

# Chapter 1

## Introduction

### Learning Objectives

On completion of this chapter, the reader will have knowledge on:

- Basic concepts of renewable energy systems.
- Implications of renewable energy and their availability in India and World.
- Basic terminologies used in the renewable energy systems.
- Grid integration issues while integrating renewable energy systems.
- Schemes, Policies and funds available for renewable energy systems.
- Role of MATLAB/SIMULINK and Soft computing techniques in renewable energy systems.

### 1.1 What Is Energy?

Prior to discussing global energy production and consumption, it is prudent to have a look at the physics associated with energy. Although many people are familiar with the term *energy*, surprisingly only a few people can appreciate energy's true nature. In everyday language, the word *energy* is used very slackly; words like *work*, *power*, *fuel* and *energy* are often used interchangeably and erroneously. Energy forms the basis of human life. There is hardly any activity that is independent of energy. In olden days man used muscle power, then fire and animal power. Later, man learnt to harness energy, convert it to useful form and put it to various uses. Over the past few decades, energy has become the backbone of technology and economic development. Not counting men, machines and money, 'energy' is now the fourth factor of production. Without energy, no machine will run and electricity has become a necessity. Hence, the energy requirements have increased in the years following the industrial revolution. This tremendous increase in use of energy has created troubles of 'demand and supply'. If this mounting world energy demand is to be met

with fossil fuels, they will not be available for energy production in few years. It is a need of today's world to concentrate on renewable energy sources to satisfy the demand and conserve our finite natural resources for the generations to come. This is an endeavor to present an overview of the concerns about energy demand and supply ratio and how to conserve energy as well how to make best use of renewable energy.

Energy is vital in the entire process of evolution, growth and survival of all living beings. Energy plays a fundamental role in the socio-economic development and human welfare of a country. The term *strategic commodity* is commonly used in countries to define energy. Any ambiguity in the supply of energy would cause a pressure to the economy of the country. Such energy security is important not only to the country's economic growth, but also for the vision of a country with reference to the activities related to human development. These activities include removal of poverty, providing employment and satisfying the Millennium Development Goals (MDGs). The issues related to the demand in energy are related to energy demand, energy poverty and environmental effects of energy growth. In this chapter, we will discuss the energy scenario, global and Indian energy crisis, energy efficiency, classification of energy sources, solar energy, wind energy, benefits of renewable energy, trends in energy consumption, worldwide potentials of renewable energy sources, and the need for new energy technologies. In addition an introduction to MATLAB and SIMULINK is provided with application of soft computing techniques in solar and wind energy generation systems.

### ***1.1.1 The Energy Scenario***

World population is expected to grow at around 1 % while GDP (Gross Domestic Product) is expected to grow around 3 %. GDP per capita can be considered a reasonable proxy for global energy demand. Demand for natural gas is expected to rise significantly, especially due to its use in power generation. Liquefied Natural Gas (LNG) becomes a significant energy carrier globally.

Fossil fuel based thermal power, hydro-electric, and nuclear constitute the conventional sources of power. Taking into consideration the profile of energy sources in India, coal has a dominant position. Coal constitutes about 51 % of India's primary energy resources followed by Oil (36 %), Natural Gas (9 %), Nuclear (2 %) and Hydro (2 %). Non-conventional sources are less than 5 % of total installed capacity in India. The present installed capacity (as in March 2006) is about 1, 25,000 MW, consisting of coal based plants (56 %), gas based plants (10 %), hydro-electric (26 %), nuclear (3 %) non-conventional (5 %). For next few decades, India would need to exploit all possible options to create reasonably large capacity base on the energy side. It needs to increase the coal generation, extract oil and gas reserves through all conceivable means wherever possible. It ought to additionally depend on import of coal, procure coal and gas reserves abroad and exploit completely the huge hydro electric potential which is over 1,50,000 MW. So far about 32,000 MW i.e. 20 % of the hydroelectric potential has been exploited.

An increase in the capacity of power generation based on the coal reserves of the nation, which are of the order of 200 billion tones is inexorable. Atomic projects have ended up being successful and effective. Atomic power plants are one of the essential choices that India is seeking since mid-1980s and early 1990s. India has immense gas holds, both on the Western, and all the more especially, around the Eastern coast. In addition, various LNG terminals have likewise been created and are, no doubt created with the goal that the utilization of gas could be supplemented through import of Liquefied Natural Gas. India is one of the minority countries which has been successful in employing wind turbine technology and today of the total capacity of 1,25,000 MW in the country about 5 % is constituted by the various non-conventional sources of generation, wind being the largest contributor.

India has the least per capita energy consumption among other countries in the world. The consumption of energy by India is 540 kgoe in 2008, whereas 1,803 kgoe is consumed by the world, 4,560 kgoe by OECD nations, and 1,600 kgoe by China. India's energy use productivity for creating Gross Domestic Product in Purchasing Power Parity is superior to numerous nations and even contrasted with the world normal. It is normal that with a development rate of 9 %, TPES necessity for India in 2021–2022 will be around 1,192 mtoe which will further expand to around 2,043 mtoe by the year 2031–2032. The power utilization per capita for India is only 566 Kwh and is far below most nations on the earth. Despite the fact that 85 % of towns are supplied with electricity, around 57 % of the domestic units in the country and 12 % of urban families, i.e. 84 million family units in the nation, don't have accessibility to electric power. Power utilization in India is required to ascent to around 2,280 Bkwh by 2021–2022 and around 4,500 Bkwh by 2031–2032. The Human Development Index (HDI) is figured from the literacy rate, infant mortality rate and GDP plotted against per capita power utilization. It is observed that for consumption over 4,000 kWh/per person the curve plateaus out and straightens. Power capacity has risen at a rate of 5.87 % per annum over the last 25 years. The aggregate supply of power has climbed at the rate of 7.2 % for every annum over the same period. This reflects a change in Plant Load Factor (PLF). In any case, the utilization is still compelled as force deficiencies proceed with torment to the nation. Availability Based Tariffs (ABT) and unscheduled exchange charges of force presented since 2003 for interstate offer of power has narrowed down the fluctuations in voltage and frequency. The deficiencies are additionally ascribed to insufficient ventures in distribution and transmission. Expanding the generation capacity has attracted wide range of investment. Aggregate Technical and Commercial (AT&C) misfortunes which incorporate theft of electricity, non billing, wrong billing, inefficient transmission and distribution losses surpassed 40 % for the nation in general in 2005. Hence, the State Electricity Boards remain monetarily sick and are unable to draw in accounts for venture. The degree of power deficiency differs from state to state.

The Planning Commission of India has set a focus of including more than 78,000 mw in a five year plan starting from 2007. Historically the plan targets have been missed and actually for this five year plan the target is likely going to be missed as capacity addition till February 2011 was just 40,000 MW. At last, the

historical backdrop of attention on speculation in power generation brings about stacking more power on a deficient transmission and distribution (T&D) system. Industrial and commercial units have been forced to look for standby generation to meet their demand on a 24×7 support.

The division is commanded by vast state imposing business models at both federal and state levels. Private distribution of electric power has been acquainted, yet it is confined to specific regions. An uneven playing field saturates the commercial center wherein the Central Power Sector Unit get ensured post-government forms of 14–16 % with full installment supported by the GOI. State Power Sector Utilities (SPSUs) are given zero or low returns by Regulators who are under consistent pressure not to raise tariffs, which are as of now around the most astounding on the planet in PPP terms for mechanical, business and family customers. The power tariffs are framed based on the premise of industrial users cross subsidizing agricultural and domestic power users. In almost all the states, the farmers are provided with un-metered power and in turn they pay an exceptionally high amount towards the horse power of their pumps. This prompts a zero peripheral expense of power which promotes wasteful use and over abuse of ground water. The local division likewise has an extent of subsidies depending upon the level of utilization including vigorously financed force for the poorest fragment wherein families pay a low amount aggregate added towards month to month billing.

### ***1.1.2 Energy Crisis: Global and Indian***

The entire world rely on coal, oil and gas (the fossil fuels) for over 80 % of the current energy needs – a situation which shows little sign of changing over the medium-term without drastic policy changes. Energy demand is expected to increase by 50 % during the following two decades. Naturally this is creating panic that our energy assets are beginning to run out, with obliterating outcomes for the worldwide economy and worldwide personal satisfaction. Created nations, no more strangers to intermittent power outages, are agonized over security of energy supply. In the creating scene, almost 2.4 billion individuals still depend on customary biomass powers, while 1.6 billion individuals – around a quarter of humankind – have no accessibility to electricity. In particular Africa suffers severely. In 2005, nearly two-thirds of Africa's 891 million people had no access to electricity. Nearly every aspect of development – from reducing poverty to improving healthcare – requires reliable access to modern energy services.

The potential for emergency in the event that we use energy is quite genuine however there is still time before that happens. In the previous two decades, demonstrated gas reserves have expanded by 70 % and demonstrated oil reserves by 40 %. At needed rates of interest development we have enough for 30 years supply. The International Energy Agency (IEA) says the world's energy needs could be 50 % higher in 2030 than they are today. The security of global energy supplies continues to be problematic. Today, oil and gas reserves are in the hands of

a small group of nations, several of which are considered political unstable or have testy relationships with large consuming countries. Eighty percent of the world's oil reserves are spotted in only three locales throughout the world: Africa; Russia and the Caspian Basin; and the Persian Gulf. While more than 50 % of the world's remaining gas reserves exist in Russia, Iran, and Qatar.

Policymakers have been prompted to seek autonomy from foreign sources of energy due to the distress about energy security. In Europe, new coal-terminated force stations are again on the political motivation, incompletely on the grounds that Russia is no more seen as a dependable supplier of gas. In the US, home-developed bio-fuels have been pushed by progressive organizations as an elective to Middle Eastern oil imports, in spite of being more costly. These responses are a characteristic outcome. The more the governments can extricate themselves from the reliance on outside energy assets, the more secure they feel.

The recent accessibility of power in India has both expanded and enhanced yet request has constantly overwhelmed supply and generous energy and top deficiencies rose in 2009–2010. There are additionally different assessments of 25,000–35,000 MW of power being processed by diesel generation to meet the shortages. Power lack is not by any means the only issue, its spread is a similarly genuine issue. Indeed, the individuals who have access to power also experience the ill effects of deficiencies in power. Industrial equipments often harmed because of the inconsistent power supply. Added to these is the expense of unmoving labor and misfortune of processing when power supply is interfered. Previously, the determination of an energy asset for power generation was overwhelmed by discovering the least expensive power generating plant. Despite the fact that such a methodology is crucial, there is a concern about different aspects of power generation such as, social, environmental, and technological consequences of selection of energy source. It could be noticed that coal has the most extreme potential next to Natural Gas and other sources of energy. Hence, it needs to be re-emphasized that for developing countries like India, the expense of transforming power is a main concern while anticipating the sort of plant to be introduced and requisitioned and all the more so with inexhaustible supply of coal. On the other hand, in the long run assuming that we produce the results of the contaminations on human health environment and cost and in addition exertions required to enhance or adjust the way of corruption, the initial expense of utilizing renewable assets for processing energy may not be too huge. A high level of alert is likewise required as rising economies in countries like India may not at present have the financial aid to jump specifically to cleaner systems of energy. Since a worldwide temperature alteration is a global wonder and it has no limits, there is an urgent necessity for the exchange of engineering and advancement of proper monetary instruments to countries that are as of now attempting to discover their legitimate spots. No contention is required to comprehend that the world is today confronting the issue of a dangerous atmospheric change because of fast industrialization and urbanization accompanied by the western world. According to the per capita value India is 145th on the earth with an annual discharge of 1.25 t CO<sub>2</sub>.

## 1.2 Energy Efficiency

It is either impractical or prohibitively expensive to install comprehensive sub-metering and so it is necessary to estimate the energy consumption of various terms of plant and equipment. It is a difficult process to estimate the equipment energy consumption, which relies on skill and judgment. Nevertheless, it is relatively easy to establish an upper limit for energy consumption by using (1.1):

$$\text{Annual energy consumption (kWh)} = \frac{Q_{out}}{\eta} \times T_h \quad (1.1)$$

where  $Q_{out}$  is the plant power output (kW),  $\eta$  is the efficiency of plant and  $T_h$  is the number of operating hours per year. Equation (7.1) provides only an upper limit on the plant's energy consumption rather than the actual operating energy consumption. Such kind of a drawback can be avoided by first monitoring the actual energy consumption of the plant using energy meters for a short duration and then multiplying the average measured load by the annual operating time. Simple measuring instruments such as the clamp-on meter is a suitable device for performing the monitoring operation. The energy consumed in producing domestic hot water can be determined; if the cold feed water is metered, by using (1.2):

$$\text{Annual energy consumption (kWh)} = \frac{m_{cf} \times c_p \times (t_s - t_{cf})}{\eta_s \times 3,600} \quad (1.2)$$

where  $m_{cf}$  is the mass of cold feed water used annually (kg),  $c_p$  is the specific heat capacity of water (i.e. 4.19 kJ/kg K),  $t_s$  is the hot water storage temperature (e.g. 60 °C),  $t_{cf}$  is the cold feed water temperature (e.g. 10 °C) and  $\eta_s$  is the seasonal efficiency of system. The seasonal efficiencies for various domestic hot water – producing systems are given in Table 1.1.

It is possible to estimate the energy consumed in producing hot water, if the cold feed water consumption is not known by using (1.3):

$$\text{Annual energy consumption (kWh)} = 0.024 \times q_{hws} A_f N_w \quad (1.3)$$

where  $q_{hws}$  is the mean power requirement ( $W/m^2$ ),  $A_f$  is the floor area ( $m^2$ ) and  $N_w$  is the number of working days.

**Table 1.1** Seasonal efficiencies for water heating systems

System type	Seasonal efficiency
Gas heater with storage cylinder	52
Gas or oil fired boiler with storage cylinder	56
Hot water cylinder with immersion heater using off-peak electricity	80
Instantaneous gas multi-point heater	62
District heating with local calorifiers	60
District heating with central calorifiers and distribution	56

### ***1.2.1 Efficient Energy Use***

Utilizing energy as effectively as could be expected under the circumstances is the most financially savvy approach to oversee energy interest, and accordingly to address carbon emissions. In most nations, regulations and budgetary motivating forces are presently set up to empower energy effectiveness yet their impact is humble and national energy utilization figures keep on rising year on year. Saving energy is much easier than producing it. Energy efficiency can be improved by adopting the following strategies:

- The demand on gas and electricity distribution networks can be reduced, energy efficiency will improve the security and resilience of these networks and reduce dependence on imported fuels.
- By decreasing the energy bills, energy efficiency will help businesses to be more productive and competitive.
- The domestic energy standards can be improved thus reducing the cost spent on fuel.

To increase sales and profits, increasing energy end use efficiency is unattractive for energy companies driven by commercial imperative. Regulations can be put in place for example that requires utilities to encourage customers to use electricity efficiently. A more revolutionary methodology imagines the utility being converted into a supplier of energy administrations, owning apparatus use in individuals' homes and hence being propelled to augment the productivity of these machines. Whatever methodology is at long last received, the essentialness of diminishing energy utilization ought to be the foundation of any CO<sub>2</sub> mitigation programme.

## **1.3 Classification of Energy Sources**

By contrast to fossil fuels which are quickly being drained, renewable energy sources, for example, sunlight and wind are regularly recharged and accordingly reasonable. Environmental change, coupled with worries about high oil and energy costs, is driving a worldwide pattern towards the expanded utilization of renewable energy. Undoubtedly, it is the apparent idea of manageability that is driving governments far and wide to present enactment pushing the utilization of renewable energy. Most wellsprings of renewable energy begin either straight forwardly or in a roundabout way from the sun. For example, both wind and wave power derives their energy indirectly from the sun. When solar radiation is absorbed by the Earth it is dissipated around the globe in the form of winds and ocean currents. In addition, solar energy promotes evaporation of water from the oceans. This airborne water ultimately falls as rain, creating rivers which may be dammed to produce hydroelectric power. Furthermore, solar energy drives the photosynthesis necessary for the plants that are used to create biofuels. Currently,

**Table 1.2** Renewable forms of energy

Energy	Percent of renewable resources	Product
Bio mass	Burning of plant materials and animal wastes	Heat and gas
Hydro power	Water flowing from higher to lower elevations through dams	Electricity
Wind	Capture of wind by turbines	Electricity
Geothermal	Tapping steam and hot water from the Earth's mantle	Heat and electricity
Solar	Absorbing and storing heat from the Sun	Heat and electricity
<b>Emerging technologies</b>		
Hydrogen fuels	Burning hydrogen gas	Power for movement
Nanotechnology	Using the unique properties of materials on the size scale of molecules or atoms	Electricity
<b>Ancient technologies</b>		
Wind	Water wheels, dams, weight	Power motion
Water	Windmills, sails	Power motion
Movement(kinetic energy)	Animals, human exertion	Power motion

only about 18 % of the world's energy demand is supplied from renewable energy sources. However, there is a great potential to increase this contribution. Indeed, it has been estimated that the technical potential of renewable energy is more than 18 times that of current global primary energy demand. This assessment, on the other hand, does not take into account budgetary and ecological imperatives and is accordingly to some degree misdirecting. So as to endeavor renewable wellsprings of energy it is regularly important to make an impressive capital financing. This is especially the case with huge framework activities, for example, hydroelectric or tidal blast plans. To be financially feasible, such ventures must assimilate substantial capital expenses and still have the capacity to contend on cost with universal wellsprings of energy – something which as a rule is challenging to do. Moreover, substantial base undertakings, for example, hydroelectric dams and tidal floods may make ecological issues. Hence, there are significant restraints to the boundless abuse of renewable energy. The various renewable forms of energy are shown in Table 1.2.

## 1.4 Solar Photovoltaics

In 2010, among the world's total power, the contribution of solar PV was a very small fraction. However a rapid growth is observed in the installation of solar PV and would continue to increase in the upcoming years. In the New Policies Scenario, power generated from solar PV in 2035 is over 26-times that of 2010,

expanding from 32 Twh to 846 Twh. The energy from installed solar PV would increase from 67 GW in 2011 to 600 GW in 2035, on account of decreasing expenses and government aids.

Based on the historical comparison, this is found to be an extremely rapid increase since the global solar PV capacity was just 1 GW in 2000. Throughout the span of 2011, solar PV capacity expanded by 30 GW, a 75 % increment. Around 60 % of the augmentations were in Germany and Italy, the world pioneers in solar PV, with 25 GW and 13 GW of installed capacity at the end of 2011. The European Union records for over 75 % of worldwide solar PV capacity in 2011. During the Outlook period, the EU capacity has expanded to exactly 146 GW, representing 5 % of its power generation in 2035 (up from 1 % in 2010). In the United States, capacity increments from 4 GW in 2011 to 68 GW in 2035. Different nations expected with huge solar PV capacity in 2035 are China (113 GW), India (85 GW) and Japan (54 GW). Speculation in solar PV establishments has been energized as of late by generous falls in solar PV costs, which resulted largely from widespread deployment and substantial oversupply (Spotlight). Between the first quarter of 2010 and the first quarter of 2012, expenses to generate energy from solar PV decreased by 44 % (Frankfurt School UNEP Collaborating Centre and Bloomberg New Energy Finance, 2012). Solar PV expenses keep on falling over the projection period, despite the fact that at lower level rates, the oversupply circumstance is revised. The increment in solar PV installations in European Union nations is utilized wholly to feeding tariffs, which impressively reduce the project risk as returns are ensured, regularly for a period of 10–20 years. These tariffs have been exceptionally liberal in a few cases and were not balanced rapidly enough to reflect the quickly falling expenses of solar PV. Subsequently, the returns offered were closer to those ordinarily connected with high-chance speculations and prompted huge financing in solar PV installations. In some countries, governments responded quickly by reducing feed-in tariffs to levels that better reflected costs. As the costs of feeding tariffs are passed on to consumers in most cases, it is essential to design incentives which attract sufficient investment while yet permitting adjustment of subsidies for new capacity additions as technology costs fall, to avoid unnecessary increases in electricity prices and maintain public acceptance. Solar PV cell generating capacity has become faster due to booming demand, at first in OECD nations, where request initially developed, and later in China, which stretched assembling limit hugely to help trades. During the recent years, capacity has expanded more significantly than genuine interest for solar PV panels. Since 2008, there has been a quite sharp fall in the expense of purged silicon, a key resource for production. Alongside expense diminishment from technical knowledge, these two factors have determined the fall in expense of PV frameworks (IEA, 2011b). The solar PV installers and final consumers have gained benefits due to the decrease in solar PV cost, while the solar PV manufacturers, especially in USA and Europe have faced several financial difficulties. Thus measures have been taken to reduce the cost and hence becoming more competitive. During April 2012 a few huge organizations have effectively gone bankrupt, for example, Germany's Q-Cells – the biggest solar unit producer in Europe – in April 2012. Exchange strains have emerged

between the United States, Europe and China, bringing about the burden of import duties by the United States in 2012 on sun based boards from China.

Difficulties are prone to persevere in the short term, while the lopsidedness between supply and interest continues. How rapidly the parity is restored depends on the rate of development of interest for sun powered PV. China speaks to a substantial potential business, yet its interest for sun oriented PV in the fleeting is questionable. In the New Policies Scenario, the oversupply proceeds over the short term.

India is blessed with plentiful sun powered energy, which is fit for processing 5,000 trillion kilowatts of clean energy. Nation is honored with around 300 sunny days in a year and sun based insolation of 4–7 kwh for every Sq. m for every day. In the event that this energy is tackled effectively, it can undoubtedly diminish the country's energy deficiency situation and with no carbon emissions. Solar Energy is the requirement for creating nation like India where huge segment of nation's populace is basically spotted in provincial ranges and needs access to power. The distribution infrastructure is not well established in the rural areas in India and hence developing such systems would lead to a major cost and such high cost cannot be upheld by the utilities existing in the present scenario.

The Government of India has initiated the Jawaharlal Nehru National Solar Mission, a significant activity with dynamic investment from States to promote environmentally sustainable development thus addressing the country's energy security challenge. It assumes a significant part in India's commitment to battle against the issues of environmental change which is an enormous concern over the globe. The goal of the Jawaharlal Nehru National Solar Mission is to build India as a worldwide pioneer in sunlight based energy, by making the strategy conditions for its substantial scale dispersion the nation over as fast as could be expected under the circumstances. The Mission embraced a 3-stage methodology, spreading over the time of the eleventh Plan and first year of the twelfth Plan (up to 2012–2013) as Phase 1, the remaining 4 years of the twelfth Plan (2013–2017) as Phase 2 and the thirteenth Plan (2017–2022) as Phase 3. During the end of each plan, and mid-term throughout the twelfth and thirteenth Plans, there will be an assessment of advancement, audit of limit and focuses for resulting stages, taking into account rising expense and engineering patterns, both local and worldwide. The point might be to ensure Government from subsidy introduction in the event that the normal expense decrease does not emerge or is more quick than anticipated. The quick point of the Mission was to concentrate on setting up an empowering environment for solar innovation in the nation both at a centralized and decentralized level. The principal phase (up to 2013) kept tabs on catching of the low hanging choices in solar; on pushing off-network frameworks to serve the populace without access to business energy and unobtrusive capacity expansion in grid based frameworks. In the second stage, based on the knowledge of from recent years, capacity will be combatively increased to make conditions for up scaled and competitive solar energy entrance in the nation. The mission National Solar mission under the brand name "Sun powered India" set a driven focus of including 20 GW of Grid connected and 2 GW of Off-grid capacity by 2022 in three stages.

### ***1.4.1 Solar Radiation***

Solar radiation is one of the brilliant energy emitted by the sun, especially electromagnetic energy. About a large portion of the radiation is in the visible short-wave path of the electromagnetic range. The other half is generally in the close infrared part, with some in the ultraviolet a piece of the range. The allotment of this ultraviolet radiation that is not ingested by the air transforms a suntan or sunburn on individuals who have been in daylight for longer duration of time.

Sunshine span is the period of time that the ground surface is illuminated by immediate sun based radiation (i.e., daylight arriving at the world's surface straightforwardly from the sun). World Meteorological Organization characterized daylight span as the period throughout which administered sunlight based irradiance surpasses a capacity quality of  $120 \text{ W/m}^2$ . This worth is identical to the level of sunlight based irradiance not long after day break or in a matter of seconds before dusk without cloud conditions. It was dictated by looking at the daylight span recorded utilizing a Campbell-Stokes daylight recorder with the real control sun powered irradiance. Campbell-Stokes daylight recorders and Jordan daylight recorders have long been utilized as instruments to measure daylight term, and are invaluable in that they have no moving parts and oblige no electric force. Their hindrances are that the qualities of the recording paper or photosensitized paper utilized within them influence estimation precision, contrasts between onlookers may emerge in deciding the event of daylight, and the recording paper must be swapped after dusk. As daylight is characterized quantitatively at present, a mixed collection of photoelectric daylight recorders have been produced and are utilized as a part of spot of these instruments. As the threshold limit for the event of daylight is characterized regarding immediate sunlight based irradiance, it is additionally conceivable to watch daylight term with a pyrheliometer.

In Solar PV framework it is important to know the measure of daylight accessible at a specific area at a given time. The two basic systems which describe sun based radiation are the solar radiance (or radiation) and solar insolation. The solar radiance is an instantaneous power density in units of  $\text{kw/m}^2$ . The solar radiance shifts for the duration of the day from  $0 \text{ kw/m}^2$  during the evening to a greatest of about  $1 \text{ kw/m}^2$ . The solar radiance is emphatically dependant on area and neighborhood climate. Solar radiance estimations comprise of worldwide or immediate radiation estimations taken intermittently for the duration of the day. The estimations are taken utilizing either a pyranometer (measuring worldwide radiation) or a pyrheliometer (measuring immediate radiation). In overall built areas, this information has been gathered for more than 20 years. An elective system for measuring sunlight based radiation, which is less faultless additionally less unmanageable, is utilizing a daylight recorder. These daylight recorders (otherwise called Campbell-Stokes recorders), measure the amount of hours in the day throughout which the daylight is above a certain level (commonly  $200 \text{ mw/cm}^2$ ). Information gathered along these lines might be utilized to focus

the solar insolation by looking at the measured number of daylight hours to those dependent upon computations and including a few rectification components. A last technique to gauge solar insolation is shadiness information taken from existing satellite pictures.

### ***1.4.2 Measurement of Solar Radiation***

Everything in nature transmits electromagnetic energy, and sun based radiation is energy emitted by the sun. The energy of extraterrestrial sun oriented radiation is disseminated over a wide persistent range running from ultraviolet to infrared beams. In this range, sun oriented radiation in short wavelengths (0.29–3.0  $\mu\text{m}$ ) represents something like 97 % of the aggregate energy.

Solar radiation is part of the way retained, scattered and reflected by atoms, mist concentrates, water vapor and mists as it passes through the climate. The immediate sunlight based shaft arriving specifically at the world's surface is called immediate sun powered radiation. The aggregate sum of sunlight based radiation falling on a level surface (i.e. the immediate sunlight based shaft in addition to diffuse sun powered radiation on a flat surface) is alluded as worldwide sun oriented radiation. Direct sun oriented radiation is watched from dawn to nightfall, while worldwide sun based radiation is watched in the dusk before day break and after nightfall, in spite of its reduced power at these times.

While sun powered irradiance is most generally measured, a more regular type of radiation information utilized as a part of framework outline is the solar insolation. The solar insolation is the aggregate sum of sun powered energy gained at a specific area throughout a specified time period, regularly in units of  $\text{kwh}/(\text{m}^2 \text{ day})$ . While the units of solar insolation and sun powered irradiance are both a force thickness (for solar insolation the “hours” in the numerator are a period estimation as is the “day” in the denominator), solar insolation is truly unique in relation to the sun based irradiance as the solar insolation is the quick solar irradiance arrived at the midpoint of over a given time period. Solar insolation information is usually utilized for straightforward PV framework configuration while sun based brilliance is utilized as a part of additional confounded PV framework execution which ascertains the framework execution at each one point in the day. Solar insolation can likewise be communicated in units of  $\text{Mj}/\text{m}^2$  for every year. For a given region the solar radiation can be presented in different ways such as:

- Average data for a year in a particular location.
- Average daily, monthly or yearly solar insolation for a specific location.
- Global isoflux contours either for a full year, a quarter year or a particular month.
- Sunshine hours data.
- Solar Insolation Based on Satellite Cloud-Cover Data.
- Calculations of Solar Radiation.

## 1.5 Wind Energy

The 2012 worldwide wind energy market developed by more than 10 % contrasted with 2011, and almost 45 GW of new wind power carried speculations of about € 56 billion. By 2020, the IEA's New Policies Scenario infers that aggregate limit might achieve 587 GW, supplying something like 6 % of worldwide power; yet the GWE0 Moderate situation recommends that this could achieve 759 GW, supplying 7.7–8.3 % of worldwide power supply. The Advanced situation recommends that with the right arrangement help wind force could arrive at more than 1,100 GW by 2020, supplying between 11.7 % and 12.6 % of worldwide power, and sparing about 1.7 billion tons of CO<sub>2</sub> discharges.

China the biggest business for wind since 2009, saw a slower showcase, which implied that the US recovered the top spot in 2012. Yet establishments in Asia still headed worldwide markets, with North America a second place, and Europe not far behind. In 2012, wind-produced energy in China added up to 100.4 billion kwh, representing 2 % of the nation's aggregate power yield a year ago, up from 1.5 % in 2011. The Japanese business sector saw new establishments of 88 MW in 2012 to achieve a combined capacity of 2,614 MW. This speaks to around 0.5 % of the aggregate power supply in Japan. The Government of South Korea has made "green development" one of its national improvement necessities. In spite of the fact that wind force is still a generally junior energy generation innovation in South Korea, there was 76 MW of new inland establishments in 2012, which carried the aggregate introduced ability to 483 MW. Pakistan requisition its first extensive scale business wind homestead of 50 MW in the territory of Sindh. The aggregate introduced capacity arrived at 56 MW by the end of 2012. In 2012, wind energy was the biggest wellspring of new US power generation, giving practically 42 % of all new capacity. Truth be told, 2012 was a strong year for all renewable energy sources, as together they gave over 55 % of new generation capacity in the nation. Canada saw 935 MW of new wind capacity come online, making it the ninth biggest market in 2012. Contrasted with 1,267 MW in 2011, Canada's wind force business saw a slight log jam in 2012, however it was still the second best year ever. Wind energy spoke to 26 % of new EU power capacity introduced a year ago, and speculations of between €12.8 billion and €17.2 billion. Wind is currently meeting 7 % of Europe's power interest, up from 6.3 % at the end of 2011 and 4.8 % in 2009. The United Kingdom has the best wind assets in Europe, and introduced 1,897 MW in 2012–2016 % of new wind capacity in Europe, 1,043 MW inland and 854 MW seaward. This puts the UK second as far as new organization a year ago and the UK's wind energy yield expanded by 33 % in 2012 contrasted with the past year. In general wind energy created 5.5 % of the UK's power needs in 2012, up from 4 % in 2011. Italy now has an aggregate introduced capacity of 8,144 MW, up from 6,737 MW in 2011; and is the seventh biggest wind showcase all around. Brazil headed Latin America with 1,077 MW of new capacity, pulling the nation into the little club of wind energy markets with yearly establishments of over 1 GW comprehensively. Brazil has a solid pipeline of nearly 7 GW to be finished by 2016.

The Australian business sector included 358 MW in 2012 (up from 234 MW in 2011), carrying the aggregate introduced capacity up to 2,584 MW.

In an undeniably tight market, with enormous descending weight on costs through oversupply in the turbine market; furious rivalry with “modest” gas; and a wave of descending modifications to help systems in a starkness driven monetary scene; the industry keeps on being tested to contend on a value premise straightforwardly with intensely sponsored fossil fuel and atomic energy plants. Having said that, all the basic drivers for wind power improvement still hold, and there is a necessity around the globe for new power generation, which is clean, reasonable, indigenous, dependable and speedy to install.

In 2012, notwithstanding an abating worldwide economy, India’s power interest kept on rising. Power deficiencies were basic, and over 40 % of the populace has no right to gain entrance to up to date energy services. India’s power interest is anticipated to more than three times between 2005 and 2030. As of National Electricity Plan (2012), the Central Electricity Authority anticipated the necessity for 350–360 GW of aggregate generation capacity by 2022. Regardless of significant capacity increases over later decades, power supply battles to stay aware of interest. India had an alternate record year of new wind energy establishments between January and December 2011, introducing more than 3 GW of new capacity despite any precedent to the contrary to achieve what added up to 16,084 MW. As of March 2012, renewable energy represented 12.2 % of aggregate introduced capacity, up from 2 % in 1995. Wind energy represents 70 % of this introduced capacity. Toward the end of August 2012, wind power establishments in India had arrived at 17.9 GW. Under the New Policies Scenario of the World Energy Outlook (2011), aggregate force capacity in India might achieve 779 GW in 2035. To achieve 779 GW in 2035, capacity must develop at a CAGR of 5.9 %, or over 20 GW for every year from 2009 through 2035. The biggest expansion for every year is almost 18 GW throughout monetary year 2011–2012; this scale of extension could represent a test for the legislature (IEA 2012) without a noteworthy part for renewable energy. Throughout financial year 2011–2012 wind energy alone conveyed over 3 GW to India’s new introduced generation capacity, representing over 16.5 % of aggregate capacity.

### ***1.5.1 Renewable Energy in the 12th Five-Year Plan (2012–2017)***

Generally, wind energy has met and frequently surpassed the target set for it under both the tenth Plan (2002–2007) and eleventh Plan (2007–2012) periods. Throughout the tenth Plan period the target set was of 1,500 MW though the genuine establishments were 5,427 MW. Additionally throughout the eleventh Plan period the updated target was for 9,000 MW and the genuine establishments were much higher at 10,260 MW. The report of the sub-bunch for wind power improvement named by

the Ministry of New and Renewable Energy to create the methodology for the twelfth Plan period (April 2012 to March 2017) settled a reference focus of 15,000 MW in new capacity increases, with an inspirational focus of 25,000 MW. Significantly the report prescribes the continuation of the Generation Based Incentive plan throughout the twelfth Plan period. The report additionally prioritized the issue of transmission, which was a powerless connection in the quality chain up to this point. A joint gathering of the MNRE, the Ministry of Power, the Central Electricity Authority and the Power Grid Corporation of India is taking a gander at this issue. Notwithstanding, for India to achieve its potential and to support the essential financing in renewable energy it will be key to present far reaching, stable and long haul help approaches, painstakingly intended to guarantee that they work in agreement with existing state level instruments to abstain from lessening their adequacy.

Presently, India has an introduced power generation capacity of 207.8 GW, of which renewable record for about 25 GW, and wind makes up a greater part of this introduced capacity. In 2011 the state-run Centre for Wind Energy Technology reassessed India's wind power potential as 102,778 MW at 80 m tower height at 2 % area accessibility, up from the prior evaluation of surmised 49,130 MW at 50 m, likewise at 2 % area accessibility. Assuming that the assessed potential of 102 GW were completely created, wind might produce 8 % of the anticipated power request in 2022 and 5 % in 2032 (LBNL, 2012). Over the previous year other exploration associations have assessed wind potential utilizing diverse models for mapping the wind asset. In one such study directed by the Lawrence Berkeley National Laboratory (LBNL), expecting a turbine thickness of 9 Mw/km<sup>2</sup>, the aggregate wind potential in India with a base capacity variable of 20 % ranges from 2,006 GW at 80-m center tallness to 3,121 GW at 120-m center stature 10 (LBNL, 2012). These exploration studies require ground level acceptance through long haul wind estimations at 80 and 120-m center tallness. By the by their discoveries may have a huge effect on India's renewable energy methodology as it endeavors to adapt to a generous and unending lack of power. In a positive advancement the Ministry of New and Renewable Energy (MNRE), has now marked a Memorandum of Understanding with the Lawrence Berkeley Lab to team up on a few issues identified with the estimation of wind asset potential and matrix reconciliation.

### ***1.5.2 Barriers to Achieving Higher Growth***

The eleventh Plan had meant to make 78.7 GW of extra capacity for lattice associated power however real acknowledgment was around 50 GW. The twelfth Plan imagines introducing 100 GW of new capacity of which 30 GW is anticipated to hail from Renewable Energy Sources, of which wind might represent 15 GW. Generally the Indian wind energy division has met and sometimes surpassed its designated target.

During FY 2011–2012, India introduced a record 3.1 GW of new wind power capacity. For this scale of development to be looked after and heightened it is fundamental that the industry is upheld by a stable arrangement and nature's turf. India had introduced just about 18 GW of wind force capacity by August of 2012 (MNRE). With C-WET's overhauled wind power potential numbers and the development towards advertising seaward wind advancement, there is a ton more that could be attained in the nation.

Based on the twelfth Plan report, a GDP development rate of 9 % for every year over the Plan period will oblige energy supply to develop at around 6.5 % for every year. The capacity to take care of this energy demand relies on upon the nation's capability to stretch household preparation in basic energy sub areas on a critical premise. Power generation (utilities + hostage) developed at 5.8 % for every annum throughout the 20-year period from 1990–1991 to 2010–2011. Wind force is a full grown and versatile clean energy innovation where India holds a domestic advantage. India has a yearly assembling capacity for over 9.5 GW of wind turbines today. The nation is seeing about 3 GW in 12-month establishments under the twelfth Plan target. This unobtrusive pace of use of the nation's wind energy assembling and asset potential so far is attributable to a few components, including absence of a proper administrative structure to encourage purchase of renewable energy from outside the host state, deficient framework connectivity, high wheeling and open access charges in a few states, and defers in securing land and acquiring statutory clearances. The more extensive worldwide financial log jam has reduced the desires for the monetary year 2012–2013 from the wind division, which is even now adapting to the decrease of the Accelerated Depreciation profit from 80 % to 35 % in the first year of a wind turbine's operation. Additionally, there are other potential restraints to attain higher development rates in the short to medium term. Throughout the most recent decade the national government has offered three key motivations to be specific the Accelerated Depreciation (AD), the Generation Based Incentive (GBI) since 2009 and the Renewable Energy Certificates (REC) component since 2010. A basic purpose behind the development of wind area had been the accessibility of the AD profit. With the quantum of this profit reduced under the current Plan (from first April 2012), the other elected plan called the GBI has now turned into an indispensable motivator for the wind segment. In spite of the fact that liable to be resuscitated in not so distant future, at present the GBI is additionally in suppression. The GBI in its initial couple of years of operation has not attracted Independent Power Producers as imagined, since the investors were of the slant that the current rate of INR 0.5/kwh (~1 Us\$ cent) was not sufficient or not standard with the monetary profit offered under the Accelerated Depreciation plan; as the two keep on being fundamentally unrelated.

The state-wise Renewable Purchase Specification (RPS) targets and the tradable Renewable Energy Certificates (REC) give further support to the division. However there are no motivators in the existing skeleton, particularly for state utilities in wind-energy rich states, to embrace RPSs higher than the levels inferred by the National Action Plan on Climate Change. Additionally the REC Mechanism, because of its constrained time allotment (5 years) confronts the test of

acknowledgement as an income stream by the money related establishments. Both the GBI and REC are at an early stage of implementation and require learning and capacity building for all stakeholders especially before the REC markets mature. Further, the multitudes of regulatory agencies add to the confusion. The electricity regulatory framework consists of the Central Electricity Regulatory Commission (CERC) at the federal level and a State Electricity Regulatory Commission (SERC) at the state level.

The CERC issues rules for deciding the feed-in-tariff for renewable energy based power generation and these are material to central government power generating stations and the individuals who transmit control in the between state passage. On the other hand, this is material to a quite little number of force makers and the dominant part is still secured by the tariff dictated by the SERCs. This duality is not of service, as the tariff controlled by the SERCs could conceivably be equal to that of CERC tariffs. Tariffs differ over the states and remain settled for a more extended control period, this could affect the returns for new undertakings requisitioned under this tax administration and contrarily affect new extend improvement action. In FY 2011–2012 a portion of the state utilities, such as Tamil Nadu, postponed FIT installments to wind power generators by over a year. This unfavorably influences mogul certainty in the area. Inadequate lattice foundation is an alternate key issue that needs to be addressed immediately. Over the majority of the states with noteworthy wind potential, the grid does not have sufficient ability to have to empty regularly expanding measures of wind energy. Thus, the state appropriation utilities are hesitant to acknowledge more wind energy generation and typically have a tendency to favor warm power generation. Consequently, there is an urgent requirement to expand general lattice capacity. This obliges better gauging of energy request the country over, and a modernization of the grid. In most states, accessibility of area for wind ranches is a quarrelsome issue. Regardless of the fact that private grounds are accessible, transformation of area use from farming to commercial is a long term process. In addition, if the area is near a secured territory or forest land then getting freedom from the corresponding authorities for utilizing the forestland for wind power generation is prolonged.

One more hindrance to the development of the wind sector is the high borrowing expenses. In India, a huge larger part of wind energy undertakings are considered with a 70:30 debt-equity ratio as a venture financing strategy. The high investment rates (at present >13 %) make for exceptionally costly obligation under intense macroeconomic conditions. Further it might be helpful for the little and medium endeavors to have admittance to concessional financing to hold up under the dangers identified with preparation limit growth, particularly for segment producers. Ultimately India's wind part has enormous employment creation potential as the domesticated business develops. There is prone to be higher interest for prepared labor and likewise, the specialized curriculum and educational system over the States may need to be upgraded.

## 1.6 Benefits of Renewable Energy Sources

A few benefits are connected with the consumption of renewable energy technologies, including quite low or no greenhouse-gas emissions, making them a key segment in any environmental change moderation methodology (IPCC, 2011). In the New Policies Scenario, absolute CO<sub>2</sub> investment funds over all parts from renewable are 4.1 Gigatonnes (Gt) in 2035. In the power sector, renewable-based generation reduces emissions when it displaces power generation from the combustion of fossil fuels. Relative to the emissions that would be generated if the growing electricity demand of the New Policies Scenario were to be supplied using the electricity generation mix of 2010, renewable help to reduce CO<sub>2</sub> emissions in the power sector by 3.6 Gt in 2035. These savings represent some 10 % of the level of emissions reached in 2035, with more than 40 % of the savings coming from increased wind generation. Although hydropower generation increases by about two-thirds over the projection period, its share of total generation declines in many regions, therefore its contribution to CO<sub>2</sub> savings is more limited than other renewable. Heat produced from renewable sources, as in wood pellet or solar heat boilers for example, reduce CO<sub>2</sub> emissions by 150 million tons in 2035 by displacing heat from boilers using coal, oil or gas. Biofuels reduce emissions from oil in the transport sector by an estimated 0.4 Gt in 2035 but only so long as their production does not result in increases in emissions from direct or indirect land-use changes. This aspect of biofuels has come under close scrutiny in recent years. Sugarcane ethanol and advanced biofuels have the highest potential to reduce emissions (IEA, 2011a). Biofuels have also been criticized for competing with food supply and contributing to deforestation. The negative impacts of biofuels, however, can be minimized or avoided if the right policies are established and enforced. Renewable energy is largely a domestic source of energy (although some proportion of biofuels and other bioenergy is traded internationally). When it dislodges foreign made powers, it helps more amazing national energy security and specifically decreases import bills, which in turn aid to an equitably noteworthy rate of GDP in numerous importing nations and frequently help an exchange shortfall. Biofuels have the possibility to diminish these impacts fundamentally. In addition, more utilization of renewable energy could in a roundabout way put descending weight on oil and gas costs and decrease value unpredictability. In the electricity sector, renewable mainly reduce the need to import gas or coal, as oil use is limited in this sector.

The use of fossil fuels gives rise to several pollutants that worsen ambient air quality and have a negative impact on human health. Two of the most important of these pollutants are sulphur dioxide (SO<sub>2</sub>) and nitrogen oxides (NO<sub>x</sub>); SO<sub>2</sub> coming mainly from burning coal but also from diesel fuel, while NO<sub>x</sub> come from burning all types of fossil fuels. They cause various ecological issues, for example, corrosive rain and ground-level ozone creations. Their effect is neighborhood and local. Air contamination is a significant issue in a few vast urban communities in non-OECD nations (and in a few urban areas in the OECD). Mix of air quality and renewable energy arrangements might be more powerful than divide

movements. A few sorts of renewable energy innovations for power generation require fundamentally less water for their operation than fossil fuel-based and atomic force plants. Solar PV and wind power do not use water to produce electricity and require only small amounts for cleaning purposes. If the significant use of water during the extraction of fossil fuels and uranium is taken into consideration, the differences in water use are even greater. Use of solar PV and wind power also avoids thermal pollution and contamination that may be caused by the discharge of cooling water for thermal power plants.

### 1.7 Trends in Energy Consumption

Worldwide energy utilization has relentlessly expanded in the course of recent years from 3,826.6 mtoe in 1965 to 10,878.5 mtoe in 2006. This is graphically represented in Fig. 1.1, which demonstrates the breakdown of worldwide energy utilization, based on the type of fuel. From these information it could be seen that in spite of the fact that development was moderately relentless over the period 1965–2000, there was a noteworthy increment (i.e. 1,315.3 mtoe) in utilization from 2000 to 2005. Moreover, it could be seen that over the period 1965–2005, development happened for all fuel types, with none declining in notoriety. While worldwide energy utilization has relentlessly expanded lately, in local terms this development has been sort of uneven. From Fig. 1.2 it could be seen that energy utilization in North America has expanded by just a modest measure, while that in Europe has really fallen. By examination, energy utilization in Asia has risen with

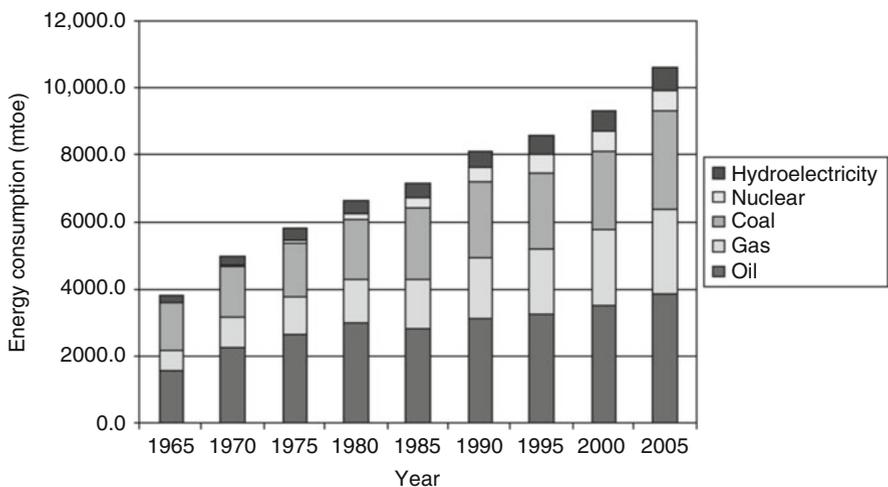
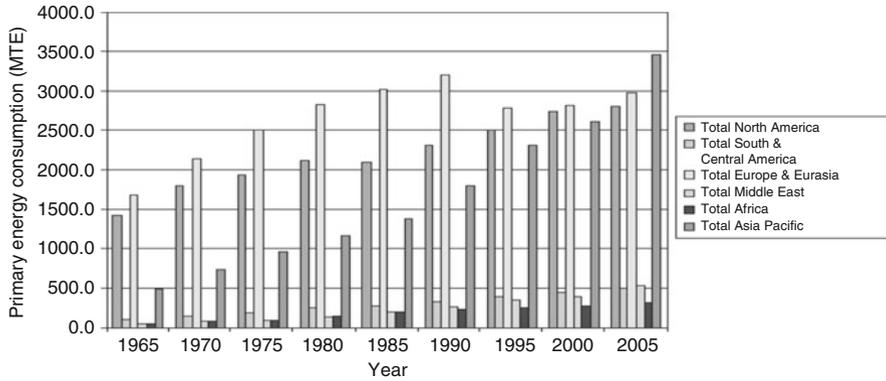


Fig. 1.1 Global energy consumption by fuel type (1965–2005)



**Fig. 1.2** Primary energy consumption by region (1965–2005)

the industrialization of China and India, so now that area consumes more energy than either Europe or North America.

Worldwide energy utilization information for 2006 is displayed in Table 1.3. These information give a nitty gritty breakdown of energy utilization on a nation by-nation and fuel-by fuel groundwork. It might be seen from Table 1.3 that in 2006 worldwide energy utilization was more or less 10,879 mtoe. Of this aggregate, just 51.1 % is devoured in the OECD nations, with 21.4 % expended in the USA and 15.8 % in the EU. While this implies that over a large portion of the world’s energy is still expended in the OECD nations, it speaks to a noteworthy movement from the position in 1999, where 59.1 % was devoured by the OECD economies. This lessening reflects the fast industrialization that has happened in China and India in recent years – a process that has been determined, to some extent, by the outsourcing of assembling ability to these nations by numerous corporate associations in Europe, Japan and North America. In 2006, China and India represented 15.6 % and 3.9 % separately of worldwide utilization. From Table 1.3 it might be seen that the fuel blend and subsequently the carbon intensity changes incredibly area wise. In the USA, for instance, the proportion of coal to regular gas utilization is 1.00:1.00, while in UK the degree is 1.00:1.87, whereas in China the proportion is just 1.00:0.04 and in India it is 1.00:0.15. These figures reflect, firstly, the movement far from coal towards regular gas that happened in the UK throughout the 1990s and, besides, the substantial dependence on coal in China and India. The Energy Information Administration (EIA) in the USA predicts that in the twenty-first century there will be significant expand in energy interest, built for the most part with respect to fossil fills. This is relied upon to happen principally due to investment development in the creating economies of Asia and South America. In creating nations, energy and monetary development have a tendency to move in parallel. Financial advancement is an energy escalated methodology which eventually raises living norms and encourages expansive access to power and mechanized transportation.

**Table 1.3** Global energy consumption data for 2006

Country	Oil (mtoe)	Natural gas (mtoe)	Coal (mtoe)	Nuclear energy (mtoe)	Hydroelectric (mtoe)	Total consumption (mtoe)	Percentage of total (%)
USA	938.8	566.9	567.3	187.5	65.9	2,326.4	21.39
Canada	98.8	87.0	35.0	22.3	79.3	322.3	2.96
Mexico	86.9	48.7	9.3	2.5	6.8	154.2	1.42
<i>Total North America</i>	1,124.6	702.5	611.6	212.3	152.0	2,803.0	25.77
Argentina	21.1	37.6	0.9	1.7	9.7	71.0	0.65
Brazil	92.1	19.0	13.1	3.1	79.2	206.5	1.90
Chile	11.4	6.8	3.0	-	6.7	27.9	0.26
Colombia	10.3	6.6	2.4	-	9.6	28.9	0.27
Ecuador	8.1	0.2	-	-	1.9	10.3	0.09
Peru	7.5	1.6	0.9	-	4.1	14.1	0.13
Venezuela	26.1	25.8	*	-	18.4	70.4	0.65
Other South & Central America	59.8	19.9	1.5	-	18.3	99.5	0.91
<i>Total South &amp; Central America</i>	236.5	117.5	21.8	4.9	147.9	528.6	4.86
Austria	14.2	8.5	3.0	-	8.1	33.7	0.31
Azerbaijan	4.7	8.6	*	-	0.6	13.9	0.13
Belarus	8.0	17.6	0.1	-	*	25.7	0.24
Belgium & Luxembourg	41.0	15.3	6.1	11.0	0.6	73.9	0.68
Bulgaria	5.0	2.7	7.4	4.4	0.8	20.3	0.19
Czech Republic	9.8	7.6	19.4	5.9	0.7	43.5	0.40
Denmark	9.5	4.6	5.5	-	*	19.6	0.18
Finland	10.6	3.8	5.2	5.4	2.6	27.6	0.25
France	92.8	40.6	13.1	102.1	13.9	262.6	2.41

(continued)

Table 1.3 (continued)

Country	Oil (mtoe)	Natural gas (mtoe)	Coal (mtoe)	Nuclear energy (mtoe)	Hydroelectric (mtoe)	Total consumption (mtoe)	Percentage of total (%)
Germany	123.5	78.5	82.4	37.9	6.3	328.5	3.02
Greece	22.1	2.9	8.8	–	1.4	35.2	0.32
Hungary	7.4	11.3	2.9	3.0	*	24.7	0.23
Iceland	1.0	–	0.1	–	1.6	2.7	0.02
Republic of Ireland	9.3	4.0	1.8	–	0.2	15.4	0.14
Italy	85.7	69.4	17.4	–	9.7	182.2	1.67
Kazakhstan	10.6	18.2	29.7	–	1.8	60.3	0.55
Lithuania	2.8	2.9	0.2	2.0	0.2	8.0	0.07
Netherlands	49.6	34.5	7.5	0.8	*	92.3	0.85
Norway	10.0	4.0	0.4	–	27.1	41.5	0.38
Poland	23.1	12.3	58.4	–	0.7	94.5	0.87
Portugal	16.8	3.7	3.7	–	2.7	26.7	0.25
Romania	10.5	15.3	7.6	1.3	4.2	38.8	0.36
Russian Federation	128.5	388.9	112.5	35.4	39.6	704.9	6.48
Slovakia	3.9	5.0	3.8	4.1	1.0	17.8	0.16
Spain	78.1	30.0	18.3	13.6	5.7	145.8	1.34
Sweden	14.9	0.8	2.2	15.4	14.0	47.3	0.43
Switzerland	12.6	2.7	0.1	6.3	7.4	29.0	0.27
Turkey	28.5	27.4	28.8	–	9.9	94.7	0.87
Turkmenistan	5.2	17.0	–	–	–	22.3	0.20
Ukraine	15.0	59.8	39.6	20.4	2.9	137.8	1.27
United Kingdom	82.2	81.7	43.8	17.0	1.9	226.6	2.08
Uzbekistan	6.9	38.9	1.1	–	1.6	48.5	0.45
Other Europe & Eurasia	26.5	13.2	22.0	1.9	17.2	80.8	0.74

<i>Total Europe &amp; Eurasia</i>	970.1	1,031.7	552.9	287.8	184.6	3,027.2	27.83
Iran	79.3	94.6	1.1	-	3.8	178.8	1.64
Kuwait	14.0	11.6	-	-	-	25.6	0.24
Qatar	4.4	17.6	-	-	-	21.9	0.20
Saudi Arabia	92.6	66.3	-	-	-	158.9	1.46
United Arab Emirates	19.7	37.5	-	-	-	57.2	0.53
Other Middle East	70.2	32.7	7.8	-	1.1	111.8	1.03
<i>Total Middle East</i>	280.1	260.3	8.9	-	4.9	554.2	5.09
Algeria	11.5	21.4	0.6	-	*	33.5	0.31

\* Data not available

Economic improvement of the foundation likewise causes development in energy escalated assembling commercial ventures. As opposed to the creating nations, in exceptional industrialized nations the connection between monetary development and energy utilization is generally frail, with energy request development falling behind budgetary development. In praiseworthy economies for every capita the utilization of energy has a tendency to be moderately stable, with old energy serious machines and gear regularly being swapped by current energy effective supplies. Hence it is anticipated that the rate development in energy interest will be significantly lower in the developed nations in contrast to the developing nations. It is anticipated by the EIA that the pattern towards the expanded utilization of regular gas in the 1990s will proceed in the twenty-first century. This is on account of regular gas is progressively observed as the fuel of decision for power generation: it has much lower carbon force than coal; the power generation procedure is more effective; it is free from the streamlined debates which are frequently connected with coal preparation; and it is much less expensive and snappier to develop gas-terminated force plants. Oil interest is anticipated to develop with the expanded utilization of mechanized transport in creating nation.

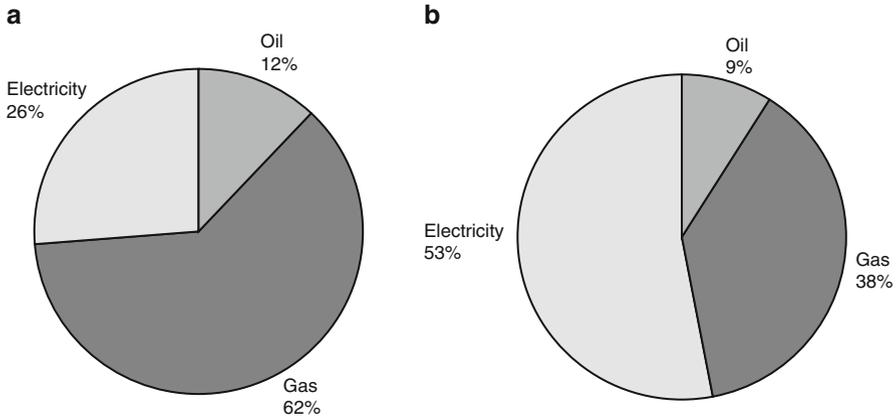
### 1.7.1 Annual Energy Consumption

Presumably the least complex investigation that might be attempted is to process a cost breakdown of 12-month energy utilization and expense information. This is a handy method which empowers the general energy execution of a building rapidly and effortlessly to be evaluated. The examination of yearly energy utilization ought to be executed as follows:

- (i) Convert all the energy consumption data into standard units (usually the kWh).
- (ii) Produce percentage breakdowns of the total consumption and cost of each energy type, and determine the average unit cost per kWh.
- (iii) Compile a table similar to the total annual energy consumption, cost and percentage breakdown of each fuel type.
- (iv) Produce pie charts to show the energy and cost contributions graphically for each energy type.
- (v) Where historical energy data are available, comparisons should be made in order to identify the trends, as illustrated in Table 1.4.

**Table 1.4** Changes in annual energy use

Year	Consumption (kWh)	Change (%)
1994–1995 (base)	201,456.4	NA
1995–1996	197,562.2	–1.9
1996–1997	203,216.2	+0.9
1997–1998	220,403.5	+9.4
1998–1999	236,800.0	+17.5



**Fig. 1.3** (a) Energy consumption (b) Cost estimation

It is critical to note that in spite of the fact that the straightforward examination portrayed above may generate energy cost breakdowns and distinguish conceivable patterns, no recompenses have been made for uneven variables, for example, the climate, which may impact the energy execution of the office. It ought to thus be seen as a noticeably unrefined dissection system, and ought not be utilized when looking at the energy execution of one building against an alternate (Fig. 1.3).

### 1.7.2 RES in INDIA

India confronts a huge test in giving access to satisfactory, competitive and clean wellsprings of energy, particularly cooking fuel to a substantial area of the populace who live in rural ranges. According to the 2011 Census, just about 85 % of rural family units were reliant on accepted biomass fills for their cooking energy prerequisites. National Sample Survey 2009–2010 uncovers the proceeded reliance on kindling in country ranges for cooking, with rate of families relying upon kindling staying at 76.3 % in 2009–2010 with a drop of just 2 rate since 1993–1994, despite the fact that the rate utilizing LPG has expanded from something like 2–11.5 % over the same period. Then again, the frequency of reliance on kindling for cooking in urban ranges has tumbled from about 30 % to 17.5 % between 1993–1994 and 2009–2010 a drop of more than 12 rate and the occurrence of reliance on lamp oil has plunged from 23.2 % to 6.5 % throughout the same period which records to 72 % lessening, while the rate of urban family units utilizing LPG has multiplied from 30 % to 64.5 %. At the end of the day, the development in pervasiveness of utilization of LPG in urban regions has been adjusted by a real decrease in usage of oil lamps accompanied by kindling and chips. In rural ranges, the ascent in LPG use

has been mostly from fertilizer cake, emulated by lamp fuel. Further, according to the NSSO Reports (55th, 61st and 66th Rounds), there has been an expansion in biomass fuel use as far as total amount expended over the previous decade around rural family units. This is a zone of concern given the respectable health effects of smoldering biomass powers separated from being a deterrent to accomplishing developmental objectives, i.e. guaranteeing a base expectation for everyday life. In this manner, a move to cleaner manifestations of energy regarding access to power and other up to date energy structures might have suggestions on energy security, as well as for empowering sexual orientation balance and achieve more terrific improvement and social advancement. It is in this connection that the part of renewable energy requirements is to be considered. It is no more “interchange energy”, however will progressively turn into a key some piece of the answer for the country’s energy needs.

India has an immense supply of renewable energy assets, and it has one of the biggest projects on the planet for conveying renewable energy items and frameworks. Renewable energy has been a paramount part of India’s energy arranging procedure since a long while. The conversion of renewable energy sources to a supportable energy base was distinguished in the early 1970s. At the Government level, political responsibility to renewable energy showed itself in the station of the first Department of Non-Conventional Energy Sources in 1982, which was then updated to a full-fledged Ministry of Non-Conventional Energy Sources (MNES) in 1992 accordingly renamed as Ministry of New and Renewable Energy (MNRE). Truth be told, India is the main nation on the planet to have a service only for renewable energy advancement. MNRE is the nodal Ministry of the Government of India at the Federal level for all matters relating to new and renewable energy. Ever since its inception, the Ministry has been launching many ambitious programs on renewable energy, facilitating the implementation of broad spectrum programs including harnessing renewable power, renewable energy to rural areas for lighting, cooking and motive power, use of renewable energy in urban, industrial and commercial applications and development of alternate fuels and applications. The Ministry has also been involving in activities such as encouraging research, designing and developing products and services related with renewable energy trends.

In view of the fast changing energy scenario both domestically and internationally, and the important role expected to be played by new and renewable energy (NRE) sources, it is imperative to take stock of the progress achieved so far adopt a more focused approach than hitherto fore and chart out a clear strategy for accelerated growth of the NRE sector over the short, medium and long term.

### ***1.7.3 National Policy Measures Supporting Renewables***

Enactment preceding the Electricity Act, 2003 (EA 2003) had no particular procurements that might promote renewable or nonconventional resources of energy. Notwithstanding this weakness, the Ministry for New and Renewable Energy has

worked towards supporting the sector by proposing policy guidelines since 1994–1995, with blended outcomes. On the other hand, the EA 2003 changed the legitimate and administrative schema for the renewable energy area in India. The EA 2003 orders strategy plan to push renewable wellsprings of energy by the national government, the State governments and the individual organizations inside their locales. The SERCs focus the duty for all renewable energy ventures over the States, and the state-possessed force Distribution Companies (DISCOMs) guarantee framework connectivity to the renewable energy venture destinations, which for the most part are arranged in remote areas far from real load focuses. The order, which is known as a Renewable Purchase Specification (RPS), shifts from 0.5 % to 10 % in different states in excess of 2012–2013. A coordinated energy approach schema in India, the first endeavor at pulling together an umbrella energy arrangement approached after just about 60 years of the nation's freedom. The Planning Commission carried out the 'Coordinated Energy Policy: Report of the Expert Committee' (IEP) in October 2006, which gave a wide framework to all systems administering the preparation, dispersion, use and so on of diverse energy sources. In spite of the fact that the report of the master advisory group has been accessible since 2006, political duty to it has been restricted. After analyzing the IEP report absolutely from the viewpoint of the help it gives to renewable, which accentuated the necessity to move far from capital subsidies towards execution motivators for pushing renewable sources. The IEP report consigned a constrained part to power generation from renewable energy sources even as late as 2032, with just 5.2 % of renewable source based generation in the framework.

#### ***1.7.4 Renewable Energy Law***

One of the basic prerequisites for India is to create and receive a coordinated energy skeleton that has a long haul vision, a period bound arrangement and an executing order that supports India's exertions for accomplishing clean, secure and all inclusive energy access for its kin. Today, most nations with progressed levels of wind force advancement have this structure set up, normally as a renewable energy law. Such a skeleton, if received, can help to address not just the concerns of moguls in connection to unstable strategy environment and business chances additionally convey indigenous power supply free from the fuel value danger connected with fossil energizes.

India will need to put resources into alternatives that give energy security as well as give practical equipments to destroying energy destitution no matter how they are focused, in the following decade. As a piece of commitments to the United Nations Climate Convention (UNFCCC), India discharged a National Action Plan on Climate Change (NAPCC) in June 2008 that laid out the legislature's vision for a maintainable and clean energy future.

The NAPCC could be actualized through the foundation of eight national missions. Two energy related missions are incorporated, to be specific the National

Solar Mission and the National Mission for Enhanced Energy Efficiency. Other significant thing about NAPCC is it doesn't have induction devoted to wind power. The NAPCC stipulates that an element least renewable buy focus of 5 % (of aggregate lattice buy) may be endorsed in 2009–2010 and this ought to build by 1 % every year for a time of 10 years. As per NAPCC by 2020, India ought to be obtaining 15 % of its energy from renewable energy sources.

### ***1.7.5 Generation Based Incentive (2009–2012)***

In 2009, for lattice associated wind force ventures, Government actualized a Generation Based Incentive (GBI) plan. A GBI of INR 0.50 for every kwh (1 US \$ penny), with a top of roughly \$29,000 for every MW for every year, totaling \$116,000 for every MW over 10 years of an undertaking's life was offered under this plan. Between March 2010 and October 2012, 2,021.29 MW capacity of wind activities had benefitted themselves of the GBI profit and 1,830.43 MW undertakings of AD profits. The GBI plan incorporates hostage wind force ventures, yet prohibits outsider bargain, for instance, dealer force plants. GBI and AD profits are totally unrelated. The GBI is far beyond the duty sanction by separate Sercs and dispensed on a half yearly support through the Indian Renewable Energy Development Agency (IREDA). At first this plan was appropriate to wind force ventures dispatched before 31st March 2012. Not long ago the MNRE proposed that the GBI proceed over the twelfth Plan period, with a conceivable amendment of the motivating force. The last support from the Cabinet is pending as of October 2012.

GBI plan was not alluring enough to draw designers far from AD in its unique structure. As per gauges by IREDA, at the predominating duties in 2010, the IRR (post-charge) for wind holdings might be higher by 1.2–1.5 % if there should be an occurrence of AD profits over all key states other than Maharashtra. Likewise, the low capacity figures in the vast majority of the states implied that the present GBI might not have made an extend more possible in correlation to AD. Then again, the GBI does not restrict wind power makers from entering the REC market. The administration activity to move far from duty subsidy backing to execution impetus backing of INR 0.50 for every kwh has not discovered an excited emulating to a great extent because of the low esteem of the motivating force and the tops on the guaranteed sum.

Continuation of the GBI conspire in its prior structure is questionable. For the advancement of wind undertakings from an assessment arranging measure to a energy arranging instrument, the GBI plan might need to be further improved. Industry masters in India infer that developing the plan to incorporate hostage and third-party bargains, and in addition multiplying the impetus to INR 1.0 for every kwh or evacuating the top of INR 6.2 million (\$116,000) for every MW could help support the advance of the plan.

### ***1.7.6 Renewable Energy Certificate Scheme***

The Electricity Act 2003 proposed required Renewable Purchase Specification (RPS) for all the states. So far till date, 26 states have specified focuses for the uptake of power from renewable energy sources. With the presentation of the Renewable Energy Certificate (REC) scheme in 2010, states are currently satisfying the RPSs under this procurement by securing comparable RECs. REC is a tradable authentication of verification that a renewable energy plant has created 1 Mwh of power. Under this schema, renewable energy generators can exchange RECs through a force trade stage that permits business sector based value revelation, inside a value reach controlled by the Central Electricity Regulatory Commission. The particular value points of confinement are called forbearance price and floor cost and their qualities are computed independently for solar based and non solar based sources (i.e. wind, biomass, little hydro). While the CERC has stipulated floor and abstinence costs for RECs; the true cost of a REC might be resolved at the force trades dependent upon predominating power supply and interest circumstances.

The exchanging of RECs in the Indian market started in February 2011. So as to meet all requirements for RECs, venture designers necessity to enroll with the National Load Dispatch Centre. The issued RECs are exchanged at qualified force trades inside the capacity set by the floor cost and abstinence cost, as controlled by the CERC. For wind power generation, as of April 2012, the amended extent is between INR 1,400 (~\$26) to INR 3,480 (~\$65) for every Mwh. By mid-October in 2012 the national REC registry had issued 3,384,257 RECs of which 3,381,714 were non-sunlight based RECs. Of the aggregate authorize venture capacity recorded by the national REC registry, wind represented over 56 % or 1993.46 MW of the capacity by October 2012. The quick expand in volume recommends that more research engineers are entering the REC market and the system is welcoming premium yet feeble authorization of RPSs at the State level is prompting climbing amounts of unsold RECs in the business. In September 2012, dealers offered to offer 7, 11, 171 (non sun oriented) RECs, however just 2,64,446 were purchased, and that too, at the floor cost of INR 1,40,030. Throughout September 2012, no state-possessed power Distribution Company (DISCOMs) approached to purchase the testaments, in spite of the fact that they are all 'committed elements'. This is because of absence of authorization of their commitments. The RPS is material on the Distribution Companies (DISCOMs), open access buyers and hostage power clients consistently. On the other hand, the present RPS system is discovered needing in viable agree ability and implementation at the State level. Also the hostage power clients in states like Gujarat, Rajasthan and Orissa are not extremely quick to buy renewable based force for gathering the RPS and have tested the RPS regulations. The configuration of the REC instrument is continuously enhanced with endeavors being made to handle the execution issues as they emerge and there is expanded taking in the business sector. A portion of the states have forced punishments for rebelliousness with RPO focuses on the

generators or utilities. Activities are continuously anticipated creating a voluntary REC showcase likewise.

Making REC a generally acknowledged instrument and an income stream for the undertaking financing group still remains a test in India. Further there is a necessity for an element RPS setting methodology with incessant upward amendment to meet the 15 % renewable energy target set under the NAPCC by 2020.

### ***1.7.7 National Clean Energy Fund***

The legislature proposed the formation of the National Clean Energy Fund (NCEF) in the Union Budget 2010–2011 by forcing a clean energy charge (cess) of INR 50 (~\$1) for every term. The Ministry of Finance, through the Clean Energy Cess principles 2010, set rules for the gathering and appraisal of this duty by the Revenue Department. From there on an inter-ministerial assembly was set up in the Ministry to support tasks and qualification necessities for entering stores from the NCEF. However since its commencement in July 2010, few data on the operationalization of the NCEF has been discharged in general society realm other than the rules and requisition structure for recommendations. A study directed by WISE gauges that at the current expense rate and the normal coal utilization rates, an aggregate of INR 670 billion (~\$12.5 billion) could gather to the trust by 2022. This store could help network and other framework improvement to take into account more excellent departure of force produced from renewable energy sources. The store could likewise be utilized for exploration, advancement and sending of clean and renewable energy innovations. The proposals presented by national Ministries were lacking quality and were not innovative, thus failing to meet the objectives of NCEF. In addition, the large amount of NCEF funds remains unutilised. Thus it is required to modify the rules of NCEF thus utilizing the funds for gathering customary budgetary deficits of Ministries. Financing to help different Ministries' customary exercises ought to be met from the suitable sources accessible inside the existing financing structure of the general Budget. In spite of the fact that admissible under the rules, there has been constrained contribution of Indian industry and examination establishments to date in the proposal advancement process. This prescribes constrained cognizance around Indian exploration foundations and industry on the NCEF subsidizing opportunity.

### ***1.7.8 Other Initiatives: Renewable Regulatory Fund Mechanism***

The Indian Electricity Grid Code (IEGC) was received in April 2010 and supercedes the Indian Electricity Grid Code, 2006. It gives itemized rules on the

part of different players included in the operation of a power system. Under Clauses 5 and 7 of the IEGC, unscheduled exchange charges because of the variety in real generation by wind and solar ought to be imparted around all the States through the 'Renewable Regulatory Charge' to be worked through the 'Renewable Regulatory Fund' instrument. This might have made gauging and planning of wind and solar power generation compulsory with impact from January 2012 with the introductory execution of the RRF component. However this still stays to be presented, despite the fact that the point by point methods presented by National Load Dispatch Centre were analyzed by CERC and the changed strategies were distributed on eighteenth February 2011.

The execution of Renewable Regulatory Fund system is postponed because of a few ground level issues; including an absence of coordination between the CERC directives and auspicious agreeability by different SERCs. Determining the concerns on both sides through early and preemptive involvement of stakeholders including different Regional and State Load Dispatch Centers, the MNRE and wind farm designers is critical. This might help in guaranteeing more level abridgement and higher generation numbers from both wind and solar power plants.

### ***1.7.9 Land Allocation Policy***

In perspective of the developing number of wind force establishments in the nation and the expanding scarce of permissible area with wind potential, the MNRE, through its correspondence dated fifteenth May 2012, has asked for state governments to inspect their property strategy for wind power establishments and figure an approach for area designation on a "footprint" hypothesis. The MNRE is working towards executing the best practices in this respect.

### ***1.7.10 Grid Integration Issues***

India's transmission system has a two-level structure: interstate networks that are overseen by the Power Grid Corporation of India (PGCIL) and the nearby lattices, which are overseen by the State Transmission Utilities. India still needs to make an interlinked and joint by combining its nearby, territorial and national networks. Frequently insufficient and frail lattices go about as a hindrance to smoother reconciliation of power generation from renewable sources. India's energy transmission framework is partitioned into five local matrices: northern, northeastern, eastern, southern and western districts. Since August 2006, four local lattices have been completely incorporated except for the southern matrix that is to be synchronized with these networks by 2014.

The variability of wind power can create problems for the traditional grids in maintaining a supply and demand balance. Most of the wind farms in India are

located in remote areas that are quite far away from load centers. Due to a weak transmission and distribution network, it is difficult to transmit the power from wind farms to the load dispatch centers. This is one of the key constraints for the future of wind power development in the country. In the past, with vertically integrated utilities, a single organization was responsible for the planning and operation of networks and giving access to generators, and therefore the technical requirements did not have to be particularly clearly defined or codified. Now, with increased ownership separation between grid operators and power generators the need for defining the technical requirements governing the relationship between them becomes essential. Renewable energy generation further complicates the process of evacuation and dispatch.

### ***1.7.11 Grid Transmission Planning Process***

Lack of adequate power evacuation capacity in the state grids is a major concern in transmission planning. Unless the transmission capacity planning process incorporates a long term vision of planned wind power additions and involves wind sector players at the planning stage, bottlenecks related to evacuation capacity are expected to remain. The remedy is more procedural than technical and requires administrative will rather than advanced technical understanding. The Ministry of Power (MOP) has recently constituted a committee chaired by the Joint Secretary of the MOP to work on accelerated development of RE through legislative and policy changes. One of the suggestions to streamline transmission planning for renewable energy is to have a separate sub-division in the Central Electricity Authority (CEA) and across all the state utilities for transmission planning of all renewable energy power plants. India's local distribution systems are weak and would require substantial augmentation or laying of parallel power evacuation infrastructure, which will invariably add not only to the costs but also to construction time. The issue is further muddled by stipulations identified with expense imparting of building this extra infrastructure. It is particularly valid for state-claimed utilities (DISCOMs) that are seriously impoverished. An alternate real concern is that of constrained power outage (curtailment) due to powerless local grid, which brings about considerable generation loss for the investing organization. In addition, intricacies related to institutional learning, ground level information and deficiency of expertise knowledge in grid integration and comprehensive power evacuation planning are adding to the postponement. For utilities that are usual to the customary model of concentrated power generation, these issues are prone to wait for some more years. In India, past regulations under the electricity grid code (IEGC) did not permit renewables based power to associate with the inter-state transmission system, bringing about interconnection of wind force tasks to a powerless State transmission or dispersion system prompting constrained blackout of generation, particularly throughout the crest wind season. The need to allow power evacuation at higher voltages in the inter-state grid of the Central transmission utility (PGCIL 36) is critical for the growth of the sector. The CERC recently allowed projects with

capacities of over 50 MW to connect directly to the central transmission network subject to scheduling requirements. This allowance has addressed one long-standing concern of investors by reducing the threat of curtailment.

### ***1.7.12 Interconnection Standards***

Grid stability is the primary consideration in interconnecting any new system to an existing grid. The conventional electricity network tuned to conventional generation's radial mode of power flow and wind power poses new challenges related to safety, reliability and efficiency of the interconnected systems. Because of the variable nature of wind power, the aim of developing an interconnection standard would be enable the grid to sustain the variability without affecting the power quality adversely. Under (IEGC) 2010, wind and solar assignments have been offered 'must-run' status. The IEGC unites a solitary set of specialized and business guidelines, incorporating all the utilities that are joined with or utilize the inter-state transmission system.

### ***1.7.13 Green Energy Corridor***

Recently, the MNRE and CERC has commissioned the Power Grid Corporation of India (PGCIL) to study and distinguish transmission infrastructure for renewable energy capacity expansion throughout the twelfth plan period. Based on extensive conferences, conclusions were drawn with different stakeholders including the State Nodal Agencies, the last report called 'Environmentally friendly power Energy Corridors' was discharged in September 2012. It examines issues of inter-state and intra-state transmission framework, for example, strengthening and augmentation, foundation of a Renewable Energy Management Centre, enhanced anticipation addressing variability viewpoints and also lattice reconciliation issues of huge scale renewable energy generation. A venture of roughly \$8 billion (~INR 42,557 crores) is continuously anticipated the advancement of this hall by 2017. Among the total sum allotted, \$3.8 billion (INR 20,466 crores) is liable to be invested in intra-state grid system and roughly \$4 billion (INR 21,867 crores) is prone to be invested in strengthening the inter-state transmission framework. This activity if executed effectively could be a significant driver for the improvement of the renewable energy division in India.

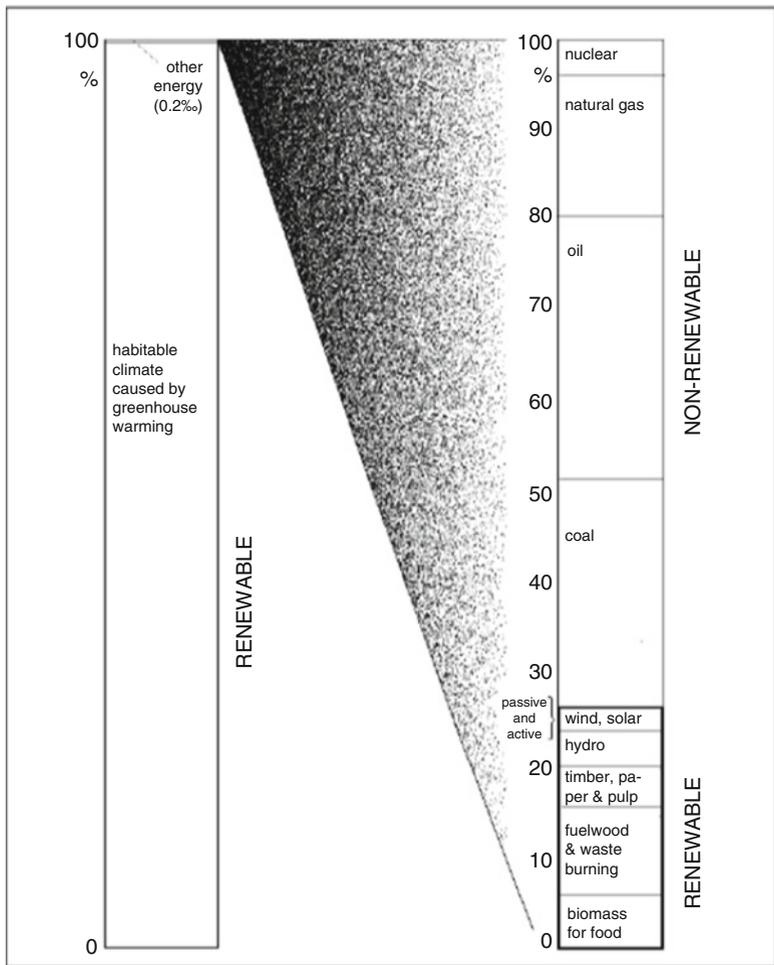
### ***1.7.14 India Smart Grid Task Force***

Particularly after the presentation of the IEGC, grids over the nation are obliged to tackle power generated from nonconventional energy sources under different plans

(RPSs and RECs). The Ministry of Power (MOP) took the first step towards lattice changes when it set up the 'India Smart Grid Task Force' (ISGTF) in June 2010. The ISGTF is an inter-ministerial group that serves as the administration point of convergence for arrangements identified with Smart Grid improvement in India. MOP's vision of a smart grid was to unite the fields of correspondences, IT and the power segment to build an extensive power grid framework. Henceforth the requirement to redo and modernize the national/regional and nearby frameworks must be one of the essential territories of speculation and advancement. Further, on the interest side it imagined giving a decision to the purchaser to choose the timing and measure of power utilization based upon the constant costs in the power market. Further, under one of the missions of the NAPCC, called the National Mission for Enhanced Energy Efficiency, India's Bureau of Energy Efficiency partnered with the IT firm IBM to create the country's first smart grid project in May 2011. The focus of the analysis will be determining India's readiness for deploying smart grid technologies. It will also develop a framework for adopting new smart grid technologies and identifying regulatory frameworks. The analysis will calculate return on investment for a range of smart grid projects planned across India. The ISGTF has set up five working gatherings, including 'Trials on new innovations' and 'Transmission misfortune decrease and robbery, information social affair and investigation'. In the interim, in view of the proposals of the Indian Smart Grid Forum, the MOP is supporting 14 pilot venture suggestions worth nearly \$72 million (INR 400 crores) for smart grid pilot projects across different areas. These suggestions concentrate on assorted ranges of the force area, including incorporation of renewable energy sources with the framework and bringing down of total specialized and business losses. On the other hand for this basic activity to be successful, it is vital that different elected services, for example, the Ministry of Power, the Ministry of New and Renewable Energy, the Ministry of Communications and Information Technology and the Ministry of Environment and Forests, and their state level partners must meet up to develop a regular movement plan. Further, both state and national grid administrators and their related electricity regulatory commissions must start community exchange across the country towards characterizing a basic comprehension of a genuinely brilliant network framework for India. A top down prescriptive report from the focal government through the ISGTF could prompt costly postponements, which might bring about the speculators and power producers proceeding towards other financing chances.

## **1.8 Worldwide Potentials of Renewable Energy Sources**

The Earth's energy framework seen by the occupants is overwhelmed by the environmental heat associated with the nursery the impact initiated via carbon dioxide (CO<sub>2</sub>) accumulation, which captures solar energy and stores it inside a surface sheet of topsoil and air around the Earth. Just 0.02 % of this energy



**Fig. 1.4** Renewable energy in the global energy system

framework is right now overseen by human culture, as delineated in Fig. 1.4. Inside this financially managed part of the energy sector, renewable energy sources as of now give around 25 % of the energy supplied. According to Fig. 1.4, a vast a piece of this renewable energy is biomass energy, either in food crops or in managed forestry supplying wood to streamlined purposes or for incineration. The moreover misused wellsprings of renewable energy incorporate hydro, wind and sun powered. Hydropower is a considerable source; however its utilization is no more developing because of ecological cutoff points distinguished in numerous areas with potential hydro assets. Passive solar warming is a key characteristic of building design all over the world, yet active solar warming power panels are still at an extremely moment level of penetration. Wind energy has a both passive and

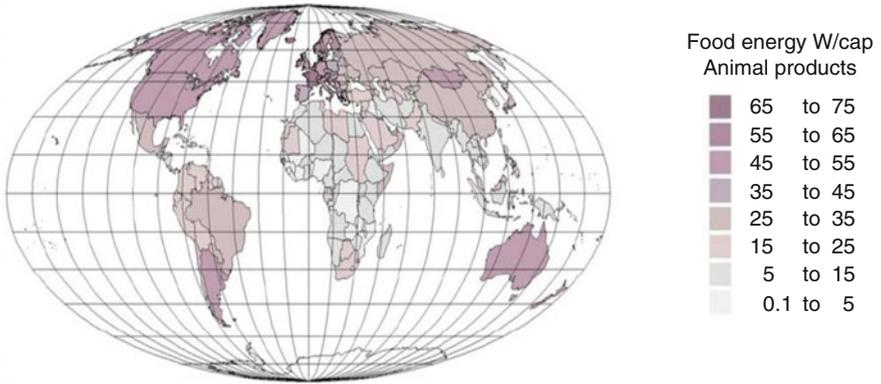
active role, inactive utilization of wind energy for ventilation of structures assumes a critical part, and active power generation by wind turbines is today a quickly developing energy innovation in numerous parts of the world. The elevated penetration reaching at almost 20 % of aggregate power produced is found in Denmark, the nation pioneering present day wind innovation. As demonstrated in Fig. 1.4, the predominant energy sources are still fossil fuels, notwithstanding the way that they are depletable and a reason for regular national clashes, because of the crisscross between their specific topographical accessibility and interest examples. Further renewable energy innovations, so far with little worldwide penetration, incorporate biofuels, for example, biogas and geothermal power and heat will start to exist.

Current renewable energy markets contain purchaser markets, markets determined by government show programmes and business sector invigorating subsidy plans. The explanation behind the initialization is in part modern arrangement, pointed at kicking new industry ranges off, the expected energy commercial ventures are not completely paying for the negative ecological effects initiated by their items. This is a complex issue, part of the way on account of the challenge in careful determination of outside expenses. Partly due to the fact that most nations recently require tariff on energy items that may to some extent be helping towards paying for the natural damage. Active use of renewable energy have been penetrating recently, in national energy frameworks, and the Figs. 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 1.14, and 1.15 show the qualities for year 2000, which may serve as a source of perspective year for surveying up to date information. In situations where the development rate is specifically high, its 12-month quality is specified indicating the national appropriation of businesses.

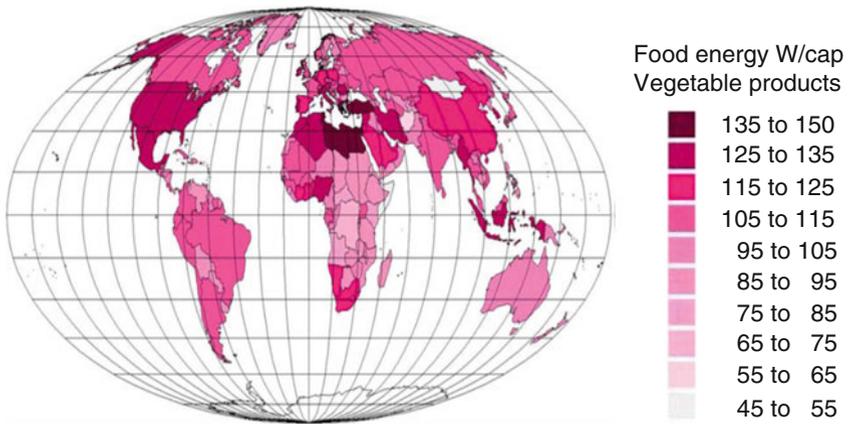
The national average values of wind power generation for year 2000 are indicated in Fig. 1.5 based upon BTM (2001) and an average capacity factor of 0.3. The world average for the year 2000 is 0.92 W/cap. The development in cumulated introduced capacity from 2000 to 2001 was 35 % (BTM 2002). A few eyewitnesses anticipate that the development will moderate throughout the accompanying years,



**Fig. 1.5** Wind power production (Courtesy: NCEP-NCAR, 1998)



**Fig. 1.6** Illustrates biomass energy contained in time-averaged food intake of animal products (Courtesy: NCEP-NCAR, 1998)



**Fig. 1.7** Shows biomass energy contained in human time averaged food intake of vegetable products (Courtesy: FAO, 2003)



**Fig. 1.8** Shows biomass energy contained in wood fuel (Courtesy: OECD/IEA 2002a; 2002b)



**Fig. 1.9** Shows energy in biomass waste (refuse) utilised for power or heat production (Courtesy: OECD/IEA 2002a; 2002b)



**Fig. 1.10** Shows energy of liquid biofuels namely ethanol and biodiesel (Courtesy: OECD/IEA 2002a; 2002b)

for monetary and political reasons, however then to continue development (Wind Control Monthly 2003).

The average animal based food consumption for the year 2000 is 22.2 W/cap. The national average values for year 2000 are shown in Fig. 1.6 (FAO 2003).

National average Values for year 2000 are shown in Fig. 1.7. The world average vegetable food intake for year 2000 is 113.7 W/cap.

National average values of biomass energy held in wood fuel for year 2000 are indicated in Fig. 1.8. The world normal wood-fuel use in year 2000, inferred by the



Fig. 1.11 Shows energy in biogas (Courtesy: OECD/IEA 2002a; 2002b)

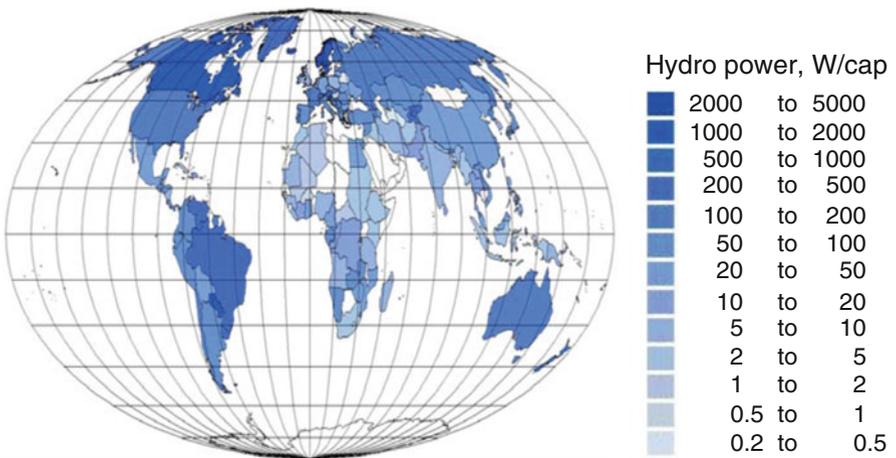


Fig. 1.12 Energy in hydropower (Courtesy: OECD/IEA 2002a; 2002b)

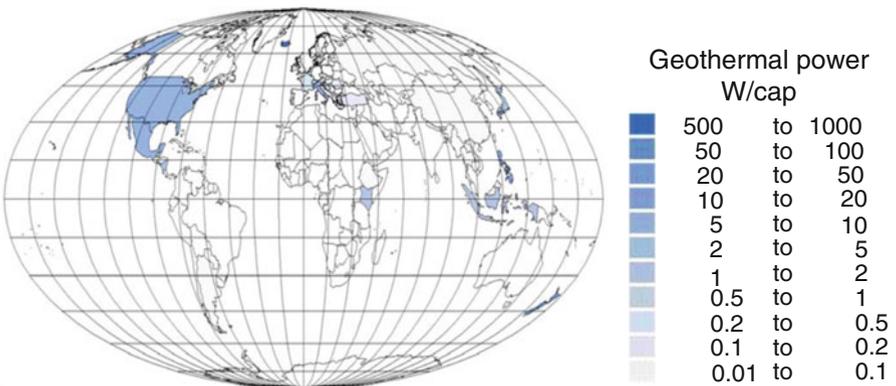


Fig. 1.13 Energy in geothermal power (Courtesy: OECD/IEA 2002a; 2002b)



**Fig. 1.14** Energy of solar power (Courtesy: OECD/IEA 2002b)



**Fig. 1.15** Energy in solar heat (Courtesy: IEA PVPS 2001)

information, is 221.9 W/cap. No wood fuel utilization is accounted for Russia, while other nations are not secured by the information source.

National average values for year 2000 are shown in Fig. 1.9 based upon OECD/IEA. The world average for year 2000 is 3.7 W/cap.

National average values for year 2000 are shown in Fig. 1.10, based upon EC-ATLAS (2003) and OECD/IEA. The world average for year 2000 is 2.3 W/cap.

National average values for year 2000 are demonstrated in Fig. 1.11, based on converting the amount of units (FAO-Asia 2003), with an assumption that for every family unit a biogas production of half that of an optimally working unit fed manure from the equivalent of 2.5 cows and producing 1,736 W of biogas. The information is obtained from OECD/IEA. The world normal for year 2000 is 2.8 W/cap.

National average values for year 2000 are shown in Fig. 1.12, based upon OECD/IEA and installed power data from Aqua-Media (1997) for countries not covered by IEA, using estimated capacity factors of 0.2–0.4. The world average for year 2000 is 50 W/cap.

National average values for year 2000 are shown in Fig. 1.13 based upon either 10 % of heat input given in OECD/IEA or 60 % of installed power from Barbier (1999). The world average for year 2000 is 9.3 W/cap.

National average values for year 2000 are shown in Fig. 1.14 based upon OECD/IEA or an average energy production equal to 10 % of the installed capacity given in IEA-PVPS (2001). The world average for year 2000 is 0.007 W/cap. The growth rate from 2000 to 2001 was 35 %.

National average values for year 2000 are shown in Fig. 1.15, based upon IEA-PVPS. Both building-integrated and central district heating thermal systems are included. The world average for year 2000 is 0.11 W/cap.

The conventional utilization of biomass for combustion is still the commanding utilization of renewable energy. The utilization of nourishment energy in biomass of creature or vegetable cause is marginally less (146 W/cap). Next comes to hydropower (50 W/cap) and after that geothermal force, which could be considered partially renewable (as numerous steam repositories are abused at a rate that will deplete the store over times of decades). Deciphering OECD information (OECD 2002) to energy units, the current entire bargain cost of grains, for example, rice or wheat are around 70 c/kwh, while the entire deal cost of normal meat and dairy items are about 100 c/kwh. Nonetheless, the quickest developing markets are those of wind and sunlight based force, both right now including 35 % of introduced power every year. Just specific gourmet items get higher costs in the commercial center. Purchaser retail costs are commonly five times higher than the mass costs recently cited. This is more than 30 times the current buyer cost of a kwh of power generated from fossil fills. Wholesale market costs for biomass waste and fuel wood range from about 1 c/kwh (of “blazing quality”, i.e. energy of ignition) in India (FAO-Asia 2003) to around 2 c/kwh in industrialized nations (e.g. straw, wood chips 1.6 c/kwh and wood pellets 1.9 c/kwh, Danish Energy Agency, 1996. For correlation, the expense of coal before acknowledging externalities is 0.5 c/kwh (Danish Energy Agency 2002). The generation expense of biogas is 3.6–7 c/kwh (Danish Energy Agency 1992). While that of wind force is 3–7 c/kwh, contingent upon wind conditions and that of photovoltaic solar energy is 40–130 c/kwh (IEA-PVPS 2002). The photovoltaic business revels in generous open start-up subsidies to industry (frequently as financing client ventures or offering engaging purchase back rates for overabundance sun based force). This is the situation in nations, for example, Germany, Japan, and in Switzerland the business has to a great extent been made by commercial enterprises purchasing PV (Photovoltaic’s) for reasons of feel or picture greening.

## 1.9 Need for New Energy Technologies

The IEA’s most recent observations on global energy are as follows:

- All current energy trends are not sustainable.
- Oil will likely remain the leading energy source.

- Oil fields have declined, so undiscovered oil reserves will be needed to sustain current consumption.
- Countries must cooperate on holding the average global temperature rise to 3.6 °F (2 °C).
- Arresting current global temperature rise requires lowering emissions in both industrialized and non industrialized regions.

For hydropower, improvement is required to be generally confined to arrangement with ecological and social effects. This could prompt accentuation on smaller, falling plans rather than the exact extensive dam establishments seen previously. Still, the basic technology must be considered as fully developed, and the cost of environmentally sound hydro schemes is rarely lower than that of fossil fuels, the expansion rate of hydropower globally has narrowed to nearly zero. There are still possible new sites available, and if social acceptance can be regained after the disasters of the past, then environmentally integrated hydro could add a further substantial amount to global renewable energy supply. On account of wind turbines, a further advancement with present patterns, especially in materials, will permit bigger flat pivot turbines to be assembled. In spite of the fact that other wind change methods could get practical, the achievement of the flat hub idea is liable to keep it in a heading position. Modification in blade profile and regulation characteristics of the blades are prone to be accompanied by the broad investment in offshore wind. Currently, the same turbines are sold for deployment on land and at sea. However, the wind conditions at sea are so different, that the land design typically chosen to optimize total annual production at good sites on land, far from the same turbine which is placed off-shore. But these concerns still involve only small adjustments to a technology which is already close to maturity, with different blade designs for different locations, and for control of pitch. The later is applied in commercial turbines and gives a few percent improvement in average efficiency. Thus, the main challenge in wind turbines is improvement of materials, particularly for blades and also for cost reduction of foundations. Such advances in blade construction will allow turbines with rated power larger than the 2–3 MW which is typical at present. Furthermore, with any mature technology continued small improvements in cost per produced kWh with time can be expected. Entirely new concepts could be imagined for harvesting, still higher wind power levels are found at open sea, i.e. much further offshore than exploited by current machines standing on the sea floor. These could be consolidated wave and wind-capturing gadgets, drifting however kept inside a limited region by praiseworthy navigation framework. The wind turbines could be covered or ducted developments, while the wave energy part is liable to utilize double air turbines. No improvements in this bearing have been fruitful so far. Wave energy devices for near-shore employment have not successfully struck the balance between the necessary strength and economic power production, and no large mid-ocean wave converters have reached interesting sizes for energy production.

Various biomass change routines are close enough to guide investment practicality for the incorporation of backhanded matters of trade and profit in expense

correlations to make them adequate. This is valid for biogas plants, especially on a mutual scale and as a major aspect of general waste administration plans. Gasification plans accompanied by hydrogen or fluid biofuel creation are additionally getting suitable, contingent upon the valuation utilized for the externalities of current fuel-based energy frameworks. Without contemplations of backhanded matters of trade and profit, such plans are not presently practical, as showed by the endeavors to generate vaporous and fluid fills from coal and sugar crops. However, in addition to altering the economic valuation, there is certainly room for technology improvements in gasification, cleaning and chemical reaction steps, involving device construction and possibly use of new pathways are possible. The entire bioenergy field may be in for a radical restructuring if the current trends of valuing high food quality continues and spreads to regions not currently being concerned. This may alter agricultural practices, both for plant and animal production, and lead to new concepts of integrated food and energy production based upon ecological principles, such as distinct from the concept of dedicated energy crops. Geothermal resources used in a sustainable way can be a stable source of low-temperature heat, and cost already appears acceptable. The market for such geothermal solutions depends on the viability of district heating. New projects of district heating by geothermal energy are coming on-line, e.g. the Amager plant serving the existing Copenhagen heat network. If the full potential for making existing and new buildings highly energy-efficient is realized, there will be very few locations in the world, where district heating is economically attractive (probably only city centre's with dense high-rise buildings).

As regards solar energy, the thermal applications are in some, not too high-latitude regions, economically viable in an assessment including externalities for conventional solutions. But also this depends on whether the building is energy-efficient in the first place. A large heat requirement in winter is little compatible with solar coverage, but if the passive and active efficiency features of the building are optimal, the heat load may be dominated by hot water use, which is more amenable to solar supply. This is especially for niche markets, for example, vacation areas (e.g. in the Mediterranean area or comparable spots) where there may be loads of building space being possessed just throughout the summer season. For solar power, the circumstances is diverse, as the current expenses of photovoltaic force frameworks are still excessively high even with liberal thought of circuitous expenses. On the other hand, the specialized improvement is fast here, and novel results under present advancement for customary solar cells may achieve financially engaging results in the following one or two decades. Likewise, there is a nearly infinite amount of novel systems for changing over solar energy that could assume a conclusive part later on. The utilization of natural colors, right now in its early stages, with characteristic low productivity and short lifetimes could pick up new force by supplanting  $\text{Tio}_2$  materials and ruthenium-based colors with ideas dependent upon polymers and natural colors or the developing three-dimensional photonic crystalline carbon structures, which would conceivably permit a built station of suitable properties.

## 1.10 Introduction to Matlab and Simulink

MATLAB is numerical computation and simulation software that was developed as a commercial tool with an easy to use interface based on the earlier numerical libraries such as LINPACK and EISPACK, which were initially composed in the FORTRAN customizing dialect. Rather than the well-known computer algebra programs, for example, MAPLE or MATHEMATICA, which are fit for performing typical operations and accordingly, ascertaining numerical comparisons as an individual would ordinarily do with paper and pencil. MATLAB has the capability to perform absolute numerical estimations. Computer algebra programs oblige complex information structures that include muddled syntax structure for the standard client and complex projects for the programmer. Anyhow MATLAB, basically includes a single information structure, whereupon all its operations are based. This is the numerical field, or, as such, the matrix. This is reflected in the name: MATLAB is an abbreviation for Matrix Laboratory. MATLAB is not only a numerical instrument for assessment of equations, however is likewise a free customizing dialect fit for treating complex issues and is provided with all the key builds of a higher modifying dialect. Since the MATLAB summon interface includes a supposed translator and MATLAB is a mediator dialect, all summons might be completed straightforwardly. This makes the testing of specific programs much easier.

In addition, MATLAB 7 is furnished with a very well conceived editor with debugging functionality, which simplifies the development and error analysis of large MATLAB programs. One of the major advantage is the interaction with the special toolbox SIMULINK, which is used for building and creating simulation models based on a graphical interface similar to block diagrams. The simulation runs under MATLAB and the interconnection between MATLAB and SIMULINK is guaranteed.

SIMULINK is a tool for simulating dynamic systems derived from the terms **Simulation** and **Link**. It is available in the form of a toolbox which is an integral part of the MATLAB environment. SIMULINK is linked with MATLAB with a graphical user interface and also includes a comprehensive library of a number of linear, non-linear, continuous, and discrete functions available in block form. The goal of this book is to introduce simple manipulations related to solar PV and wind energy conversion systems with SIMULINK blocksets.

## 1.11 Introduction to Soft Computing

Numerous human mental exercises, for example, composing PC projects, performing arithmetic calculations, logical thinking, comprehension dialect, and even driving a car demand “intelligence”. Over the past few decades, a few PC frameworks have been assembled, that can perform complex tasks. Exclusively,

there are machine frameworks that can diagnose illnesses, arrange the combination of complex natural synthetic mixes, compute differential mathematical equations in symbolic structure, dissect electronic circuits, understand constraints in problems, or compose mini PC projects to meet formal requirements. Such frameworks possess a certain level of Soft computing. Most of the above mentioned intelligent work has occurred in the field called Soft computing (AI). Several AI projects are truly perplexing complex tasks and mastering their multifaceted nature is a major research objective.

Such kind of intelligent techniques are required in several areas and in this book the authors provide different AI methods in solar and wind energy applications. Solar energy provisions incorporate the estimation of solar radiation, solar heating, solar PV systems, MPPT models and numerous others. While wind energy includes power factor calculation, pitch angle control in wind turbines, and MPPT controllers. The major objectives of AI research are:

- Understand human cognition.
- Cost-effective automation replaces humans in intelligent tasks.
- Cost-effective intelligent amplification builds systems to help humans think better, and faster.
- Superhuman intelligence builds programs to exceed human intelligence.
- General problem-solving solves a broad range of problems.
- Coherent discourse communicates with people using natural language.
- Autonomy has intelligent systems acting on own initiative.
- Training of the system should be able to gather own data.
- Store information and know how to retrieve it.

### ***1.11.1 Soft Computing Techniques***

AI techniques have the potential for making better, quicker and more practical predictions than any of the traditional methods. AI consists of several branches such as artificial neural network (ANN), fuzzy logic (FL), Adaptive Network based Fuzzy Inference System (ANFIS) and Data Mining (DM).

#### **1.11.1.1 Artificial Neural Networks (ANN)**

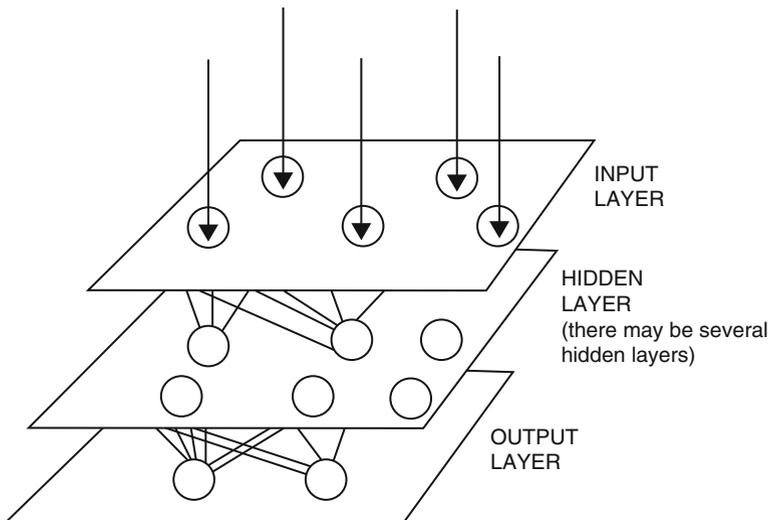
Artificial Neural Networks are relatively crude electronic models based on the neural structure of the brain. The brain basically learns from experience. It is natural proof that some problems that are beyond the scope of current computers are indeed solvable by small energy efficient packages. This brain modeling also promises a less technical way to develop machine solutions. This new approach to computing also provides a more graceful degradation during system overload than its more traditional counterparts.

These biologically inspired methods of computing are thought to be the next major advancement in the computing industry. Even simple animal brains are capable of functions that are currently impossible for computers. Computers do not do things well, like keeping ledgers or performing complex math. But computers have trouble recognizing even simple patterns much less generalizing those patterns of the past into actions of the future.

Now, advances in biological research promise an initial understanding of the natural thinking mechanism. This research shows that brains store information as patterns. Some of these patterns are very complicated and allow us the ability to recognize individual faces from many different angles. This process of storing information as patterns, utilizing those patterns, and then solving problems encompasses a new field in computing. This field, as mentioned before, does not utilize traditional programming but involves the creation of massively parallel networks and the training of those networks to solve specific problems. This field also utilizes words very different from traditional computing, words like behave, react, self-organize, learn, generalize, and forget.

Basically, all artificial neural networks have a similar structure or topology as shown in Fig. 1.16. In this structure some of the neurons interface to the real world to receive its inputs. Other neurons provide the real world with the network's outputs. This output might be the particular character that the network thinks that it has scanned or the particular image it thinks is being viewed. All the rest of the neurons are hidden from view.

But a neural network is more than a bunch of neurons. Some early researchers tried to simply connect neurons in a random manner, without much success. Now, it is known that even the brains of snails are structured devices. One of the easiest



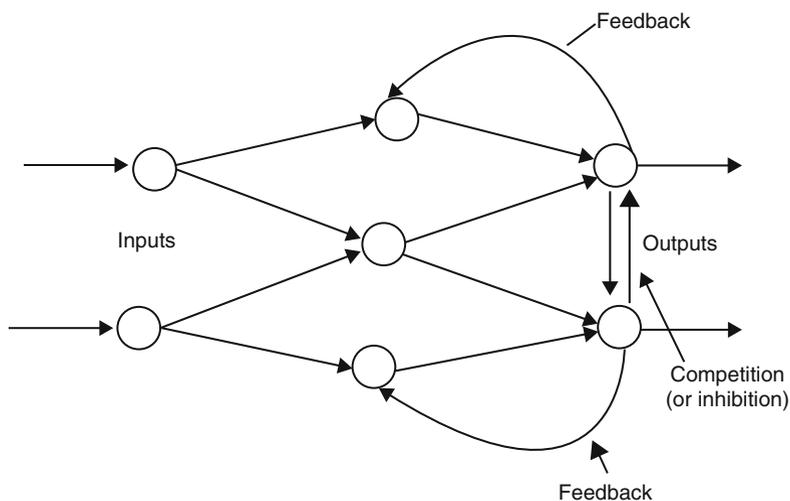
**Fig. 1.16** A simple neural network diagram

ways to design a structure is to create layers of elements. It is the grouping of these neurons into layers, the connections between these layers, and the summation and transfer functions that comprises a functioning neural network. The general terms used to describe these characteristics are common to all networks.

Although there are useful networks, which contain only one layer, or even one element, most applications require networks that contain at least the three normal types of layers – input, hidden, and output. The layer of input neurons receives the data either from input files or directly from electronic sensors in real-time applications. The output layer sends information directly to the outside world, to a secondary computer process, or to other devices such as a mechanical control system. Between these two layers can be many hidden layers. These internal layers contain many of the neurons in various interconnected structures. The inputs and outputs of each of these hidden neurons simply go to other neurons.

In most networks each neuron in a hidden layer receives the signals from all of the neurons in a layer above it, typically an input layer. After a neuron performs its function it passes its output to all of the neurons in the layer below it, providing a feed-forward path to the output. These lines of communication from one neuron to another are important aspects of neural networks. They are the connections, which provide a variable strength to an input. There are two types of these connections. One causes the summing mechanism of the next neuron to add while the other causes it to subtract. In more human terms one excites while the other inhibits. Another type of neural network connection is feedback. This is where the output of one layer routes back to a previous layer. An example of this is shown in Fig. 1.17.

The way that the neurons are connected to each other has a significant impact on the operation of the network. In the larger, more professional software development packages the user is allowed to add, delete, and control these connections at will. By “tweaking” parameters these connections can be made to either excite or inhibit.



**Fig. 1.17** Simple network with feedback and competition

Once a network has been structured for a particular application, that network is ready to be trained. To start this process the initial weights are chosen randomly. Then, the training, or learning, begins. There are two approaches to training – supervised and unsupervised. Supervised training involves a mechanism of providing the network with the desired output either by manually “grading” the network’s performance or by providing the desired outputs with the inputs. Unsupervised training is where the network has to make sense of the inputs without outside help.

Neuron connection weights are not just modified in one pass. The process by which neuron weights are modified occurs over iterations. The neural network is presented with training data, and then the results are observed. These results must in some way change the connection weights in order for the neural network to be learn. The exact process by which this happens is determined by the learning algorithm.

### 1.11.1.2 Fuzzy Logic (FL)

Fuzzy Logic was initiated in 1965 by Lotfi A. Zadeh, professor for computer science at the University of California in Berkeley. Basically, Fuzzy Logic (FL) is a multivalued logic that allows intermediate values to be defined between conventional evaluations like true/false, yes/no, high/low, etc. These intermediate values can be formulated mathematically and processed by computers, in order to apply a more human like way of thinking. Based on Aristotle and other later mathematicians, the so called “Laws of Thought” was posited. One of these, the “Law of the Excluded Middle,” states that every proposition must either be True or False. Even when Parmenides proposed the first version of this law (around 400 B. C.) there were strong and immediate objections: for example, Heraclitus proposed that things could be simultaneously True and not True. It was Plato who laid the foundation for what would become fuzzy logic, indicating that there was a third region (beyond True and False) where these opposites “tumbled about.” Other, more modern philosophers echoed his sentiments, notably Hegel, Marx, and Engels. But it was Lukasiewicz who first proposed a systematic alternative to the bi-valued logic of Aristotle. Even in the present time some Greeks are still outstanding examples for fussiness and fuzziness. Fuzzy Logic has emerged as a profitable tool for the controlling and steering of systems and complex industrial processes, as well as for household and entertainment electronics, as well as for other expert systems and applications like the classification of SAR data. A few features of fuzzy logic are listed below:

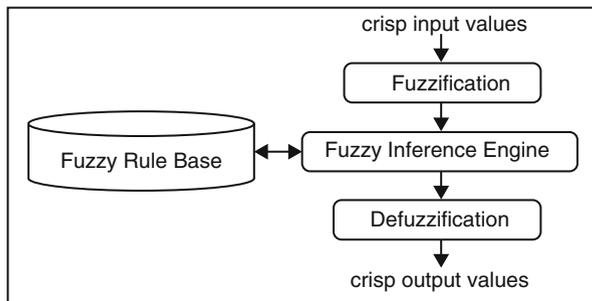
- *Fuzzy logic is conceptually easy to understand.* The mathematical concepts behind fuzzy reasoning are very simple. Fuzzy logic is a more intuitive approach without the far reaching complexity.
- *Fuzzy logic is flexible.* With any given system, it is easy to add on more functionality without starting again from scratch.

- *Fuzzy logic is tolerant of imprecise data.* Everything is imprecise on a closer look, but more than that, most things are imprecise even on careful inspection. Fuzzy reasoning builds this understanding into the process rather than tacking it on to the end.
- *Fuzzy logic can model nonlinear functions of arbitrary complexity.* A fuzzy system can be created to match any set of input-output data. This process is made particularly easy by adaptive techniques like Adaptive Neuro-Fuzzy Inference Systems (ANFIS), which are available in Fuzzy Logic Toolbox software.
- *Fuzzy logic can be built on top of the experience of experts.* In direct contrast to neural networks, which use training data and generate opaque, impenetrable models, fuzzy logic lets the user rely on the experience of people who already understand the system.
- *Fuzzy logic can be blended with conventional control techniques.* Fuzzy systems don't necessarily replace conventional control methods. In many cases fuzzy systems augment them and simplify their implementation.
- *Fuzzy logic is based on natural language.* The basis of fuzzy logic is human communication. This observation underpins many of the other statements about fuzzy logic. Because fuzzy logic is built on the structures of qualitative description used in everyday language, fuzzy logic is easy to use (MATLAB Fuzzy logic toolbox user's guide).

A fuzzy expert system shown in Fig. 1.18 consists of four components namely, the fuzzifier, the inference engine, and the defuzzifier, and a fuzzy rule base.

In the fuzzifier, crisp inputs are fuzzified into linguistic values to be associated to the input linguistic variables. After fuzzification, the inference engine refers to the fuzzy rule base containing fuzzy IF-THEN rules to derive the linguistic values for the intermediate and output linguistic variables. Once the output linguistic values are available, the defuzzifier produces the final crisp values from the output linguistic values.

**Fig. 1.18** Fuzzy expert system model



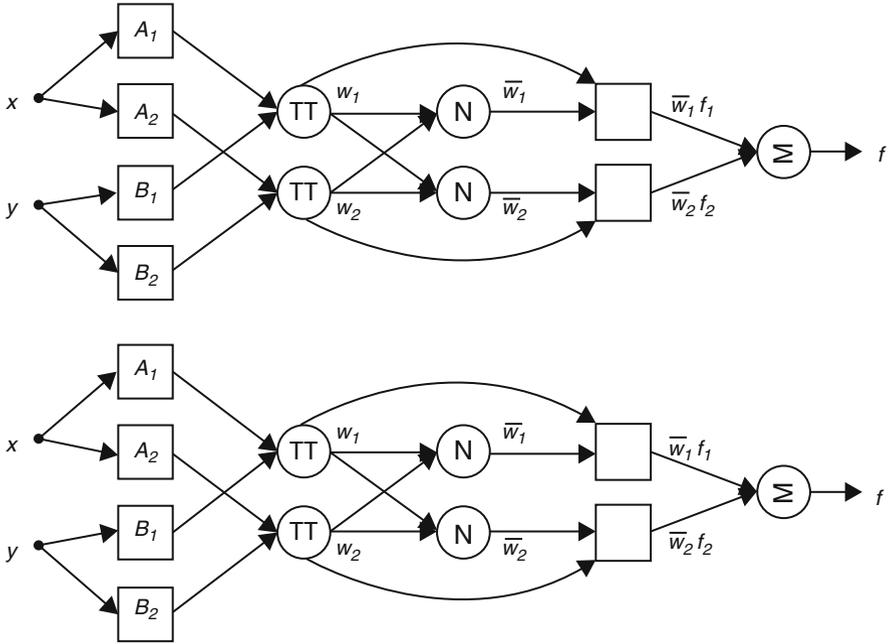


Fig. 1.19 ANFIS architecture

**1.11.1.3 Adaptive Network Based Fuzzy Inference System (ANFIS)**

ANFIS implements a Takagi Sugeno FIS and has a five layered architecture as shown in Fig. 1.19. The first hidden layer is for fuzzification of the input variables and T-norm operators are deployed in the second hidden layer to compute the rule antecedent part. The third hidden layer normalizes the rule strengths followed by the fourth hidden layer where the consequent parameters of the rule are determined. Output layer computes the overall input as the summation of all incoming signals. ANFIS uses backpropagation learning to determine premise parameters (to learn the parameters related to membership functions) and least mean square estimation to determine the consequent parameters. A step in the learning procedure has got two parts: In the first part the input patterns are propagated, and the optimal consequent parameters are estimated by an iterative least mean square procedure, while the premise parameters are assumed to be fixed for the current cycle through the training set. In the second part the patterns are propagated again, and in this epoch, backpropagation is used to modify the premise parameters, while the consequent parameters remain fixed. This procedure is then iterated.

The functionality of nodes in ANFIS can be summarized as follows:

- *Layer 1*: Nodes are adaptive; membership functions (MFs) of input variables are used as node functions, and parameters in this layer are referred to as antecedent or premise parameters.
- *Layer 2*: Nodes are fixed with outputs representing the firing strengths of the rules.

#### 1.11.1.4 Genetic Algorithms (GA)

The Genetic Algorithm (GA) is a model of machine learning which derives its behavior from a metaphor of some of the mechanisms of evolution in nature. This is done by the creation within a machine of a population of individuals represented by chromosomes, in essence a set of character strings that are analogous to the base-4 chromosomes. The individuals in the population then go through a process of simulated “evolution”. Genetic algorithms are used for a number of different application areas. An example of this would be multidimensional optimization problems in which the character string of the chromosome can be used to encode the values for the different parameters being optimized.

In practice, the genetic model of computation can be implemented by having arrays of bits or characters to represent the chromosomes. Simple bit manipulation operations allow the implementation of crossover, mutation and other operations. Although a substantial amount of research has been performed on variable-length strings and other structures, the majority of work with genetic algorithms is focused on fixed-length character strings. The users should focus on both this aspect of fixed-length and the need to encode the representation of the solution being sought as a character string, since these are crucial aspects that distinguish genetic programming, which does not have a fixed length representation and there is typically no encoding of the problem.

The genetic algorithm is implemented by evaluating the fitness of all of the individuals in the population. Then a new population is created by performing operations such as crossover, fitness-proportionate reproduction and mutation on the individuals whose fitness has just been measured. The old population is discarded and the iteration continues using the new population. A single iteration of this cycle is referred to as a generation. There is no theoretical reason for this as an implementation model. Indeed, behavior in populations in nature is not found as a whole, but it is a convenient implementation model.

The first generation (generation 0) of this process operates on a population of randomly generated individuals. From there on, the genetic operations, in concert with the fitness measure, operate to improve the population.

The pseudocode of GA is given as follows:

```

// start with an initial time
t := 0;
// initialize a usually random population of individuals
initpopulation P (t);
// evaluate fitness of all initial individuals of population
evaluate P (t);
// test for termination criterion (time, fitness, etc.)
while not done do
  // increase the time counter
  t := t + 1;
  // select a sub-population for offspring production
  P' := selectparents P (t);
  // recombine the "genes" of selected parents
  recombine P' (t);
  // perturb the mated population stochastically
  mutate P' (t);
  // evaluate its new fitness
  evaluate P' (t);
  // select the survivors from actual fitness
  P := survive P,P' (t);
od
end GA.

```

### ***1.11.2 Applications of Soft Computing Techniques in Solar Energy***

Soft computing (SC) techniques have been used by various researchers in solar energy applications. This section deals with an overview of these applications and some examples on the use of SC techniques in the solar energy applications are summarized in Table 1.5. ANNs are used to predict and estimate local and global solar radiation. The energy consumption can be predicted using ANNs in solar building and also in modeling solar steam generators. Efficiency of solar flat PV collectors can be estimated using appropriate ANN models. Fuzzy logic is applied in photovoltaic solar energy systems, solar tracking system, to predict solar radiation and in solar powered energy. Fuzzy logic controllers are applied to control solar air-conditioning system, for maximum power point tracking, and in charge controllers. Combination of neural networks and fuzzy logic are applied as ANFIS systems to predict solar radiation and temperature. The ANFIS systems are also applied to model the power supply of PV systems. Genetic Algorithms are used as optimization tools in solar PV based systems in the areas such as solar tracking, solar irradiation, parameter identification in solar cells, and for temperature control in solar water heating systems.

**Table 1.5** Summary of SC applications in solar energy

Soft computing technique	Area
Artificial neural networks	Prediction of solar radiation
	Modeling of solar steam-generator
	Estimation of global solar radiation
	Prediction of the energy consumption of a passive solar building
	Characterization of PV modules
	Efficiency of flat-plate solar collectors
	Heating controller for solar buildings
	Modeling of a solar air heater
	MPPT controller
	Prediction of solar energy potential
Fuzzy logic	Photovoltaic solar energy systems
	Sun tracking system
	Solar powered energy
	Prediction of solar radiation
	Control of solar buildings
	Controller of solar air-conditioning system
	Sizing of PV systems
	MPPT controller
	Solar tracking system
	Charge controller
	Solar heating
	Solar irradiance
Adaptive network based fuzzy inference system	Prediction of solar radiation and temperature
	Modeling of photovoltaic power supply
Genetic algorithms	Photovoltaic solar energy systems
	Solar irradiation
	Determination of Angstrom equation coefficients
	Solar water heating systems
	Hybrid solar–wind system
	PV-diesel hybrid system
	Solar cell
	Solar tracking
	Parameter identification in solar cells
	Sizing of a solar thermal electricity plant
	Sizing of solar water heaters
	Solar thermal energy storage
Flat plate solar air heater	

### 1.11.3 Applications of Soft Computing (AI) Techniques in Wind Energy

Recent researches report the application of Soft computing techniques such as neural networks, fuzzy logic, and genetic algorithms in wind energy. Several SC applications in different areas of wind energy are presented in Table 1.6. ANNs have been applied to forecast wind energy, to predict online wind power, to predict short term wind speed, to predict power ratio in wind turbine and to detect and identify faults in wind turbine systems. These networks are also applied to the controllers such as PID in the wind energy conversion systems. Fuzzy logic has been successfully applied to MPPT control and pitch angle control of wind turbines. In addition, they are also used to predict power generation and parameters in wind turbines. ANFIS systems have been applied to forecast regional wind generation and to forecast wind power. They have produced capable results in predicting power factor of wind turbines. Optimization of power factor, wind blade chord, twist angle, and pitch angle of wind turbines can be effectively performed using GAs. The parameters of wind turbine can also be tuned to their optimal values using genetic algorithms.

**Table 1.6** Summary of SC applications in wind energy

Soft computing technique	Area
Artificial neural networks	Controllers for grid connected wind turbine
	PID control of wind energy conversion systems
	Wind energy forecasting
	Online prediction of wind power
	Wind turbine flicker calculation
	Short term wind speed prediction
	Prediction of the power ratio in wind turbine
	Wind turbine siting
	Fault detection and identification for wind turbine systems
Fuzzy logic	MPPT control for wind turbines
	Pitch angle control of wind turbines
	Predicting wind turbine power generation
	Wind speed forecasting
	Prediction of wind turbine parameters
Adaptive network based fuzzy	Forecasting of regional wind generation
	Wind power forecasting
Inference system	Prediction of wind turbine power factor
Genetic algorithms	Wind turbine siting
	Optimization of wind turbine energy and power factor
	Modeling of wind energy systems
	Pitch angle control for wind turbines
	Wind blade chord and twist angle optimization
	Tuning of wind turbine controller

## 1.12 Summary

Energy plays a fundamental role in the socio-economic development and human welfare of a country. Energy demand is expected to increase by 50 % during the following two decades. Naturally this is creating panic that our energy assets are beginning to run out, with eliminating the outcomes for the worldwide economy and worldwide personal satisfaction. This chapter discussed the energy scenario, global and Indian energy crisis, energy efficiency, classification of energy sources, solar energy, wind energy, benefits of renewable energy, trends in energy consumption, worldwide potentials of renewable energy sources, and the need for new energy technologies. In addition an introduction to MATLAB and SIMULINK is provided with application of soft computing techniques in solar and wind energy generation systems.

### Review Questions

1. What is the DC electrical output of PV cells?
2. How are PV cells configured to produce large amount of usable power?
3. How reliable are the PV modules? Discuss their lifetime.
4. What are the factors to be considered while choosing PV cells?
5. State the differences between solar irradiance and solar insolation.
6. Collect a few sources where solar radiation data is available.
7. Discuss about system commissioning, inspection and operation.
8. How does a solar water-heating system work?
9. Can a solar water heater replace an electric or gas water heater?
10. Discuss a few applications of renewable energy systems based on soft computing techniques.

## Bibliography

- Adzic E, Ivanovic Z, Adzic M, Katic V (2009) Maximum power search in wind turbine based on fuzzy logic control. *Acta Polytech Hung* 6(1):131–149
- Ahmed MM, Sulaiman M (2003) Design and proper sizing of solar energy schemes for electricity production in Malaysia. *National Power and Energy Conference 2003*, pp 268–271
- Alameda Lozada JI (2008) *Las Energías Renovables: ¿Solución a la Crisis Económica?*, Seminario de Energía: Opciones Energéticas para el Comercio, 24 de Abril 2008
- Ardente F, Beccali G, Cellura M (2004) Life cycle assessment of a solar thermal collector. *Science Direct*
- AVA Solar website (2008) IEEE standard for interconnecting distributed resources with electric power systems, New York: IEEE, IEEE Std.1547–2003. <http://www.avasolar.com>. Accessed June 2008.
- Azar C, Schneider S (2002) Are the economic costs of stabilizing the atmosphere prohibitive? *Ecol Econ, Science Direct*
- Basso TS, DeBlasio RD (2003) IEEE P1547-series of standards for interconnection. IEEE, New York

- Bergmann A, Colombo S, Hanley N (2006) Rural versus Urban preferences for renewable energy developments. Science Direct.
- Bernal-Agustin J, Dufo-Lopez R (2005) Economical and environmental analysis of grid connected photovoltaic systems in Spain. Science Direct
- Bode GH, Loh PC, Newman MJ, Holmes DG (2005) An improved robust predictive current regulation algorithm. IEEE Trans Ind Appl 41(6):1720–1733
- Borowy BS, Salameh ZM (1996) Methodology for optimally sizing the combination of a battery bank and PV array in a wind/PV hybrid system. IEEE Trans Energy Conv 11(2):367–375
- Brini S, Abdallah HH, Ouali A, Economic dispatch for power system included wind and solar thermal energy. Leonardo J Sci (14):204–220
- Bryan J, Duke R, Round S (2003) Distributed generation – nanogrid transmission and control options. Int Power Eng Conf 1:341–346
- Castro I, Silveira J (2006) Ecological efficiency in thermoelectric power plants. Science Direct
- Chaudhari M, Frantzis L, Hoff TE (2004) PV grid connected market potential under a cost breakthrough scenario. Navigant Consulting, Sept 2004. <http://www.ef.org/documents/EF-Final-Final2.pdf>. Accessed June 2008
- Chowdhury AA, Koval DO (2005) Impact of photovoltaic power sources on a power system’s capacity reliability levels. I&CPS
- Chowdhury BH, Rahman S (1988) Is central power station photovoltaic power dispatchable? IEEE Trans Energy Convers 3(42):747–754
- Clean energy project analysis: RETSCREEN® engineering & cases textbook, [Online]. [www.retscreen.net](http://www.retscreen.net). Accessed June 2008
- Connor H (2006) Strategies for development in islands: assessing the need for a paradigm shift. IEEE Paper
- Conti S, Raiti S, Tina G, Vagliasindi U (2003) Integration of multiple PV units in urban power distribution systems. Sol Energy 75:87–94
- Corzine KA, Wielebski MW, Peng FZ, Wang J (2004) Control of cascaded multilevel inverter. IEEE Trans Power Electron 19(3):732–738
- Davidson J, The new solar electric home, 20th printing 2001
- Duffie JA, Beckman WA (2006) Solar engineering of thermal processes, 3rd edn. Wiley, New York
- Dunlop JP (1997) Batteries and charge control in stand alone photovoltaic systems, Jan 1997 Energy Information Administration website. <http://www.eia.doe.gov>. Accessed June 2008
- Estimating PV system size and cost, [Online]. [www.InfinitePower.org](http://www.InfinitePower.org). Accessed Apr 2007
- Griese H, Stobbe L, Reichl H (2005) Eco-design and beyond-key for a global sustainable development. IEEE Paper
- Hagbin S, Khan K (2010) Integrated chargers for EV’s and PHEV’s: examples and new solutions. In: Proceedings of ICEM, pp 1–6, Sept 2010
- Hammad AE (1995) Comparing the voltage source capability of present and future var compensation techniques in transmission systems. IEEE Trans Power Deliv 1(1)
- Hart DW (1997) Introduction to power electronics. Prentice Hall, New Jersey
- Houck CR, Joins JA. A genetic algorithm for function optimization: a matlab implementation <http://www.ren21.net>. Accessed June 2008
- Hyman D (1988) Modern microeconomics, 2nd edn, pp 148–149
- Jäger-Waldau A (2007) PV status report 2007: research, solar cell production and market implementation of photovoltaics. European Commission Directorate General Joint Research Center. [http://re.jrc.ec.europa.eu/refsys/pdf/PV\\_StatusReport\\_2007.pdf](http://re.jrc.ec.europa.eu/refsys/pdf/PV_StatusReport_2007.pdf). Accessed June 2008
- Jenkins N (1995) Photovoltaic systems for small scale remote power supplies. Power Eng J 9 (2):89–96
- Jing W, Jia-hai Y (2006) Green cost of electricity concept and preliminary account system. IEEE Paper
- Kannan R, Leong K, Osman R (2005) “Life Cycle Assessment” study of solar PV systems: an example of a 2.7 kWp distributed solar PV system in Singapore. Science Direct

- Karki S, Mann M, Salehfar H (2006) Substitution and price effects of carbon tax on CO<sub>2</sub> emissions reduction from distributed energy sources. IEEE Paper
- Kleinkauf W, Cramer G, Ibrahim M (2005) PV systems technology: state of the art developments and trends in remote electrification. SMA Technologies AG
- Komor P (2004) Renewable energy policy. iUniverse, New York
- Li C, Yu Cheng, Zhang L (2008) Research of externality of electricity generation in electricity market. IEEE Paper
- Lin C-T, Lee CSG (1996) Neural fuzzy systems: a neuro-fuzzy synergism to intelligent systems. Prentice-Hall, Upper Saddle River
- Marquez C, Ryan F (2007) New Fomento open for business. Caribbean Business, Thursday, 12 Apr 2007. <http://www.pridco.org/>. Accessed Nov 2007
- Marxuach SM (2005) Restructuring the Puerto Rico Electricity Sector, vol 3, White paper. Center for the New Economy, San Juan
- Mashford K (2007) Unearthly mess. IEEE Paper
- Moran D, Wackernagel M, Kitzes J (2007) Measuring sustainable development nation by nation. Science Direct, Ecol Econ
- Mortensen J (2008) Factors associated with photovoltaic system costs, NREL/TP.620.29649. <http://www.doe.gov/bridge>. Accessed June 2008
- National Fire Protection Association, National Electrical Code, 1990 Edition
- Naval Facilities Engineering Command, Maintenance and Operation of Photovoltaic Power Systems, NAVFAC MO-405.1
- Navigant Consulting (2006) A review of PV inverter technology cost and performance projections NREL/SR-620-38771, Jan 2006. [www.nrel.gov](http://www.nrel.gov). Accessed June 2008
- NFPA 70-1999, National Electrical Code
- NREL (2008) Planning for PV: the value and cost of solar electricity, DOE/GO-102008-2555 Jan 2008. [www.eere.energy.gov](http://www.eere.energy.gov). Accessed June 2008
- Olivier J, Harms T, Esterhuysen D (2007) Technical and economic evaluation of the utilization of solar energy at South Africa's SANAE IV base in Antarctica. Science Direct
- Pacca S, Sivaraman D (2007) Parameters affecting the life performance of PV technologies and systems. Science Direct
- PREPA (2007) Puerto Rico Electric Power Authority official statement. Apr 2007
- Puerto Rican Census website. <http://www.gobierno.pr/Censo/>
- Puerto Rican Government website. <http://www.gobierno.pr>. Accessed Dec 2007
- Puerto Rico Electric Power Authority website. <http://www.prepa.com>
- Puerto Rico Industrial Economic Incentives Law (Law 73), May 2008
- Puerto Rico Renewable Energy Incentives Law, Aug 2008
- PV system installation and grid-interconnection guidelines in selected IEA countries, Task V, Report IEA PVPS T5-04:2001
- Ramakumar R (1993) Photovoltaic systems. Proc IEEE 81(3):365–376
- Ramos-Robles CA (2005) Determination of favorable conditions for the development of a wind power farm in Puerto Rico. Master of Science thesis, Department of Electrical and Computer Engineering, University of Puerto Rico, Mayagüez Campus
- Rashid MH (2006) Power electronics devices, circuits and applications. Academic Press, San Diego
- Renewable energy technology characterizations, Dec 1997, TR-109496. [www.nrel.gov/docs/gen/fy98/24496.pdf](http://www.nrel.gov/docs/gen/fy98/24496.pdf). Accessed June 2008
- RETScreen software online user manual: photovoltaic project model, [Online]. [www.retscreen.net](http://www.retscreen.net). Accessed June 2008
- RETScreen International, Clean Energy Decision Support Center, Photovoltaic project analysis. Minister of Natural Resources Canada 2001–2004
- Rolf F, Grosskopf S, Pasurka C (2007) Pollution abatement activities and traditional productivity. Ecol Econ, Science Direct

- Secretaria Auxiliar de Relaciones Exteriores, Datos Basicos sobre Puerto Rico website. [www.estado.gobierno.pr/datos\\_basicos.htm](http://www.estado.gobierno.pr/datos_basicos.htm)
- Solar Electric Power Association (2001) TEAM-UP final reports: six reports documenting the TEAM-UP program, and the experiences and data collected from the 35 TEAM- UP ventures, Dec 2001. <http://www.solarelectricpower.org>. Accessed June 2008
- Solero L (2001) Nonconventional on-board charger for electric vehicle propulsion batteries. *IEEE Trans Veh Technol* 50:144–149
- Soytas U, Sari R (2007) Energy consumption, economic growth, and carbon emissions: challenges faced by an EU candidate member. *Science Direct*
- Stand-alone photovoltaic systems – a handbook of recommended design practices, Sandia National Laboratories, SAND87-7023, revised Nov 1991
- Stoppato A (2006) Life cycle assessment of photovoltaic electricity generation. *Science Direct Surface meteorology and solar energy: a renewable energy resource web site (release 6.0)*. <http://eosweb.larc.nasa.gov/sse/RETScreen/>
- Svrzek M, Sterzinger G (2005) Solar PV development: location of economic activity. *Renewable Energy Policy Report*
- The Delphi Group (2007) Overview of renewable electricity costs and cost variation final report. Prepared For: The Commission for Environmental Cooperation
- Udo H, Heijungs R (2007) Life cycle assessment for energy analysis and management. *Science Direct*
- Vachon S, Menz F (2006) The role of social, political, and economic interests in promoting state green electricity policies. *Science Direct*
- Valarmathi R, Palaniswami S, Devarajan N (2012) Simulation and analysis of wind energy and photo voltaic hybrid system. *Int J Soft Comput Eng* 2(2):193–200, ISSN: 2231-2307
- Waldau A (2007) PV status report 2007\_Research, solar cell production and market implementation of photovoltaics
- Wiles J (2006) Photovoltaic systems and the 2005 National Electrical Code: suggested practices. Sandia National Laboratories
- Wiser R, Bolinger M, Cappers P, Margolis R (2008) Letting the sun shine on solar costs: an empirical investigation of photovoltaic cost trends in California, NREL/TP-620-39300. <http://eetd.lbl.gov/EA/EMP>. Accessed June 2008
- Zhang C, Zhao Z, Han J (2007) Renewable energy in China: an strategic imperative. *IEEE Paper*