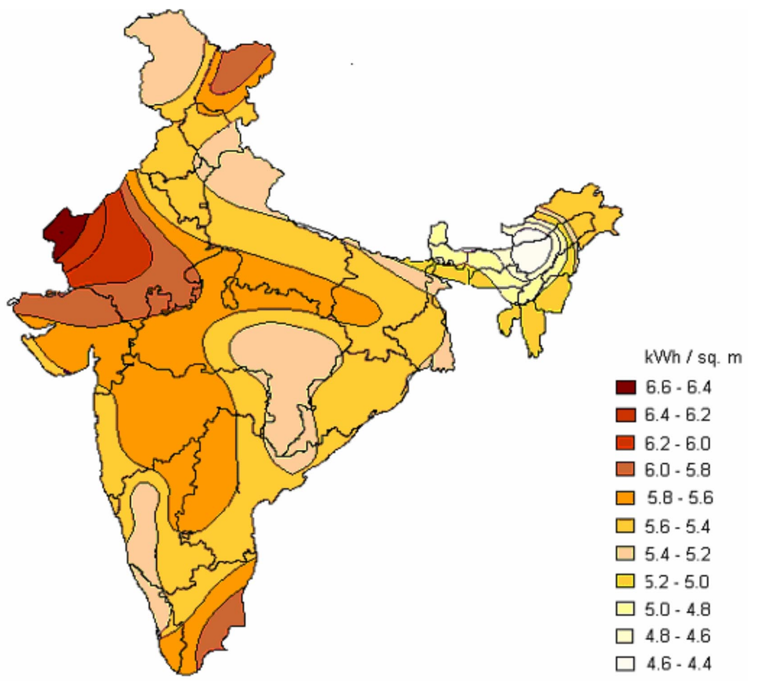
1. Production of electricity from solar energy is non-polluting and does not generate water or gases as residue, because it does not involve any combustion.

2. Over their lifetime, solar panels generate nine to seventeen times the energy required to produce them[27].
3. Solar energy can be stored for future use by attaching batteries to solar panels.
4. Unlike non-renewable sources of energy, solar power involves no fuel cost for production of power. Also, it does not involve raw material transportation cost. Thus, only one time installation cost has to be incurred.
5. It is a flexible source of energy. Any increase in demand can be met by installing more solar PV panels.
6. Solar energy does not have any harmful environmental impact. Solar panel systems do not emit carbon dioxide or other greenhouse gas while producing energy[28].
7. Unlike hydropower projects, solar projects do not cause forced migration for the inhabitants of project sites. Thus, power generation through solar projects does not generate negative social impact.
8. Solar panels are less space consuming in case of roof-mounted and wall-mounted panels, as against wind mills, which occupy large piece of land and also need to be located in wide open areas where strong wind currents can rotate turbine blades at a high speed to generate power.

Benefits to India

Being a tropical country which has an average of 250-300 sunny days per year, India's potential to generate power from solar radiations is substantially higher than that from other renewable sources of energy. The subcontinent also has a high potential for wind energy, but this entails a high requirement for land, as compared to roof-mounted solar panels, patio covers and solar walls, which are installed on those surfaces of buildings which are exposed to the sun.

Figure 5: Solar Radiation Map of India



Source: The Energy and Resources Institute (TERI), India[29].

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Also, almost all parts of the country receive solar radiations. This helps in generation of electricity locally and thus reduces distribution cost as well as loss of electricity in transmission over long distances. Moreover, it helps in electricity generation in remote areas, which may otherwise not be connected to energy supply grids. Figure 5 shows the availability of solar radiations to various parts of India.

The Indian states of Rajasthan and Gujarat and parts of Ladakh regions receive the highest incidence of global radiations. Parts of Andhra Pradesh, Maharashtra and Madhya Pradesh receive larger amounts of radiation than countries such as Japan, US and those in Europe, which have invested the most in developing and deploying solar technologies.

India has a high potential for utilising wind energy and vast investment resources are being diverted for the development of this sector. But, in a densely populated country such as India, it is difficult to find spare land for wind energy generation, which is largely empty – a pre-requisite for generation of wind energy[30].

Solar energy can also provide heat for cooking. This can reduce the traditional dependence on biomass by the rural Indian masses, which use biomass more often for direct combustion than in its gaseous form

Solar energy can also provide heat for cooking. This can reduce the traditional dependence on biomass by the rural Indian masses, which use biomass more often for direct combustion than in its gaseous form. The dependence on combustible renewables and wastes in India can be ascertained from the fact that share of renewables in total primary energy supply reduces drastically from 39.4 percent to 1.2 percent upon the exclusion of combustible renewables and wastes (2003 data). The combustion of biomass releases toxic gases which pose risks of suffocation and prolonged respiratory problems, especially when used indoors as a fuel for cooking.

Thus, solar energy is a more dependable source of energy for a tropical country such as India and practically has no unwanted impact on the society and environment.

Cost Analysis

Though solar energy displays huge potential for energy generation in the form of both heat and electricity, the economic viability of harnessing solar energy depends upon the capital cost and per unit cost involved in the generation of power from this source.

Table 4 illustrates the cost involved in utilising renewable sources of energy in India. The third column of the table shows the initial capital cost involved in installation of unit capacity for power (MW) generation from renewable sources, whereas the fourth column lists the estimated variable per unit cost of generation (KWh).

Table 4: Cost of Electricity Production Using Various Renewable Resources[31]

Sl. No.	Source	Capital Cost (Crores of Rs/MW)	Estimated Cost of Generation Per Unit (Rs./kWh)
1.	Small Hydro-Power	5.00-6.00	1.50-2.50
2.	Wind Power	4.00-5.00	2.00-3.00
3.	Bio-mass Power	4.00	2.50-3.50
4.	Bagasse Cogeneration	3.5	2.50-3.00
5.	Bio-mass Gasifier	1.94	2.50-3.50
6.	Solar Photovoltaic	26.5	15.00-20.00
7.	Energy from Waste	2.50-10.0	2.50-7.50

Source: Planning Commission Report, 2005.

The variable unit cost of production in the case of coal fired thermal energy is around Rs 2-6. Gas-based generation costs higher at around Rs 4-5 a unit, while liquid fuel-based generation costs over Rs 7 a unit[32]. As against this figure, solar PVs generate power at a much higher cost of Rs 15-20 per unit in 2005. Moreover, the initial capital cost involved in solar power generation is as high as Rs 26.5 crore per MW.

As can also be observed from the table 4, solar power is much more expensive than other sources of renewable energy. On comparing the capital costs involved in extracting energy from a renewable source in India, biomass (gas, co-generation and power generation) is the best source, which is followed by energy from waste, wind power and hydro-power. Moreover, all other renewables cost in the range of Rs 1.50-3.50 per KWh, much cheaper than solar power.

With improved R&D in solar technology, efficiency will improve and the cost will reduce. Over the next ten years in their solar energy facilities in India

However, in the long run, the price of solar power can be brought down drastically and increased demand for power can be met with a smaller investment in installation of more solar panels in the same grid setup. With improved R&D in solar technology, efficiency will improve and the cost will reduce. India's largest PV cell and module maker, Moser Baer Photovoltaic Ltd. (MBPV), plans to invest US$5bn over the next ten years in their solar energy facilities in India.

The rigorous research and development which is being carried on in this sector is expected to bring the unit variable cost to Rs 4-6 per unit from the current Rs 12-14 per unit (2008) in the next 3-5 years. The investment cost per unit capacity (MW) is expected by industry leaders to come down from US$5.5-7mn to a low US$2.5mn over the next ten years[33].

Weaknesses of Solar Energy Sector

The growth of this sector has been obstructed by certain factors:

1. The recessionary trends in the world have made industries defer their investment in R&D and installation of green technology, given the high per unit and capacity creation costs associated with solar power. Solar power generation has been affected in recession hit countries such as the US. This is despite the interest of customers in buying green technology, because they are unable to afford it

due to tight credit policies and concerns for personal finances[34]. This, in turn, poses a serious obstacle to scaling up of solar energy generation systems and eventual reduction of cost with economies of scale.

Moreover, the benefits of solar energy are spread over a long period of time and thus the present discounted value of net benefits may not seem so attractive. This dampens the will and efforts to install these systems.

The benefits of solar energy are spread over a long period of time and thus the present discounted value of net benefits may not seem so attractive

2. This sector is currently subsidy-driven. The Ministry of New and Renewable Energy subsidises the solar power produced in the country. The policies which have been devised by the government subsidise the solar power suppliers to the extent of Rs 10-12 per unit (KWh) of electricity produced[35]. This will create an additional burden on the exchequer and, in turn, lead to higher taxes.

   Government subsidies also tend to distort economic signals. Moreover, as has been observed in the energy sector, in the long term, subsidies can lead to inefficiencies of operation because of assured aid from the government. At the consumers' end, it may induce wastage and over-consumption.

3. Current solar photovoltaic technology has a big technological flaw, i.e., low capacity factor (load factor). Capacity factor is the ratio of actual energy produced by a power plant in a given period of time to the energy it would have produced if it had functioned at its full capacity the entire time. Current solar PVs exhibit only 12-15 percent capacity factor, whereas wind farms exhibit a 20-40 percent capacity factor and hydro-power plants 30-80 percent. Large coal plants have a reported capacity factor which is as high as 70-90 percent. Thus, initiatives to harness solar energy, as compared to those for harnessing conventional and non-conventional sources of energy, are limited[36].

4. Production of solar panels, if not regulated by pollution control authorities, may leave a dirty trail behind over the life cycle of energy production. These emissions can be attributed to mining of quartz sand (for silicon PV) and metal ore (for CdTe PV), production of material for solar cells, modules and apparatus through smelting and other processes and the input of energy from coal-fired power plants in production facilities. Thus, if the carbon footprint of PV production is not checked, then even though they reduce emissions by 90 percent, they may still pose environmental threats at a later stage. Also, innovation for using more environment-friendly inputs for solar cell and component production is critical.

Recognition of the renewable energy sector as a Priority Sector by the Reserve Bank of India is a critical step which has helped in creation of a strong manufacturing base, backed by International Industrial Partnerships (IIPs)

Initiatives for Solar Power Generation

Recognising India's huge potential of solar power generation and the urgent need to ensure development with the smallest possible carbon footprint, the government has provided several fiscal and financial incentives to encourage the installation of solar power systems. Recognition of the renewable energy sector as a Priority Sector by the Reserve Bank of India is a critical step which has helped in creation of a strong manufacturing base, backed by International Industrial Partnerships (IIPs)[37]. These incentives include capital/interest subsidy, nil or reduced excise and customs duties, tax waivers on profits earned and low interest bearing loans. The various provisions of the government to support the growth of solar energy in India are listed in table 5.

Table 5: Government Schemes for Solar Energy

S. No.	Scheme/Programme	Central Financial Assistance Provided
1.	**Remote Village Electrification: Electricity generation/lighting systems for households in remote un-electrified census villages/hamlets**	90 percent of the cost of electricity generation systems subject to a pre-specified maximum amount for each technology and an overall ceiling of Rs 18,000 per household 100 percent cost of a single light SPV home lighting system for BPL households
2.	**Solar Photovoltaic (SPV) Systems** SPV lanterns	• Rs 2400 for NE and special areas; nil for other • 100 percent cost of one SPV lantern for school going girl child of BPL family during entire period of school study
	SPV home lighting systems	• Rs 4500 to 8,660 for NE and special areas • Rs 2500 to 4,800 for general areas, as per model
	SPV street lighting systems	• Rs 17,300 for NE and special areas • Rs 9,600 for general areas
	SPV stand alone power plant of capacity > 1 kWp	• Rs 2,25,000/kWp for NE and special areas • Rs 1,25,000/kWp for general areas
	SPV stand alone power plant of capacity > 10 kWp	• Rs 2,70,000/kWp for NE and special areas • Rs 1,50,000/kWp for general areas
	Solar Thermal Systems/Devices	Solar Water Heating Systems • Subsidised loan@two percent to domestic users, three percent to institutions and five percent to community users plus Rs 100/ square metre of collector area as incentive to motivator • Capital subsidy@Rs 825/1100 per sq. m. to commercial establishments/ institutions Solar Air Heating/ Steam Generating Systems • Capital subsidy@35-50 percent of the cost, subject to certain ceilings Dish/Community Type Solar Cookers • 30 percent of cost limited to Rs 1,500 for dish type cookers and Rs 15,000 for Scheffler/Community type cookers

Contd...

S.No.	Scheme/Programme	Central Financial Assistance Provided
	Solar Photovoltaic (SPV) applications in Urban Areas	
	SPV streetlight control systems	25 percent of cost, subject to a maximum of Rs 5000/-
	SPV street/public garden lights (74/75 Wp modules)	50 percent of cost, subject to a maximum of Rs 10,000/- & Rs 12,000/- for 11 W and 18 W CFL, respectively
	SPV illuminated hoardings (with maximum 1kWp SPV module)	50 percent cost, subject to a maximum of Rs 15,000/100 Wp module
	SPV road studs	50 percent of cost, subject to a maximum Rs 1000/-
	SPV blinkers (minimum 37 Wp module)	50 percent of cost, subject to a maximum Rs 7,500/-
	SPV traffic signals (minimum 500 Wp module)	50 percent of cost, subject to a maximum Rs 2.5 lakh
	SPV power packs (maximum 1 kWp module)	50 percent of cost, subject to a maximum Rs 1.00 lakh per kWp
	Akshay Urja Shops	Subsidised loan @ seven percent up to Rs 10 lakh and performance-based grant & incentive up to Rs 10000 per month

Source: Ministry of New and Renewable Energy.

Apart from the above listed schemes, as has been mentioned earlier, the government also provides output-based incentives of Rs 10 and 12 per KWh of solar thermal power and solar photovoltaic power, respectively, fed into the grid.

The Government of Gujarat has announced its Solar Power Policy 2009, which will include a stream of incentives for solar power projects which do not come under the purview of the Central Government schemes

At the state level also, various schemes have been rolled out by the state governments which have a high potential for generating solar energy. The Government of Gujarat has announced its Solar Power Policy 2009, which will include a stream of incentives for solar power projects which do not come under the purview of the Central Government schemes. One of the schemes provides for fixed tariff rates of Rs. 13 per unit for a long period of 12 years and then Rs 3 per unit for the next 13 years. This will ensure that the production units work continuously towards improvement of efficiency and scale which is expected to help them reduce per unit cost below Rs 3 by 2022.

Another scheme allows these production units to sell energy generated by them to distributors in the state for the next 25 years, under a Power Purchase Agreement (PPA), which is to be specified by the state utility, Gujarat Urja Vikas Nigam Limited (GUVNL). This will ensure high demand for solar units in the State of Gujarat and also promote more private initiatives[38].

The US-based Clinton Foundation and Gujarat government are in talks to establish a Integrated Solar City, with solar power generation capacity of 5000 MW, over a period of time. This may be the world's largest solar power project at a single location[39]. The project is expected to produce the raw material for solar systems within the premises, which is bound to reduce the cost of production.

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The State of Rajasthan receives the highest solar radiation intensity among all Indian States and also the highest minimum rainfall, making it most suitable for solar power generation. Acknowledging this, the Rajasthan government-owned company, Rajasthan Discom, has ordered installation of eight solar panels of 200 KW capacity[40]. Rajasthan Renewable Energy Corporation Limited has been directed by Rajasthan State Regulatory Commission to identify technically feasible potential sites for solar power development for which tariff would be determined on cost plus basis or through competitive bidding. In addition to this, the state government has received approval from the Energy Department to select developers for setting up solar power plants of capacity less than 100 MW each[41]. An area of 35000 sq. km. has been set aside in the Thar desert for the development of the solar energy sector.

The Government of Karnataka-owned Karnataka Renewable Energy Development Ltd. (KREDL) is working towards helping power generating companies set up nine grid-connected solar power units in different areas of the state, with a total capacity of 44 MW. It also plans to launch an ambitious self-sustaining solar technology programme in 3,900 villages in 39 most backward blocks to cater to the energy needs of 50 lakh people[42].

In collaboration with various state agencies, the Ministry of New and Renewable Energy has designed National Solar Mission which aims to feed 20,000 MW into the national grid by 2022, through an initial investment of Rs 4,337 crore. This mission has been approved by the Union Cabinet and will be implemented in three phases. This plan involves promotion of solar power generation units through compulsory purchase of power by the state utilities and the development of infrastructure through sanctioned amounts for initial activities. The mission aims to generate 1,000 MW of solar power by 2013[43]. The government is also planning to rope in National Thermal Power Corporation, a public sector unit, for successful implementation of this mission.

Private Sector Initiatives

The government is also planning to rope in National Thermal Power Corporation, a public sector unit, for successful implementation of this mission

The private sector has also started venturing into the solar power sector. Tata BP Solar, India's largest solar company and one of the early movers in the private sector, produces solar modules as well as provides customised solutions for solar power harnessing in homes, streets and communities and for pumping of water for irrigation, heating of water for residential and commercial applications, road-safety aids, as well as building of integrated photovoltaic capacities. It executed one of the largest solar projects in the country, installing 8,700 Home Lighting Systems and distributing over 6,000 Solar Lanterns in Leh, at the altitude of 10000 feet.

Moser Baer, a leading Indian technology company, announced the creation of its wholly-owned subsidiary, Moser Baer Photovoltaic Limited (MBPV), in 2005. This company produces solar cells, panels, modules and concentrator facilities. It is a leader in the solar energy sector and supplies its output globally. Along with production, it also concentrates on innovation in solar technology, which is expected to reduce per unit cost of solar energy. The company has setup the world's largest Thin Film Solar Fab and has accomplished one of India's largest rooftop solar PV installations in Surat, India. MBPV is also looking at power projects in Karnataka, West Bengal and Jammu and Kashmir. The private sector is expected to invest about Rs 10 billion (US$253.7mn) in solar plants in India in the next few years. In 2009, 12 projects from private companies such as PV Technologies India (a subsidiary of Moser Baer), Titan Energy Systems, Reliance Industries Ltd and Tata BP Solar Power would entail an investment of Rs 76,500 crore over a 10-year period[44].

Chapter 9

Conclusion and Policy Implications

India is among the few countries which did not report any fall in investments in solar power due to recessionary trends. Its energy sector, given the pace of recovery and growth of the economy, has proved to be largely recession proof and thus has great prospects of growth. India, evidently, has taken the first steps in harnessing its solar energy capacity. Government schemes are supporting private investment for research and development, setting up of new units and expansion of scale in the already established ones, with the objective of cost reduction and large-scale implementation. The Indian government has also created a consortium of eminent scientists from IITs to carry out research on solar energy production, in association with the Department of Science and Technology, India[45].

India, evidently, has taken the first steps in harnessing its solar energy capacity. Government schemes are supporting private investment for research and development, setting up of new units and expansion of scale in the already established ones, with the objective of cost reduction and large-scale implementation

However, there are certain in-built gaps which may distort the future trends from those which are being predicted. The renewable sector, as has been mentioned in the paper, is essentially subsidy-driven. This is undoubtedly one of the significant factors attracting private investment and R&D efforts in this sector. But, most of the government schemes have not prescribed any route to ensure attainment of self-sustainability of these production units.

The private sector is generally sufficiently motivated to reduce costs over a period of time, but due to the provision of timeless government support for capital and output cost and contract bound energy demand agreements with the state utilities, there may be a chance of inefficiencies creeping in. The schemes must instead include measures for gradual dilution of government's monetary support and set cost reduction targets for such companies, with maintenance of their accountability to the government on a regular basis.

In a country like India, which has an elaborate bureaucratic system, government buildings have been constructed in large numbers to support the functioning of this system, both in states as well as in the Centre. These buildings should be compulsorily fitted with solar power modules, which can be financed by the Centre and the states jointly. Also, all commercial buildings should be instructed to be self-sufficient in power, through ground — fitted solar modules or those on the rooftop.

Availability of energy for production will also induce other industries to setup their production units in these far-flung areas. Thus, this will lead to inclusive growth of the regions which may have been unattractive so far

India also lacks detailed studies of potential sites for renewable energy generation, especially in the Northeast. There should be rigorous studies by researchers to collect such data at the regional and sub-regional levels to facilitate knowledge creation about potential markets for solar cell production units. Availability of energy for production will also induce other industries to setup their production units in these far-flung areas. Thus, this will lead to inclusive growth of the regions which may have been unattractive so far.

The lack of awareness about the need to switch to renewable sources of energy is widespread among Indian masses, along with the added disadvantage of lack of access of the common man to renewable energy generation modules. The schemes so far only provide soft loans at a lower rate of interest for individuals who wish to install the apparatus. But, the high capital cost, along with dispersed benefits over time, prevents them from installing these modules.

The Indian government should involve non-governmental organisations (NGOs) to a greater extent to spread awareness about renewable sources of energy. This is highly critical in the case of solar power which can easily be generated though stand alone systems for individual households. Self-help groups (SHGs) can also participate in establishing self-sustained solar power projects at individual and community level, by lending money for purchase of solar lanterns and other solar power generation equipments. Separate budgetary allocation is necessary to facilitate evaluation of the efforts made to this effect.

In the period of transition, the expanding energy needs of the Indian economy have to be met to facilitate unhindered economic growth. The energy needs of India's economy in this period of transition should be fulfilled unhindered to witness unsurpassed growth. As is recognised globally, the only way forward for sustained global progress is through minimal impact on the environment. This can be done either by reducing the overall consumption of energy, or by utilisation of renewables which have a non-depletion guarantee. It is difficult to achieve the former, as it hampers growth itself. As a result, it becomes necessary to enhance our dependence on renewable sources.

The route which is most preferable is increasing diversion of research and development efforts towards technologies which harness energy from renewables and parallel reduction of dependence on combustion of non-renewables

However, it is easier said than done. The long history of resource use and technological development throughout the world, which is essentially based on conventional, pollution emitting sources, makes it nearly impossible to completely stop their use. Thus, the route which is most preferable is increasing diversion of research and development efforts towards technologies which harness energy from renewables and parallel reduction of dependence on combustion of non-renewables. These efforts need to be backed by laws and regulations which bind the emissions of countries and production units initially and eventually those of communities and individuals as well.

Dealing with climate change and responsible factors is not an easy task. India being one among the more vulnerable economies needs to initiate measures to avoid deterioration of the environment. The intertwined efforts of Legislature, Executive and Judiciary, supported by research institutions, NGOs and civil society, are required to revolutionise the energy sector of the country which would ensure low carbon growth and sustainable development in the long term.

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