Green Energy and Technology

Ramchandra Pode
Boucar Diouf

Solar Lighting

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Ramchandra Pode · Boucar Diouf

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Ramchandra Pode
Department of Physics
Kyung-Hee University
Hoegi-dong
Seoul 130-701
Republic of South Korea
e-mail: rbpode@khu.ac.kr

Boucar Diouf
Department of Information Displays
Kyung-Hee University
Hoegi-dong
Seoul 130-701
Republic of South Korea
e-mail: diouf@khu.ac.kr

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Preface

Access to electricity considered as a fundamental human need is still very biased in the twenty-first century. Numerous developing countries are deprived of electricity, while such an issue is generally inexistent in developed countries; nevertheless, the energy sources that made the development possible are mainly based on fossil fuels that raise more and more environmental concerns.

Renewable energies are a good option to equilibrate this situation and provide a real opportunity for a better environment. Their successful implementation cannot be followed unless governments adopt adequate favorable policies that should necessarily go along with good education. Renewable energies should not be seen as a luxury, but a cost effective alternative that will bring jobs as well as improve living conditions.

One of the goals of the Millennium Development Program of the United Nations Organization is to provide regular electricity to 1.4 billion people around the world, mostly in the rural areas. Access to electricity and home lighting are considered essential for a decent quality of life. However, rural areas frequently lack the safe and uninterrupted electricity supply that is desired for the development of numerous economic activities. Grid expansion is a vital objective of several developing countries but is expensive and could be a long-term solution. However, the remoteness, isolation, and low electricity demand of many rural communities make them very unlikely to be reached by the extension of the power grid. Consequently, autonomous off-grid generation systems, such as photovoltaic or wind energies, seem to be the most suited to provide electricity services to these isolated rural communities.

This book has evolved from a number of years of intensive research on organic as well as inorganic LED lighting and practicing solar home systems. We feel that knowledge of the literature in the last couple of years has made a significant leap forward to warrant a comprehensive presentation. A large part of the book is based on the practical experience in solar home systems and energy efficient and future lighting devices such as LEDs and organic LEDs.

We acknowledge the open and intense discussion with many colleagues in the Physics and Information Display Departments of Kyung Hee University, Seoul

and participations in meetings and workshops on LED lightings and PV systems. Professor Syed Abdus Samad, Ex-Professor, Business Administration Division, Hankuk University of Foreign Studies, Seoul, South Korea and presently, Executive Chairman, Board of Investment, Government of Bangaladesh, Dhaka has made valuable suggestions and inputs while writing the research articles to enhance the acceptability of solar powered LED lighting and energy security which are now parts of this book.

We believe that the application of energy efficient lighting devices with solar home systems will experience significant growth in the years to come. We hope that this book will serve as a useful text and reference for academicians, business, and renewable energy engineering communities.

Seoul, June 2011

Ramchandra Pode
Boucar Diouf

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Chapter 1
Why Clean Energy?

1.1 Introduction

Energy plays the most vital role in the economic growth, progress and development, poverty eradication, and security of any nation. Uninterrupted energy supply is a vital issue for all countries today. Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible, and environmentally friendly. Security, climate change, and public health are significantly dependent on the energy as schematically shown in Fig. 1.1. Abundant, cheap, and clean energy are prerequisites for decent human living conditions and a healthy economy. In recent decades, the overwhelming increase in development activities have triggered the increasing demand for energy [1–4], resulting in further contributions to green house gas (GHGs) emissions. The world had already experienced its first and second energy crises due to the oil and gas scarcities in 1973 and 1979, respectively.

The recent International Energy Agency (IEA) World Energy Outlook Report shows that over 20% of the global population or 1.4 billion people lack access to electricity [5, 6]. Nearly 40% of the global population or 2.7 billion people, mostly in rural areas, rely on the traditional use of biomass for cooking. To meet the growth aspirations of billions of off-grid people, the development activities in the energy sector are expected to be accelerated globally. The world energy demand is projected to rise by 50% over the next 20 years, mostly because hundreds of millions of people in China, India, and other developing worlds will be buying cars and living more energy-intensive lives. The future projection of energy needs is displayed in Fig. 1.2. The production of fossil fuels, particularly oil, is going to have trouble keeping up with that demand. And even if we could meet that demand with fossil fuels, we would end up with irreversible climate change. At present, 80% of our energy comes from fossil fuels such as coal, oil, and natural gas and only 2% from wind and solar combined. The world needs to change the kind of energy we use, even as we need more and more of it.

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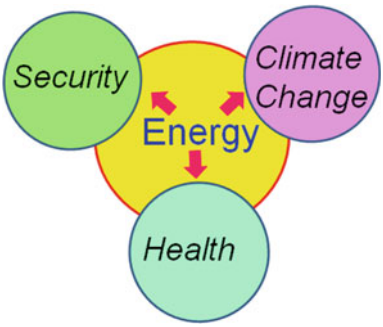

Fig. 1.1 Energy influences security, climate change, and public health

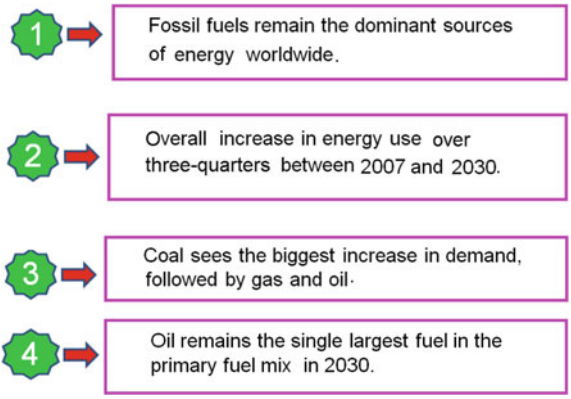

Fig. 1.2 Future projections of requirements of energy fuels

Lack of energy resources could jeopardize not only the economic progress but also the security and strategic interests of several countries. Adequate quantities of economically priced clean, sustainable and green fuels need to be made available to consumers. In a new paradigm, sustainable economic growth and industrial development without endangering the climate are envisaged.

Another concern regarding primary energy sources which has attracted attention of several developing and developed economies is that of energy security with uninterrupted supply of energy fuels. Indeed, this issue is imperative and needs to be addressed more seriously as these fuel sources are concentrated in a few countries. Unfortunately, primary fuel materials required to produce energy are not evenly distributed throughout the world. In fact, some countries in recent days are hopelessly marginalized by the global price volatility, increasingly competitive world demand, and associated geopolitical hazards. Faced with serious concern to energy security, competition for acquiring the overseas energy resources by developing and developed economies has significantly intensified in the recent years. Furthermore, environment pollution is influencing our health in many ways. Air pollution borne diseases include, (1) respiratory diseases, (2) gastric problems, (3) skin problems, (4) eye problems, (5) cardiac problems, and (6) others. Several poor countries do not have a robust health care system, like developed countries,

and the majority of off-grid rural habitants are suffering from the air pollution borne diseases. An unhealthy workforce seriously affects the country's economic growth.

Consequently, energy, economics, environmental and climate change, and health care are intertwined issues. For a sustainable future economic progress and industrial growth, these issues must be addressed collectively. Furthermore, to avoid the next energy crisis and address the environment issue, existing windows of opportunities such as energy efficient technology and new and renewable technology need to be explored.

In this chapter, conventional energy sources, its impacts on health, environment and climate change and security, diversification of energy mix, and the feasibility of interchangeability of mix of energy sources, use of alternative fuels and estimation of CO_2 emission, and conclusions are discussed.

1.2 Present Scenario of Energy Mix

World Energy Outlook, IEA has projected that the world primary energy demand is increasing by 1.5% per year between 2007 and 2030, from just over 12,000 to 16,800 million tonnes of oil equivalent (Mtoe) with an overall rise of 40% [7]. Figure 1.3 shows the world energy mix in 2008 [8] and 2030 [9] in the Reference Scenario based on current policies. Assuming similar rates of consumption and the economic conditions in the future, World Oil indicates that oil reserves in the world would be depleted more or less in 43 years, coal in 417 years, and natural gas in 167 years [10]. The total *energy mix* size is projected to increase from 11,294.9 Mtoe in 2008 to 17,014 Mtoe in 2030 in the Reference Scenario with the current policies as estimated by the IEA [5]. Fossil fuels such as coal, oil, and natural gas remain the dominant sources of primary energy worldwide, accounting for the 50% overall increase in energy use between 2008 and 2030. In absolute terms, coal sees the biggest increase in demand over the projection period, followed by gas and oil. Although oil remains the single largest fuel in the primary fuel mix in 2030, its share will drop from 34% now to 30%. The energy mix of some industrialized and developing countries are listed in Table 1.1 [8, 11, 12]. Four developed countries namely Iceland, Norway, Sweden, and Finland have renewables contribution of 73, 60, 26, and 23% in the total energy mix, respectively. Whereas, France, Sweden, Switzerland, and Belgium have 40, 37, 24, and 22% of nuclear energy share in their energy mix, respectively. Interestingly, the energy mix of Iceland has the highest fraction of renewables (72.6%) of any country and that of only 27.4% of fossil fuel contribution. On the other extreme, the performance of the United States of America (USA) on the energy mix portfolio is not encouraging as it is strongly dependent on the fossil fuel (86%) as regard to 8 and 6% of nuclear and renewable energies, respectively. Also noteworthy are Australia (97%), Ireland (97%), and Indonesia (97.8%); their

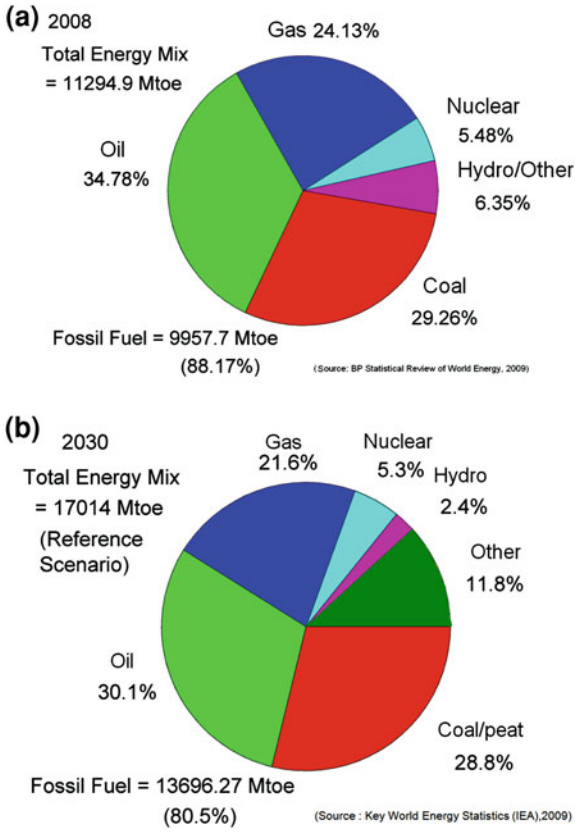

Fig. 1.3 **a** World energy mix in 2008, **b** in 2030 in the Reference Scenario based on current policies

economies are almost entirely reliant on fossil fuels. These results demonstrate that the interchangeability of the mix of energy sources model is practically feasible.

Global oil concentrations are shown in Fig. 1.4 [13] and Table 1.2 [8]. Around 60% of the world's proved oil reserves in 2008 were located in Middle East countries, while 57% of the world's proved gas reserves in 2008 were found in just three countries Russia, Iran, and Qatar as displayed in Fig. 1.5 and Table 1.2. While, the world's proved coal reserves are more evenly located around the globe, except the Middle East and South American Countries as listed in Table 1.2. Middle East and African countries are rich in energy resources which are sufficient to meet the current levels of the world energy demand. As a consequence, many developed and developing economies are investing in Latin American, African and Asian countries to secure energy resources. Indeed, the recent political interest of several countries in Africa illustrates their energy security concerns. Political instability and disruption of production and distribution chains due to accidents or natural events in key energy producing regions are further adding anxieties to consuming countries. Individual consuming countries continue to face specific energy security issues related to cost, geography, and political relationships with

Table 1.1 Energy mix of some industrialized and developing countries in 2008

Country	Energy mix				Reference
	Fossil (%)	Nuclear (%)	Renew-ables (%)	Other (%)	
Luxembourg	92	0	2	6	[11, 12]
United States	86	8	6	0	[11, 12]
Australia	97	0	3	0	[11, 12]
Canada	67	7	25	0	[11, 12]
Finland	59	16	23	2	[11, 12]
Belgium	75	22	2	1	[11, 12]
Ireland	97	0	2	1	[11, 12]
Netherlands	94	1	3	2	[11, 12]
Germany	84	12	4	0	[11, 12]
Denmark	85	0	14	1	[11, 12]
Japan	83	12	5	0	[11, 12]
Norway	37	0	60	0	[11, 12]
Austria	77	0	21	2	[11, 12]
United Kingdom	89	9	2	0	[11, 12]
Italy	90	0	7	3	[11, 12]
New Zealand	71	0	29	0	[11, 12]
Iceland	28	0	73	0	[11, 12]
France	52	40	6	2	[11, 12]
Bulgaria	71	22	5	2	[11, 12]
Portugal	83	0	15	2	[11, 12]
Sweden	37	37	26	0	[11, 12]
Switzerland	63	24	13	0	[11, 12]
Brazil	62.45	1.36	–	36.08 (hydro)	[8]
China	92.6	0.77	–	6.61 (hydro)	[8]
India	92.82	0.80	–	6.06 (hydro)	[8]
Indonesia	97.80	–	–	2.16 (hydro)	[8]
South Korea	85.32	14.22	–	0.37 (hydro)	[8]
World mean	**87**	**6**	**6**	**1**	–

producers. Diversifying oil and gas supply sources may be one strategic approach to enhance energy security for many counties, but does not address the climate change issue.

1.3 Climate Change

Energy use and supply is of fundamental importance to society and, with the possible exception of agriculture and forestry, has made the greatest impact on the environment of any human activity–a result of the large-scale and pervasive nature of energy-related activities. Although energy and environment concerns were originally local in character–for example, problems associated with extraction, transport, or noxious emissions–they have now widened to cover regional and global issues. The primary environmental impact of electricity consumption is the

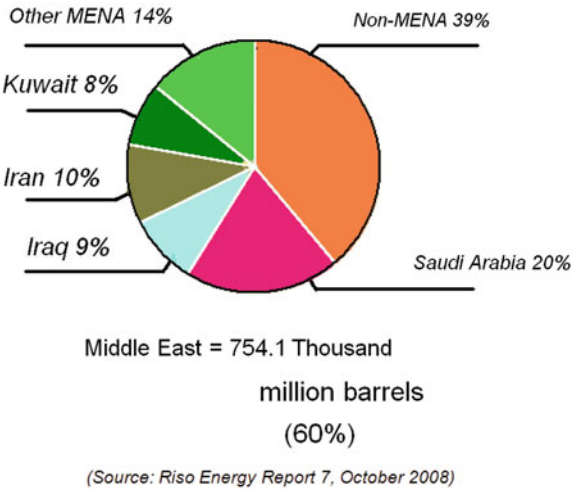

Fig. 1.4 Global oil concentration

Table 1.2 Proved global oil, natural gas, and coal (including anthracite and bituminous coal) at the end of 2008

Region	Oil (Thousand million barrels)	Natural Gas (Trillion cubic meters)	Coal (Thousand million tonnes)
Asia Pacific	42.0	15.39	155.8
North America	70.9	8.87	246.1
South and Central America	123.2	7.31	15.0
Africa	125.6	14.65	320
Europe and Eurasia	142.2	62.89	272.2
Middle East	754.1	75.91	1.4

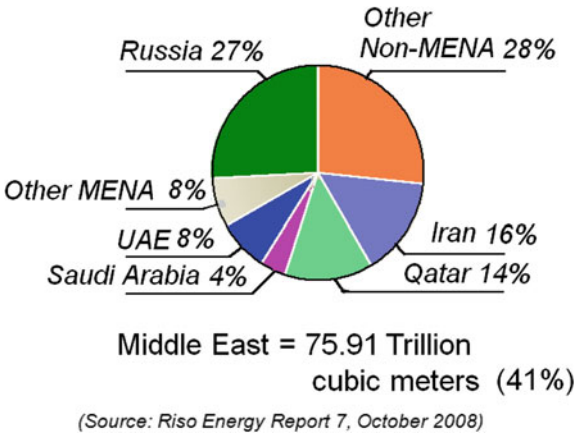

Fig. 1.5 World's proved gas reserves in 2008

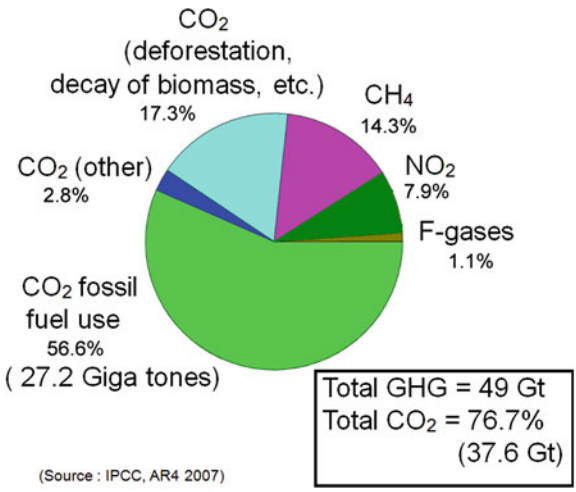

Fig. 1.6 Contribution to anthropogenic GHG emissions due to the various human activities

production of GHGs that contribute to global warming. Such problems have now become major political issues and the subject of international debate and regulation. It is for this reason that there is a need to address energy and environment issues together.

The main driver of demand for fossil fuels is the inexorable growth in the energy needs for power generation. The world net electricity generation increases by an average of 2.4% per year from 2006 to 2030 in the International Energy Outlook (IEO) 2009 reference case, a net increase by 77% [14]. Non-OECD countries are expected to contribute nearly 90% of the total world energy demand growth [14]. Population growth and mass industrialization in emerging economies are two main factors driving these figures [15]. Fossil fuels are expected to provide the bulk of primary energy in 2030 mainly due to the continued reliance on the existing coal-fired plants. Coal continues to provide a secure energy source for many consuming countries although there is a major concern about GHGs emissions. Figure 1.6 shows the contribution to anthropogenic GHG emissions due to the various human activities [16, 17]. The Use of fossil fuels contributes about 56.6% of all GHG emissions.

The global emissions of carbon dioxide from the three fossil fuels in 2008 are shown in Table 1.3 [18, 19]. Although China's total emission (21.67%) has taken over the US (20.22%), its annual per capita emission of 4.88 tonnes CO_2 is much lower than those of USA, Canada, and Australia at 19.96, 18.82, and 17.72 tonnes, respectively. As seen from the Table 1.3, India's annual per capita CO_2 emission is merely 1.17 tonnes which is much below the World average at 4.51 tonnes. Emissions from the three major developing nations of Brazil, China, and India account for 27.57% of the world total emission in 2008. While other countries designated here as the Rest-of-World account for 22.09% of the emissions. The per capita emission from this part of the world is also low at 2.42 tonnes CO_2 per person.

Table 1.3 Global emissions of CO_2 in 2008 and CO_2 emission per capita (IEA Statistics, CO_2 emissions from fuel consumption, 2010 edition) (Ref. [18, 19])

Country	Total CO_2 emissions (million tonnes)	CO_2 emissions from electricity and heat production (million tonnes)	CO_2 emissions per capita (metric tone/person)	
			2007	2008
Canada	550.9	119.3	17.33	16.53
United States	5,595.9	2,403.4	19.10	18.38
Brazil	364.6	41.2	1.81	1.90
Austria	69.3	15.2	8.36	8.31
Belgium	111.0	23.0	9.97	10.36
Bulgaria	48.8	30.0	6.56	6.40
Denmark	48.4	21.8	9.37	8.82
France	368.2	50.8	5.86	5.74
Finland	56.6	24.3	12.15	10.65
Germany	803.9	337.3	9.74	9.79
Iceland	**2.2**	**0.0**	**7.53**	**6.89**
Ireland	43.8	14.3	10.06	9.85
Italy	430.1	146.9	7.43	7.18
Luxembourg	10.4	1.1	22.35	21.27
Netherlands	177.9	57.2	10.84	10.82
Norway	37.6	0.8	8.08	7.89
Portugal	52	19	5.18	4.94
Russia	1593.8	873.9	11.11	11.24
Sweden	46	8	5.07	4.96
Switzerland	44	2	5.54	5.67
United Kingdom	511	195	8.54	8.32
Bangladesh	46.4	20.1	0.27	0.29
China	6,508.2	3,108.1	4.58	4.91
India	1,427.6	8,03.7	1.19	1.25
Japan	1,151.1	472.2	9.72	9.02
Nepal	3.3	0.0	0.11	0.12
South Korea	501.3	229.6	10.12	10.31
Kenya	8.6	2.3	0.22	0.22
South Africa	337.4	213.3	7.16	6.93
Iran	505.0	124.8	6.80	7.02
Kuwait	69.5	31.8	25.11	25.47
UAE	146.9	72.6	29.91	32.77
Australia	397.5	227	18.30	18.48
Indonesia	385.4	108.5	1.62	1.69
New Zealand	33.3	9.4	7.62	7.74

1.4 Environment and Health

Energy and clean environment are essential for sustainable development. The poor are disproportionately affected by any environmental degradation and lack of access to clean, affordable energy services. Proper environmental management is the key to avoiding the quarter of all preventable illnesses directly caused by environmental factors. The environment influences our health in many ways—through exposures to physical, chemical, and biological risk factors, and through related changes in our behavior in response to those factors. Air pollution borne diseases include respiratory diseases, gastric problems, skin problems, eye problems, cardiac problems, and others [20]. Thirteen million deaths annually are due to preventable environmental causes. Preventing environmental risk could save as many as four million lives a year, of children alone, mostly in developing countries.

Environment sustainability has become the critical issue across the world. Overwhelming evidence shows that human activities are affecting the environment. Environment-linked issues such as water quality, air pollution, and sustainability of agriculture have serious implications on public health. Figure 1.7 shows the impact of the environment on health. An unhealthy workforce is bound to (1) enhance medical expenditure, (2) reduce productivity, and (3) contribute to the lower economic growth of the nation. Catastrophic weather events, variable climates that affect food and water supplies, ecosystem changes are all associated with global warming and pose health risks. Climate and weather exert strong influences on health: increased deaths in heat waves, and in natural disasters such as floods, as well as changing patterns of life-threatening vector-borne diseases such as malaria and other existing and emerging infectious diseases are observed. The poor are the greatest sufferers as they do not and afford to have robust health care system as in the industrialized nations.

The World Health Organization (WHO) estimates that up to 25% of the global burden of disease is due to preventable environmental exposures. Children are especially vulnerable because they receive a higher dose than adults, with more extreme consequences. The unborn child's health can also be affected because the environment can influence gene expression and organogenesis. The burden of disease is unevenly distributed, with children being the most vulnerable in developing and low-income countries. While children in such countries still have to cope with traditional threats, including lack of access to safe water, poor sanitation and hygiene, and infectious diseases, they suffer from emerging environmental exposures that threaten their health, such as the effects of rapid globalization, an upsurge in urbanization, transboundary chemical transport, and unsustainable consumption.

Table 1.4 shows the per capita power consumption in 2007 and the environment performance index (EPI) in 2009 in some countries [21, 22]. The EPI score was calculated by considering various factors such as environmental burden of disease, water resources for human health, air quality for human health, air quality