Green Energy and Technology

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Energy Sustainability Through Green Energy

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Foreword

The debate about climate changes due to industrial activity post mid-nineteenth century is no more a subject of academic discussions and modelling various scenarios. The after-effects of greenhouse gas emissions due to human activity is there for all of us to see manifesting in the form of extreme climatic conditions. In November 2014, it was widely reported in newspapers that all the 50 states of the United States recorded sub-zero temperatures, a never heard before phenomenon. Coupled with such facts another challenge that the world is likely to face by 2030, according to some UN estimates, is the *stress nexus* of rising demands for water, food and energy.

The growing population of the planet, which according to estimates is likely to be around 9 billion by 2050 as against 2 billion during the mid-nineteenth century and aspirations of people leading a reasonably decent lifestyle is putting more and more pressure on the existing *congealed* resources of our planet. And at the same time, it is also being realized that the days of *easy oil* are over. Oil (and its equivalents like gas) as a major source of primary energy is gradually to be explored in inhospitable, difficult and deeper terrains. Thus, the Energy Returned On Energy Invested (EROEI) has also gradually been reducing from the levels of 100:1 in the 1860s to somewhere around 17–18:1 in 2010 and is projected to fall further. This ratio, below the levels of 5–9:1, according to some estimates, will make oil production unviable with the available technology.

Thus, energy being the quintessential requirement for human progress, two fundamental questions need to be considered in right earnest. The *first* being the ability to produce enough primary energy to meet demand and the *second*, not damaging the climate further with human activity leading to greenhouse gas (GHGs) emissions beyond the IPCC (Intergovernmental Panel on Climate Change) recommended limits of 450 ppm.

IPCC, in its latest deliberations, has brought out the following facts:

1. Average surface temperature has already increased by 0.85 °C over the period from 1880 to 2012.
2. Existing levels of three key GHGs—carbon dioxide, methane and nitrous oxide—are the highest in at least 800,000 years.

3. Global mean sea level rose by 19 cm from 1901 to 2010.
4. Period from 1983 to 2012 was the warmest 30-year period in the last 1,400 years.

IPCC has further said that the world will have to totally phase out fossil fuels in power generation by the end of the century.

These developments have, obviously, led to the search for commercially exploitable *other sources* of energy that while meeting human needs do not cause further damage to the environment for the sustenance of our planet. It is expected that *energy mix* of the planet will change substantially in the years to come.

Green Energy or Renewable Energy is an area that will form a substantial portion of the energy mix in the country and will occupy centre stage in providing the much needed fillip to the void likely to be experienced by us in the near foreseeable future. There is enough promise for various green energy initiatives like solar, solar thermal, wind, bio-mass, hydro, hydrogen and nuclear power.

It is, indeed, a very timely effort by Dr. Atul Sharma and Dr. Sanjay Kumar Kar, known to me for over five years now, from Rajiv Gandhi Institute of Petroleum Technology (RGIPT), an institute of national importance, to have come out with a book that discusses myriad ways in which the natural resources of our well-endowed country can be made use of for meeting the energy needs of our millions of citizens without causing further damage to the environment.

In course of my interactions with both the professors of RGIPT, which is co-promoted by various organizations from the petroleum industry, we have often discussed about the likely energy scenarios in the days ahead. During such discussions, the need to publish a book on energy sustainability was felt. I congratulate both the editors for having come out with the book which will be of immense help to students, practising managers and policy makers alike.

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Preface

A few decades ago, energy sustainability was just thought in terms of accessibility relative to the rate of use. Today, in the context of the decent agenda of sustainable growth, including concerns about global warming, greenhouse gas emissions, climate change and so on are very important issues. These include environmental effects and the question of the energy generation process as well as emissions, which are the primary reasons for damage to the earth environment during energy production, distribution and consumption. Sustainable energy development criteria have been promoted in several years into the front line of energy policy, which also showed how we address our energy needs on a sustainable basis.

Energy demand is likely to increase in the entire world, the ratio supplied by electricity is likely to rise rapidly, however, more energy demand is for continuous, and this qualitative consideration will continue to dominate in the energy sector. Meeting the needs of the present energy demand without compromising the needs of the future, the whole world has to pay attention to the energy sustainability, so that environmental protection remains equally important at the same time. Energy sustainability could drive environment friendly technological innovations with viable techno-commercial applications for social upliftment.

Renewable resources such as solar energy, wind energy, biomass, bio-gas and bio-fuels, hydro energy provide a source of sustainable energy. Worldwide, renewable energy resources are available to supply the expanding energy needs without environmental damage. However, the current renewable energy share is less in the worldwide energy production. It is an acknowledged fact that it should have been much higher as much as in favour of the environment, which is the most essential issue globally. Almost everywhere in the globe, clean energy production is given much attention due to the current environmental issues, which can only be solved by the renewables. Many countries are making significant efforts to move up the renewable energy ratio and overall approximated 19 % of global energy consumption produced by renewable energy in 2012 which continued to grow in 2013.

The aim of this book is to share the latest developments and advances in materials and processes involved in green energy generation, transmission-distribution, storage, etc., with chapters written by professors and researchers in the energy

and materials field, using original research materials. This book may be used as a reference book in college/university/training institute/professionals all over the world. This book can also be referred in all the green energy-related laboratories, industries and academic libraries and as a refereed book for "Alternative Energy Sources, Renewable Energy Resources, Climate Change, Energy Sustainability, Energy Policies etc." for undergraduate and graduate students. The book presents a perfect blend of research and practice explained in a very simplistic manner. It also covers the sustainable provision of energy that meets the needs of the present without compromising on the ability of future generations to meet their needs.

Rae Bareli, India — Atul Sharma
Noida, India — Sanjay Kumar Kar

Overview of the Book

The increasing level of greenhouse gas emissions and the rise in fuel prices are the main reason for efforts to more effectively use various sources of renewable energy. Scientists all over the world are in search of sustainable energy options, which demands sustainable planning of sustainable energy developments. This confirms that the urgency of meeting the present needs without compromising the ability of future generations to satisfy their needs.

Increasing the share of green energy sources can trim down greenhouse gas emissions, which is a major factor in global warming as well as climate change worldwide. The operating cost of technologies to capture green energy, which is speedily declining and becoming economically competitive with fossil fuels, while also reducing the risk of climate change is what is actually needed worldwide. Investing in green energy creates a bunch of jobs, quick economic growth, and improves energy security, which is highly required worldwide because of shortage of fossil fuel resources.

The book explores the latest developments and advances in materials and processes involved in energy generation, transmission-distribution and storage, etc., and chapters written by several scientists, researchers and academicians in the field of energy. The results and recommendations are essential reading for policymakers, professionals, researchers and anyone concerned with energy sustainability through green energy. The book with 19 chapters is divided into six parts, which include relevant topics presented in detail below:

- Solar energy
- Wind energy
- Green buildings
- Thermal energy Storage
- Bio-mass, Bio-fuels, Bio-gas
- Other Green Energy

Part I: Solar Energy

Solar Photovoltaic Technology and Its Sustainability

In this chapter, Anil Kumar, Geetam Richhariya and Atul Sharma have discussed the application of solar photovoltaic technology for sustainable growth. The renewable energy sources are the clean green technology, which motivates the healthy environment but also encourages using them in rural areas where grid supply is not applicable. The fundamentals of solar photovoltaic technologies and their sustainability on the earth are discussed. The various internal phenomena that occur inside the sun and the solar spectrum is also discussed. The various applications of photovoltaic and modelling of the solar cell are presented in this chapter.

Solar Drying—A Sustainable Way of Food Processing

Co-authors of this chapter, M.A. Aravindh and A. Sreekumar explore deployment of Solar Drying as a sustainable way of food processing. In a developing country like India, having the second largest population and with agriculture as a source of income to nearly 60 % of the total population, post harvest and storage loss is a major quandary which needs to be addressed in due diligence. There are many food preservation techniques such as cold storage, drying, etc., that have evolved over the years to tackle the above losses. The major constraint is that almost all the technologies utilize fossil fuel resources, which are depleting very fast and wise use of these precious resources are preferred for long-term energy sustainability. Therefore, sustainable methods for food preservation are the need of the hour. Solar drying is one of the best choices in this context. There are many models of solar dryers developed and a good quantum of research is progressing in many parts of the world to propagate the solar drying technology for value addition of agriculture products. The solar drying technology is a classic example to showcase how the sun's free energy could be effectively utilized for the benefit of mankind. This chapter explains the different types of dryers, aspects of solar drying, parameters involved in the drying process and the economic analysis to analyse the feasibility of the solar drying system. Case studies of some of the successful installations are also included to propagate the solar drying technology in the country.

Jawaharlal Nehru National Solar Mission in India

In this chapter, co-authors Atul Sharma, K. Srivastava and Sanjay K. Kar discuss the importance, objectives and achievements of the Jawaharlal Nehru National Solar Mission in India. The global environmental scene has changed fiercely over the last century. The changing scenario demands greater concern and an action-oriented enabling policy framework for use of sustainable and renewable energy. The Government of India has taken necessary cognizance of the global developments and initiated several green environment policy measures under the National Action Plan on Climate Change. One of the initiatives is the Jawaharlal Nehru National Solar Mission (JNNSM). This chapter discusses the objectives of JNNSM and the developments made so far to improve the share of solar energy and reduce energy poverty in India.

Part II: Wind Energy

Insights into Wind Energy Market Developments in India

In this chapter, co-authors Sanjay K. Kar and Atul Sharma discuss wind market developments in India. According to the authors wind power is gaining a stronger position in the Indian electricity market, mainly caused by preferential feed-in tariff and other incentives given by the central and state governments. Through the chapter, the authors assess the growth of the Indian wind market compared to other leading markets across the globe. Then, state level progress is discussed in detail. The authors review wind-specific policy measures and incentive schemes devised by the central government, state government and regulatory bodies to achieve the desired objectives. The authors discuss the challenges of increasing wind penetration in India. They conclude that to achieve greater wind penetration the Central government, the State government and the regulatory bodies need to work cohesively and collaboratively to iron out implementation failures and take appropriate measures for successful implementation of various rules, regulations and policies.

Wind Energy Technology and Environment Sustainability

The author of this chapter Vilas Warudkar emphasizes that wind power plays an important role in the development of a country's economy as it reduces the country's dependency on fossil fuels. Wind energy is generally categorized as a clean, environment friendly and renewable source of energy. India is blessed with an immense amount of renewable energy resources and wind energy is one of the promising sources for energy supply option. The demand for electricity has grown significantly in the recent years and India depends widely on coal and oil to meet its energy demands. In the recent past, there has been intense research activity carried out in the development, production and distribution of energy in India, which results in the development of the need for new sustainable energy due to limited fossil fuel resources and problems associated with the environment (smog, acid rain and greenhouse gass emissions).

Development and promotion of non-conventional sources of energy such as solar, wind, geothermal and bio-energy are also getting increasing attention. Wind energy is a non-polluting source of energy and its mature technology and comparatively low cost makes it a promising and primary non-conventional energy source in India. The gross wind power capacity in the country is estimated at about 49,000 MW; a capacity of 21,264 MW upto May 2014 has been added so far through wind.

Continued research and development to increase the value of forecasting power performance, reducing the uncertainties related to engineering integrity, enabling large-scale use and minimizing environmental impact are some of the areas needing concerted efforts in wind energy. These efforts are also expected to make wind power more reliable and cost competitive with conventional technologies in the future for environmental sustainability.

Part III: Green Buildings

Achieving Energy Sustainability Through Green Building Approach

In this chapter, co-authors Ashish Shukla, Renu Singh and Poonam Shukla throw light on green building approaches for sustainability. There are three urgencies in the UK climate and energy policies (i) reducing greenhouse gas emissions, specifically CO_2 by 80 %, by 2050 (ii) decreasing fossil fuel consumption especially built environment sector; and (iii) reducing dependence on imported energy. Buildings account for 40 % of the total non-transport energy consumption both in the UK and EU, therefore reduction of energy consumption in the built environment will make a significant contribution in meeting these targets. On average, UK residents spend between 2.7 and 8.4 % on gas and electricity bills. Water bills also account for 0.5–3 % of their income. These scenarios make it important to consider green building design and reduce the social, environmental and economic impacts building are creating on us. Sustainability through green building design should encompass "cradle-to-grave analysis". Building Research Establishment Environmental Assessment Methodology (BREAM) is the world's foremost environmental assessment method and rating system for buildings. BREAM was launched in 1990 and sets the standard best practice in sustainable building design, construction and operation. The assessment uses measures of performance against established benchmarks. This chapter highlights interesting features for achieving sustainable development through green building design.

Aerogel-Based Materials for Improving the Building Envelope's Thermal Behavior: A Brief Review with a Focus on a New Aerogel-Based Rendering

In this chapter, co-authors M. Ibrahim, Pascal Henry Biwole, Patrick Achard and Etienne Wurtz recommend aerogel-based materials for improving the building envelope's thermal behaviour. Most developed countries have set the objective to reduce their energy consumption and greenhouse gas emissions. In most countries, the building sector is the largest energy consumer. This sector offers a significant potential for improved energy efficiency through the use of high-performance insulation and energy-efficient systems. For existing buildings, renovation has high priority in many countries, because these buildings represent a high proportion of energy consumption and they will be present for decades to come. Several studies have shown that the best way to reduce the energy consumption in buildings remain the reduction of heat losses through the envelope. Nowadays, there is a growing interest in the highly insulating materials such as Aerogels. Due to their highly insulating characteristics, aerogels are becoming one of the most promising materials for building insulation. Although the cost of aerogel-based materials remain high for cost sensitive industries such as buildings, this cost is expected to decrease in the following years as a result of the advancement in the aerogel production technologies as well as the large-scale material production leading to lower unit costs. In this study, a brief review of aerogel applications in buildings is presented. Some examples of opaque aerogel-based materials and translucent aerogel-based systems are illustrated. Then, a new insulating rendering based on silica aerogels is presented. Its impact on energy performance for different houses is examined.

An Overview of Phase Change Materials for Building Applications

In this chapter Helia Taheri and Atul Sharma offer an overview of phase change material for building applications. The increasing level of greenhouse gas emissions and the rise in fuel prices are the main reasons for efforts to more effectively use various sources of renewable energy. One of the effective ways to reduce the economic consumption of fuel is by using thermal energy storages. The use of a latent heat storage system using phase change materials (PCMs) is an effective way of storing thermal energy and has advantages of high-energy storage density and isothermal nature of the storage process. Nowadays, by using lightweight materials in buildings, architects need lightweight thermal storages, therefore the use of PCMs has started. In this chapter, the authors discuss the benefits of using PCMs as thermal mass instead of the common thermal mass. Next, the characteristics of PCMs, their categories and building applications that can use PCMs as thermal mass are discussed. Finally, PCMs can be of benefit for lightweight buildings as thermal mass for reducing building loads and fuel consumption.

Part IV: Thermal Energy Storage

Phase Change Materials—A Sustainable Way of Solar Thermal Energy Storage

G. Raam Dheep and A. Sreekumar emphasize the use of phase change material for sustainable solar thermal storage. Renewable energy sources are time-dependent in nature and the effective utilization of devices based on renewable energy requires appropriate energy storage medium to commensurate the mismatch between energy supply and demand. Solar energy is the primary source of energy among renewable energy sources which can be used for a wide variety of electrical and thermal applications. The intermittent and unpredictable nature of solar energy generally necessitates a storage medium in-between that stores energy whenever it is available in excess and discharges energy whenever it is inadequate. Therefore, the storage of thermal energy becomes necessary to meet the larger energy demand and to achieve high efficiency. Thermal energy storage using latent heat-based Phase Change Materials (PCM) tends to be the most effective form of thermal energy storage that can be operated for a wide range of low, medium and high temperature applications. This chapter explains the need, desired characteristics, principle and classification of thermal energy storage. It also summarizes the selection criteria, potential research areas, testing procedures, possible application and case studies of PCM-based thermal energy storage system.

Latent Heat Thermal Storage (LHTS) for Energy Sustainability

Latent Heat Thermal Storage (LHTS) has been an interesting topic for researchers, readers and producing companies across the globe. In this chapter, co-authors M.A. Rahman, M.A. Kibria, M.M. Hossain, S. Rahman and H. Metselaar describe application of LHTS in solar power production and green buildings. In order to restrain the trend in present fossil fuel consumption, Latent Heat Thermal Storage (LHTS)