Second Edition

Energy Efficiency and Renewable Energy Handbook

Edited by

D. Yogi Goswami

Frank Kreith

CRC Press
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SECOND EDITION

ENERGY EFFICIENCY AND RENEWABLE ENERGY HANDBOOK

MECHANICAL and AEROSPACE ENGINEERING

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Preface

Purpose

The goal of this handbook is to provide information necessary for engineers, energy professionals, and policy makers to plan a secure energy future. The time horizon of the handbook is limited to approximately 20 years because environmental conditions vary, new technologies emerge, and priorities of society continuously change. It is therefore not possible to make reliable projections beyond that period. Given this time horizon, the book deals only with technologies that are currently available or that are expected to be ready for implementation in the near future.

Energy is a mainstay of an industrial society. As the population of the world increases and people strive for a higher standard of living, the amount of energy necessary to sustain our society is ever increasing. At the same time, the availability of nonrenewable sources, particularly liquid fuels, is rapidly shrinking. Therefore, there is general agreement that to avoid an energy crisis, the amount of energy needed to sustain society will have to be contained and, to the extent possible, renewable sources will have to be used. As a consequence, conservation and renewable energy (RE) technologies are going to increase in importance and reliable, up-to-date information about their availability, efficiency, and cost is necessary for planning a secure energy future.

The timing of this handbook also coincides with a new impetus for the use of RE. This impetus comes from RE policies in Europe, Japan, China, India, and Brazil and the emergence of renewable portfolio standards (RPS) in many states of the United States**.** Germany introduced electricity feed-in laws that value electricity produced from RE resources much higher than that from conventional resources, which have created demand for photovoltaic and wind power. Following the success of Germany, other European countries introduced feed-in laws, which accelerated the deployment of RE in Europe. Other countries, such as China and India, have adopted modified versions of feed-in laws, whereby RE power companies bid discounts to the feed-in tariffs determined by the governments. RPS policies adopted by many states in United State require that a certain percentage of energy used be derived from renewable resources. RPSs and other incentives for RE are currently in place in 34 of the 50 states of the United States and the District of Columbia (DC) and Puerto Rico. The details of the RPS for RE and conservation instituted by state governments vary, but all of them essentially offer an opportunity for the industry to compete for the new markets. Thus, to be successful, renewable technologies will have to become more efficient, reliable, and cost-effective. RPSs have already demonstrated that they can reduce market barriers and stimulate the development of RE. The use of conservation and RE can help meet critical national goals for fuel diversity, price stability, economic development, environmental protection, and energy security and thereby play a vital role in national energy policy. The expected growth rate of RE from portfolio standards and other stimulants in the United States is impressive. As a result of various policy initiatives in the world, the global growth in solar photovoltaics (PV) production has averaged over 43% per year from 2000 to 2012 and 61% from 2007 to 2012, with Europe showing the maximum growth. The average annual growth in worldwide wind energy capacity from 2001 to 2012 was over 25%. The average annual growth in the United States over the same period was

37.7%. More recently, China has increased its capacity faster than any other country. China accounted for more than a quarter of the global wind capacity in 2012. With appropriate regulations and careful planning, the technical information in this handbook will ensure an orderly and peaceful transition to a sustainable energy future.

Organization and Layout

The book is essentially divided into three sections:

- General overviews, policy, and economics (Section I: Chapters 1 through 13)
- Energy efficiency, energy generation, infrastructure, and storage (Section II: Chapters 14 through 18; and Section III: Chapters 19 through 35)
- Renewable energy technologies (Section IV: Chapters 36 through 48; and Section V: Chapters 49 through 53).

The first chapter is a survey of current and future worldwide energy issues. A discussion of sound finance policies and stimulants for energy efficiency and RE is treated in Chapter 2. State and federal policies for RE in the United States are described in Chapter 3. Chapters 4 through 11 give an assessment of policies in Europe, China, India, Brazil, Israel, Australia, and Japan. Economic assessment methods for conservation and generation technologies are covered in Chapter 12, and the environmental costs of various energy generation technologies are discussed in Chapter 13. The use of renewables and conservation will initiate a paradigm shift toward distributed generation and demand-side management procedures, which are covered in Chapter 14 and 15. Although renewables, once in place, produce energy from natural resources and cause very little environmental damage, energy is required in their initial construction. One measure of the energy effectiveness of a renewable technology is the length of time required, after the system begins operation, to repay the energy used in its construction, called the energy payback period. Another measure is the energy return on energy investment ratio. The larger the amount of energy a renewable technology delivers during its lifetime compared to the amount of energy necessary for its construction, the more favorable its economic return on the investment will be and the less its adverse environmental impact. But during the transition to renewable sources, a robust energy production and transmission system from fossil and nuclear technologies is required to build the systems. Moreover, because there is a limit to how much of our total energy needs can be met economically in the near future, renewables will have to coexist with fossil and nuclear fuels for some time. Furthermore, the supply of all fossil and nuclear fuel sources is finite, and their efficient use in meeting our energy needs should be a part of an energy and CO_2 reduction strategy. Therefore, Chapters 16 and 17 give a perspective on the efficiencies, economics, and environmental costs of the key fossil and nuclear technologies. Finally, Chapter 18 provides projections for energy supply, demand, and prices of energy in the United States through the year 2040. Petroleum engineers predict that worldwide oil production will reach its peak within the next 10 years and then begin to decline. At the same time, demand for liquid fuel by an ever-increasing number of vehicles, particularly in China and India, is expected to increase significantly. As a result, gasoline prices will increase precipitously unless we reduce gasoline consumption by increasing the mileage of the vehicle fleet, reducing the number of vehicles on the road by using mass transport, and producing synthetic fuels from biomass and coal. The options to prevent an energy crisis in transportation include plug-in hybrid vehicles, biofuels, diesel engines, city planning, and mass-transport systems. These are treated in Chapter 19; biofuels and fuel cells are treated in Chapters 50 and 53, respectively. It is an unfortunate fact of life that the security of the energy supply and transmission system has recently been placed in jeopardy from various sources, including natural disasters and worldwide terrorism. Consequently, energy infrastructure security and risk analysis are an important aspect of planning future energy transmission and storage systems, and these topics are covered in Chapter 20. Energy efficiency is defined as the ratio of energy required to perform a specific task or service to the amount of energy used for the process. Improving energy efficiency increases the productivity of basic energy resources by providing the needs of society with less energy. Improving the efficiency across all sectors of the economy is therefore an important objective. The least expensive and most efficient means in this endeavor is energy conservation, rather than more energy production. Moreover, energy conservation is also the best way to protect the environment and reduce global warming.

Recognizing that energy conservation in its various forms is the cornerstone of successful national energy strategy, 11 chapters (22 through 32) are devoted to conservation. The topics covered include energy management strategies for industry and buildings, HVAC controls, co-generation, and advances in specific technologies, such as motors, lighting, appliances, and heat pumps. An important aspect of energy efficiency is efficient electric grid management, which includes energy storage, advanced concepts in transmission and distribution, and smart grid technology. These topics are covered in detail in Chapters 33 through 35.

The third section of the book deals with energy storage and energy generation from renewable sources. Chapters 36 through 39 present the availability of renewable sources: solar, wind, municipal waste, and biomass. The renewable generation technologies for solar thermal, wind power, PV, biomass, and geothermal are then covered in Chapters 40 through 53.

At this time, it is not clear whether hydrogen will play a major role in the national energy structure within the next 25 years, but there is an ongoing discussion about the feasibility and cost of what is called the hydrogen economy. Energy experts recognize that the generation and use of hydrogen has a critical inefficiency problem that is rooted in basic thermodynamics. There are also ground transportation options that are less expensive than using hydrogen vehicles powered by fuel cells. But there is substantial support for continuing research to eventually develop a viable place for hydrogen in a future energy structure. Therefore, the topics of hydrogen energy and fuel cells are included in Chapters 52 and 53, respectively. This information should be useful background for comparing competing options for energy generation, storage, and distribution.

We hope that this handbook will serve as a useful reference to all engineers in the energy field and pave the way for a paradigm shift from fossil fuels to a sustainable energy systems based on conservation and renewable technologies. But we also recognize the complexity of this task, and we invite readers to comment on the scope and the topics covered. A handbook such as this needs to be updated every 5–10 years, and we will respond to readers' comments and suggestions in the next edition.

D. Yogi Goswami
Frank Kreith
Editors-in-chief

Acknowledgments

At the time CRC suggested that the *Handbook of Energy Efficiency and Renewable Energy* deserved a second edition, I was approaching my 90th birthday. I was reluctant at this point in my life to undertake such a large and demanding assignment, but my long-time associate and co-editor, Yogi Goswami, and Bev Weiler, my long-term assistant, offered to help me in the endeavor. The new edition owes its existence to the invaluable contributions that these two have made in contacting previous authors and helping to find new qualified experts whenever necessary. I would also like to thank my wife Marion for having helped me in many tangible and intangible ways to continue an active professional life in my seventh decade as an engineering author.

Frank Kreith

Editors

Dr. D. Yogi Goswami is a university distinguished professor, the John and Naida Ramil Professor, and director of the Clean Energy Research Center at the University of South Florida, Tampa, Florida.

He conducts fundamental and applied research on solar thermal energy, thermodynamics, heat transfer, HVAC, photovoltaics, hydrogen, and fuel cells.

Dr. Goswami has served as an advisor and given testimonies on energy policy and the transition to renewable energy to the U.S. Congress and the Government of India, as well as provided consultant expertise to the U.S. Department of Energy, USAID, World Bank, and NIST, among others.

Professor Goswami is the editor-in-chief of the *Solar Energy* and *Progress in Solar Energy* journals. Within the field of RE, he has published as author/editor 16 books, 6 conference proceedings, and 393 refereed technical papers. He has delivered 52 keynote and plenary lectures at major international conferences. He holds 18 patents.

A recognized leader in professional scientific and technical societies, Professor Goswami has served as a governor of ASME-International (2003–2006), president of the International Solar Energy Society (2004–2005), senior vice president of ASME (2000–2003), vice president of ISES and president of the International Association for Solar Energy Education (IASEE, 2000–2002).

Dr. Goswami is a fellow of AAAS, ASME International, ASHRAE, the American Solar Energy Society, the National Academy of Inventors and a member of the Pan American Academy of Engineers. He is a recipient of the following awards:

- Technical Communities Globalization Medal, (ASME) 2013.
- Theodore and Venette Askounes-Ashford Distinguished Scholar Award, Univ. South Florida, 2011.
- Frank Kreith Energy Award, ASME, 2007
- Farrington Daniels Award, ISES, 2007 (highest award of ISES)
- Hoyt Clark Hottel Award, ASES, 2007
- Charles Greely Abbott Award for Outstanding Scientific, Technical and Human Contributions to the Development and Implementation of Solar Energy (highest award of the American Solar Energy Society), 1998.
- John Yellott Award for Outstanding Contributions to the Field of Solar Energy, ASME Solar Energy Division, 1995 (highest solar energy award from ASME).

He has also received more than 50 other awards and certificates from major engineering and scientific societies for his work in renewable energy.

Professor Frank Kreith is an internationally known energy consultant and professor emeritus of engineering at the University of Colorado, Boulder, Colorado. In 1945, after graduation from the University of California, Berkeley, he accepted a position at the Jet Propulsion Laboratory of the California Institute of Technology, where he developed a heat transfer laboratory and conducted research on building heat transfer. He received his MS in engineering in 1949 from the University of California, Los Angeles, and in 1950 was awarded a Guggenheim Fellowship to Princeton University, followed in 1951 by an appointment to the faculty of the University of California, Berkeley. From 1953 to 1959, he was associate professor of mechanical engineering at Lehigh University, where he did research on heat transfer in rotating systems and wrote the first edition of *Principles of Heat Transfer*, now in its seventh edition. In 1958, he received the Robinson Award from Lehigh University for excellence in teaching. In 1959, he joined the University of Colorado where he held appointments as professor of mechanical and chemical engineering. In 1962, he published a text on the design of solar power plants based on his consulting for the NASA space program. During his 20 years of tenure at the University of Colorado, he did research on heat transfer in biological systems and renewable energy. In 1964, he was awarded a doctorate in engineering from the University of Paris.

Dr. Kreith served as chief scientist and ASME legislative fellow at the National Conference of State Legislatures (NCSL) from 1988 to 2001, providing professional advice and assistance to all 50 state legislatures on energy and the environment. Prior to joining NCSL, he was senior research fellow at the Solar Energy Research Institute (now the National Renewable Energy Laboratory) where he participated in the Presidential Domestic Energy Review and served as energy advisor to the governor of Colorado. From 1974–1977, he was president of Environmental Consulting Services. Dr. Kreith has been an energy consultant to NATO, the U.S. Agency of International Development, and the United Nations. He has published more than a hundred peer-reviewed technical articles and more than 15 books, many translated into foreign languages and used extensively in engineering programs around the world. His books include *Principles of Heat Transfer* (now in its seventh edition), *Principles of Solar Engineering* (with J.F. Kreider), *Nuclear Impact* (with C.B. Wrenn), the *Handbook of Solid Waste Management*, the *CRC Handbook of Mechanical Engineering*, and *Principles of Sustainable Energy*, which is now in its second edition. He is a fellow of AAAS and was promoted to honorary member of ASME in 2004. Dr. Kreith's work has received worldwide recognition, including the Washington Award, Charles Greeley Abbot Award from ASES, the Max Jacob Award from ASME-AIChE, and the Ralph Coats Roe Medal from ASME for "significant contributions…through provision of information to legislators about energy and the environment." In 2004, ASME recognized Dr. Kreith's lifelong contributions to heat transfer and renewable energy by establishing the Frank Kreith Energy Award. He has recently completed an autobiography, *Sunrise Delayed: A Personal History of Solar Energy*, which is available on Amazon.com.

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Section I

Global Energy Systems, Policy, and Economics

1

Global Energy Systems

D. Yogi Goswami and Frank Kreith

CONTENTS

> A thing that will assume enormous importance quite soon is the exhaustion of our fuel resources. Coal and oil have been accumulating in the earth over five hundred million years, and at the present rates of demand for mechanical power, the estimates are that oil will be all gone in about a century, and coal probably in a good deal less than five hundred years. For the present purpose, it does not matter if these are under-estimates; they could be doubled or trebled and still not affect the argument. Mechanical power comes from our reserves of energy, and we are squandering our energy capital quite recklessly. It will very soon be all gone, and in the long run we shall have to live from year to year on our earnings.*

* Quote from *The Next Millenium*, 1953, by Charles Galton Darwin, the grandson of Charles Darwin, author of *On the Origin of Species.*

1.1 Global Energy Needs and Resources

Global energy consumption in the last half century has rapidly increased and is expected to continue to grow over the next 50 years, however, with significant differences. The past increase was stimulated by relatively "cheap" fossil fuels and increased rates of industrialization in North America, Europe, and Japan; yet while energy consumption in these countries continues to increase, additional factors make the picture for the next 50 years more complex. These additional factors include China's and India's rapid increase in energy use as they represent about a third of the world's population; the expected depletion of oil resources in the near future; and, the effect of human activities on global climate change. On the positive side, the renewable energy (RE) technologies of wind, biofuels, solar thermal, and photovoltaics (PV) are finally showing maturity and the ultimate promise of cost competitiveness.

Statistics from the International Energy Agency (IEA) World Energy Outlook 2004 and 2010 show that the total primary energy demand in the world increased from 5,536 MTOE in 1971 to 10,345 MTOE in 2002, representing an average annual increase of 2% (see Figure 1.1 and Table 1.1).*

By 2008, the world energy demand had increased to 12,271 MTOE representing an average annual increase of about 3%. The main reason for a 50% increase in the annual rate is the fast growing energy demand in Asia Pacific, more specifically China. Since the per capita energy used in the most populous countries, China and India is still very small,

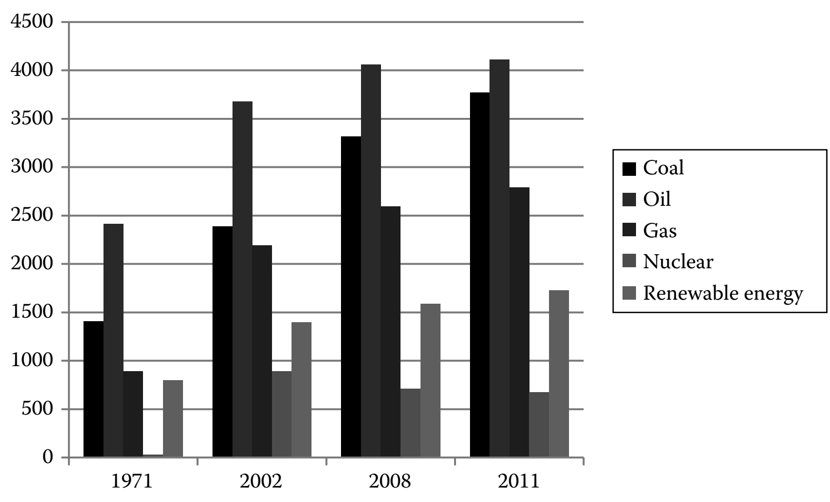

FIGURE 1.1
World primary energy demand (MTOE). (Data from IEA, *World Energy Outlook*, 2004; IEA, *World Energy Outlook 2010*, International Energy Agency, Paris, France, 2010; IEA, *World Energy Outlook 2013*, International Energy Agency, Paris, France, 2013.)

* The energy data for this chapter came from many sources, which use different units of energy, making it difficult to compare the numbers. The conversion factors are given here for a quick reference.
MTOE = Mega tons of oil equivalent; 1 MTOE = 4.1868×10^4 TJ (Terra Joules) = 3.968×10^{13} Btu.
GTOE = Giga tons of oil equivalent; 1 GTOW = 1000 MTOE.
Quadrillion Btu, also known as Quad: 10^{15} British Thermal Units or Btu; 1 Btu = 1055 J.
1 TWh = 10^9 kilowatt hours (kWh), 1 kWh = 3.6×10^6 J.

TABLE 1.1

World Total Energy Demand (MTOE)

Energy Source/Type	1971	2002	2008	2011	Annual Change 1971–2002 (%)	Annual Change 2002–2008 (%)	Annual Change 2008–2011 (%)
Coal	1,407	2,389	3,315	3,773	1.7	5.6	4.4
Oil	2,413	3,676	4,059	4,108	1.4	1.67	0.4
Gas	892	2,190	2,596	2,787	2.9	2.88	2.4
Nuclear	29	892	712	674	11.6	−3.7	−1.8
Hydro	104	224	276	300	2.5	3.6	2.8
Biomass and waste	687	1,119	1,225	1,300	1.6	1.6	2
Other renewables	4	55	89	127	8.8	8.46	12.6
Total	5,536	10,345	12,271	13,069	2.0	2.9	2.1

Sources: Data from IEA, *World Energy Outlook*, 2004; IEA, *World Energy Outlook 2010*, International Energy Agency, Paris, France, 2010; IEA, *World Energy Outlook 2013*, International Energy Agency, Paris, France, 2013.

their energy use may continue to increase at a high rate. From 2008 to 2011, the annual increase in energy use dropped back to 2.1% mainly because of a deep recession in United States and Europe where the energy use actually declined.

The last 10 years data for energy consumption from BP Corp. shows that during the most recent 10-year period even though the total primary energy use in North America and Europe has gone down, the global average increase has gone up to 2.8% (see Table 1.2). The rate of growth has risen mainly due to very rapid growth in Asia Pacific, which recorded an average annual increase of 6.1%. More specifically, China increased its primary energy consumption by approximately 10%/year from 2002 to 2012. Based on the current plans of China this trend will continue for at least another decade (IEA, 2013).

Even at a 2% increase per year, the primary energy demand of 12,271 MTOE in 2008 would double by 2043 and triple by 2063. Of course the global energy use cannot continue to increase at the same rate forever. IEA (2013) estimates that the global energy use will increase at an average annual rate of 1.2 up to 2035. Even at that optimistic slow growth rate of 1.2%, the global energy use will increase by 38% by 2035 reaching a value of 16,934 MTOE/year.

TABLE 1.2

Primary Energy Consumption (MTOE)[a]

Region	2002	2011	2012	2002–2012 Average Increase/Year (%)	2012 Change Over 2011 (%)
North America including United States	2741.1	2,774.3	2,725.4	−0.1	−2.0
United States	2295.5	2,265.2	2,208.8	−0.5	−2.8
South and Central America	474.9	649.5	665.3	3.5	2.2
Europe and Euro-Asia	2852	2,936.6	2,928.5	0.25	−0.5
Middle East	464.3	727.4	761.9	5.1	4.5
Africa	291.9	384.0	403.3	3.3	4.7
Asia Pacific	2773.7	4,753.2	4,992.2	6.1	4.7
China	1073.8	2,540.8	2,735.2	9.8	7.7
India	310.8	534.8	563.5	6.15	5.1
World	9487.9	12,225.0	12,477.0	2.8	1.8

Source: Data from BP Corp., London, U.K.

[a] This data does not include traditional biomass which was approximately 835 MTOE in 2011 according to IEA data.

Of the total world primary energy demand in 2002, fossil fuels accounted for about 80% with oil, coal, and natural gas being 36%, 23%, and 21%, respectively. Biomass accounted for 11% of all the primary energy in the world, with almost all of it being traditional biomass for cooking and heating in the developing countries, which is used very inefficiently. By 2011, fossil fuels contribution increased to approximately 82% of the global primary demand with oil, coal, and natural gas accounting for 31%, 29%, and 21%, respectively. Even though the oil use has continued to increase year after year, its overall share in the primary energy went down from 35% in 2002 to 31% in 2011. On the other hand, the share of coal in the primary energy increased from 23% in 2002 to 29% in 2011. The predominant reason for this shift is the rapid increase in power production in China where coal provides more than 75% of the electrical power (Table 1.3). The power capacity of China has been increasing at an annual rate of 12% since 2000 (Table 1.4) (Zhou, 2012) and has already overtaken the power capacity of United States.

With such high energy demand expected in the future, it is important to look at the available resources to fulfill the future demand 50 years from now, especially for electricity and transportation.

Although not a technical issue in the conventional sense, no matter what types of engineering scenarios are proposed to meet the rising demands of a growing world population, as long as that exponential growth continues, the attendant problems of energy and food consumption, as well as environmental degradation may have no long term solution (Bartlett, 2002). Under current demographic trends, the United Nations forecasts a rise in the global population to around 9 billion in the year 2050. This increase in 2.5 billion people will occur mostly in developing countries with aspirations for a higher standard of living. Thus, population growth should be considered as a part of the overall supply and demand picture to assure the success of future global energy and pollution strategy.

TABLE 1.3

Power Production in China by Energy Source

	1990	**%**	**2008**	**%**	**2011**	**%**
Coal	471	72.5	2759	79.0	3598	76.2
Oil	49	7.5	24	0.7	133.2	2.8
Gas	3	0.5	43	1.2	166.2	3.5
Nuclear	0	0.0	68	1.9	87.4	1.9
Hydro	127	19.5	585	16.7	662.6	14.0
Renewables	0	0.0	15	0.4	73.2	1.6
Total	650	100.0	3494	100.0	4720.6	100.0

TABLE 1.4

Power Capacity of China

Year	**GW**	**% Increase/Year**
1990	138	
2000	319	8.8
2008	793	12
2011	1056	11

1.2 Major Sectors of Primary Energy Use

The major sectors using primary energy sources include electrical power, transportation, heating and cooling, industrial and others, such as cooking. The IEA data shows that the electricity demand almost tripled from 1971 to 2002 and quadrupled by 2011. This is not unexpected as electricity is a very convenient form of energy to transport and use. Although primary energy use in all sectors has increased, their relative shares except for transportation and electricity have decreased (Figure 1.2). Figure 1.2 shows that the relative share of primary energy for electricity production in the world increased from about 20% in 1971 to about 40% in 2011. This is because electricity is becoming the preferred form of energy for all applications.

Figure 1.3 shows that coal is presently the largest source of electricity in the world. Consequently, the power sector accounted for almost 42% of all CO_2 emissions in 2011. Emissions could be reduced by increased use of RE sources. All RE sources combined accounted for about 20% share of electricity production in the world. Wind and solar power technologies have vastly improved in the last two decades and are becoming more cost effective. Therefore, their share of electricity production has been increasing at a very fast pace. Over the last decade wind power capacity has been increasing at an annual rate of close to 30% and solar photovoltaic power capacity has been increasing at an annual rate of close to 50%, which has resulted in wind and solar providing a combined 2% of all the electricity generation in the world in 2011, almost all of it coming online in less than two decades. Since solar and wind technologies are now mature, substituting fossil fuels with RE for electricity generation must be an important part of any strategy of reducing CO_2 emissions into the atmosphere and combating global climate change.

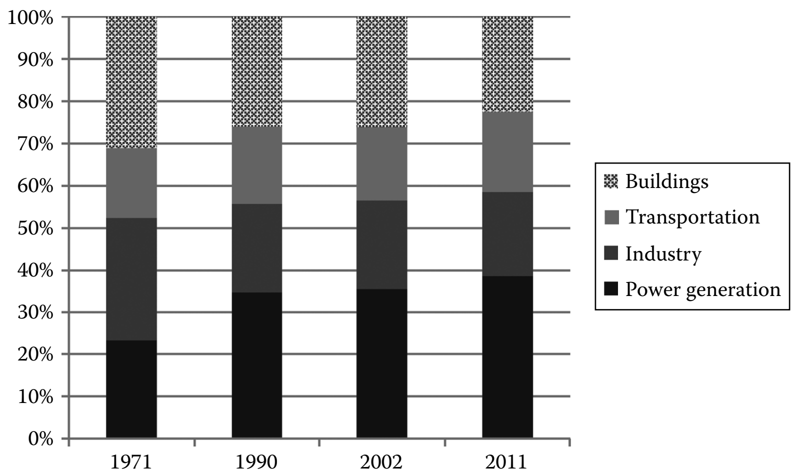

FIGURE 1.2
Sectoral shares in world primary energy demand. (Data from IEA, *World Energy Outlook*, 2004; IEA, *World Energy Outlook 2013*, International Energy Agency, Paris, France, 2013.)

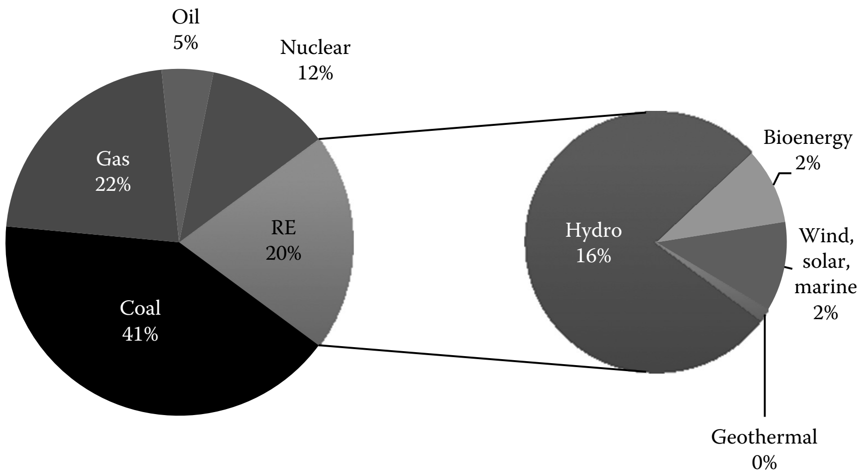

FIGURE 1.3
World electricity production by fuel in 2011. (Data from IEA, *World Energy Outlook 2013*, International Energy Agency, Paris, France, 2013.)

1.3 Electricity-Generating Capacity Additions to 2040

Figure 1.4 shows the global electricity-generating capacity in 2010 and additional electricity-generating capacity forecast by Energy Information Agency (EIA) of the U.S. Department of Energy for different regions in the world. The overall global annual increase of 1.6% in the electricity-generating capacity is in general agreement with the estimates from IEA (2013), which projects an average annual growth of 1.6% up to 2035. It is clear that of all countries, China will add the largest capacity with its projected electrical needs accounting for about 27.5% of the total world electricity-generating capacity. Non-OECD Asian countries (including China, India, Thailand, and Indonesia) combined will add about 60% of all the new capacity of the world. Therefore, what happens in these countries will have important consequences on the worldwide energy and environmental situation. If coal provides as much as 70% of China's electricity in 2030, as forecasted by IEA (2013), it will certainly increase worldwide CO_2 emissions which will further increase global warming.

1.4 Transportation

Transportation is a major sector with a 20% relative share of primary energy. This sector has serious concerns as it is a significant source of CO_2 emissions and other airborne pollutants—and it is almost totally based on oil as its energy source (Figure 1.5). In 2010, the transportation sector accounted for about 20% of all CO_2 emissions worldwide. An important aspect of future changes in transportation depends on what happens to the available

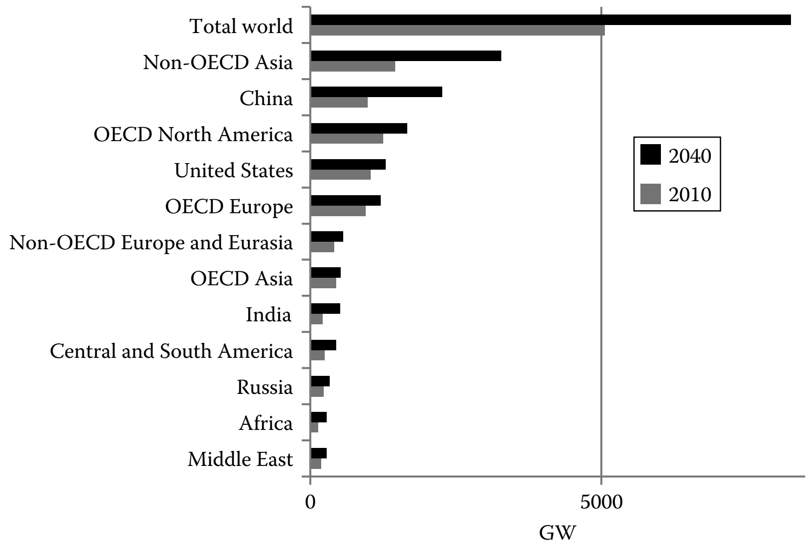

FIGURE 1.4
Electricity-generating capacity and projected additions to 2040 by region. (From EIA, *Annual Energy Outlook 2013*, U.S. Department of Energy, Washington, DC, 2013, www.eia.gov/ies.)

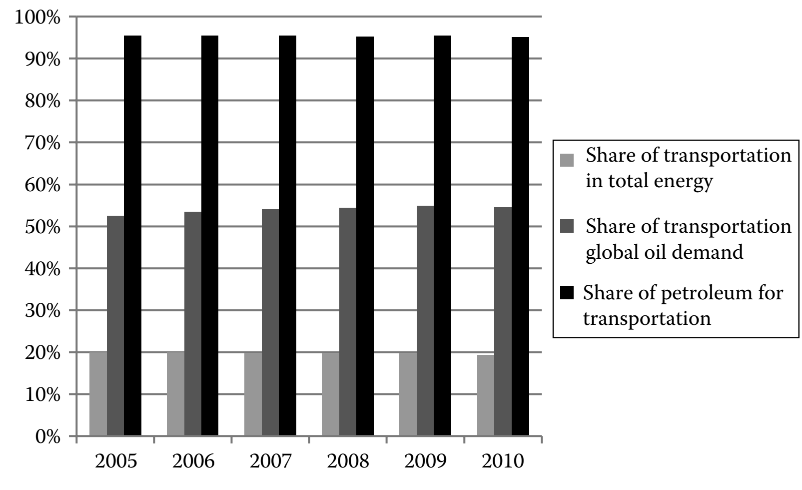

FIGURE 1.5
Share of transport in global oil demand and share of oil in transport energy demand. (Data and Forecast from EIA, *Annual Energy Outlook 2013*, U.S. Department of Energy, Washington, DC, 2013, www.eia.gov/aeo.)

oil resources, production, and prices. At present 95% of all energy for transportation comes from oil, and according to Figure 1.5, the EIA projects that petroleum will still provide 95% of all energy for transportation in 2040. However, with policy changes happening in the world due to serious concerns about global climate change and expected future technology developments, projections simply based on the past use will probably prove to be wrong.

As explained later in this chapter, irrespective of the actual amount of oil remaining in the ground, oil production will peak in the foreseeable future. Therefore, the need for careful planning for an orderly transition away from oil as the primary transportation fuel is urgent. An obvious replacement for oil would be biofuels such as ethanol, methanol, biodiesel, and biogases. Some believe that hydrogen is another alternative, because if it could be produced economically from renewable energy sources or nuclear energy, it could provide a clean transportation alternative for the future. Some have claimed hydrogen to be a "wonder fuel" and proposed a "hydrogen-based economy" to replace the present carbon-based economy (Veziroglu and Barbir, 1992). However, others (Shinnar, 2003; Kreith and West, 2004; Hammerschlag and Mazza, 2005) dispute this claim based on the lack of infrastructure, problems with storage and safety, and the lower efficiency of hydrogen vehicles as compared to hybrid or fully electric vehicles. Electric transportation presents a promising viable alternative to the oil-based transportation system (West and Kreith, 2006). Already plug-in hybrid-electric automobiles are becoming popular around the world as petroleum becomes more expensive.

The environmental benefits of renewable biofuels could be increased by using plug-in hybrid electric vehicles (PHEVs). These cars and trucks combine internal combustion engines with electric motors to maximize fuel efficiency. But PHEVs have more battery capacity that can be recharged by plugging it into a regular electric outlet. Then these vehicles can run on electricity alone for relatively short trips. The electric-only trip length is denoted by a number, for example, PHEV 20 can run on battery charge for 20 miles. When the battery charge is used up, the engine begins to power the vehicle. The hybrid combination reduces gasoline consumption appreciably. Whereas the conventional vehicle fleet has a fuel economy of about 22 mpg, hybrids can attain about 50 mpg. PHEV 20s have been shown to attain as much as 100 mpg. Gasoline use can be decreased even further if the combustion engine runs on biofuel blends, such as E85, a mixture of 15% gasoline and 85% ethanol (Kreith, 2006; West and Kreith, 2006).

Plug-in hybrid electric technology is already available and could be realized immediately without further R&D. Furthermore, a large portion of the electric generation infrastructure, particularly in developed countries, is needed only at the time of peak demand (60% in the United States), and the rest is available at other times. Hence, if batteries of PHEVs were charged during off-peak hours, no new generation capacity would be required. Moreover, this approach would levelize the electric load and reduce the average cost of electricity, according to a study by the Electric Power Research Institute (EPRI) (Sanna, 2005).

Given the potential of PHEVs, EPRI (2004) conducted a large-scale analysis of the cost, battery requirements, and economic competitiveness of plug-in vehicles today and in the future. As shown by West and Kreith, the net present value of lifecycle costs over 10 years for PHEVs with a 20 mile electric-only range (PHEV 20) is less than that of a similar conventional vehicle (West and Kreith, 2006). Furthermore, currently available nickel metal-hydride (NiMH) batteries are already able to meet required cost and performance specifications. More advanced batteries, such as lithium-ion (Li-ion) batteries, may improve the economics of PHEVs even further in the future.

1.5 World Energy Resources

With a view to meet the future demand of primary energy in 2050 and beyond, it is important to understand the available reserves of conventional energy resources including fossil fuels and uranium, and the limitations posed on them due to environmental considerations.

1.5.1 Conventional Oil

There is a considerable debate and disagreement on the estimates of "ultimate recoverable oil reserves," however, there seems to be a good agreement on the amount of "proven oil reserves" in the world. According to BP (2013), total identified or proven world oil reserves at the end of 2012 were 1668.9 billion barrels (bbl). This estimate is close to the reserves of 1700 billion bbl from other sources listed by IEA (2013). The differences among them are in the way they account for the unconventional oil sources. Considering the production rate of about 86.5 million bbl/day at the end of 2012, these reserves will last for about 53 years if there is no increase in production. Of course there may be additional reserves that may be discovered in the future. An analysis by the U.S. Energy Information Agency (2006) estimates the ultimately recoverable world oil reserves (including resources not yet discovered) at between 2.2×10^{12} and 3.9×10^{12} bbl. More recently, IEA has estimated that the ultimate remaining recoverable oil resources are as much as 2670 billion bbl of conventional oil (including Natural Gas Liquids), 345 billion bbl of light oil, 1880 billion of extra heavy oil and bitumen, and 1070 billion bbl kerogen oil. It is important to note that for this high estimate the IEA puts in a disclaimer, "However, resource estimates are inevitably subject to a considerable degree of uncertainty; this is particularly true for unconventional resources that are very large, but still relatively poorly known, both in terms of the extent of the resource in place and judgments about how much might be technically recoverable."

Ever since petroleum geologist M. King Hubbert correctly predicted in 1956 that U.S. oil production would reach a peak in 1973 and then decline (Hubbert, 1974), scientists and engineers have known that worldwide oil production would follow a similar trend. Today, the only question is when the world peak will occur. Bartlett (2002) has developed a predictive model based on a Gaussian curve similar in shape to the data used by Hubbert as shown in Figure 1.6. The predictive peak in world oil production depends on the assumed total amount of recoverable reserves.

If the BP estimated oil reserves are correct, we are close to the peak in the world oil production. If, however, estimates of the ultimate reserves (discovered and undiscovered)

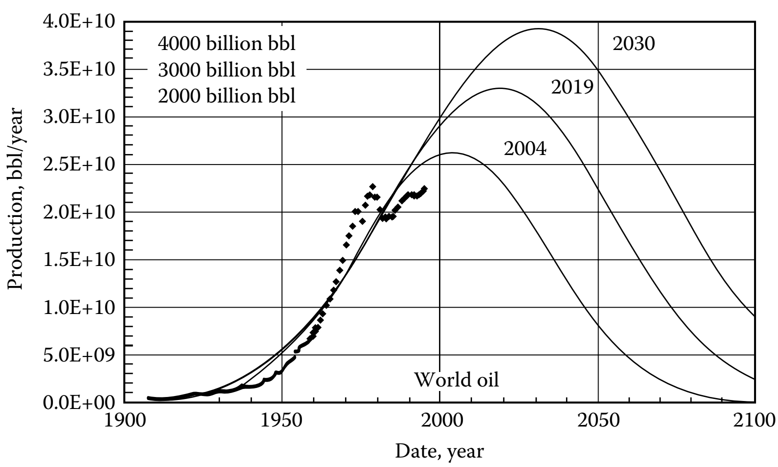

FIGURE 1.6
World oil production vs. time for various amounts of ultimate recoverable resource. (From Bartlett, A.A., *Math. Geol.*, 32, 1, 2002.)

are used, we may expect the oil production to increase a little longer before it peaks. But changing the total available reserves from 3×10^{12} to 4×10^{12} bbl increases the predicted time of peak production by merely 11 years, from 2019 to 2030. IEA World Energy Outlook 2013 estimates that under one policy scenario the oil production will peak at about 91 million bbl/day in 2020 while another policy scenario puts the peak at 101 million bbl/day in 2035. It is clear that no matter which scenario turns out to be true, the global oil production will peak sometime between 2019 and 2035. There is no question that once the world peak is reached and oil production begins to drop, either alternative fuel will have to make up the difference between demand and supply, or the cost of fuel will increase precipitously and create an unprecedented social and economic crisis for our entire transportation system.

The present trend of yearly increases in oil consumption, especially in China and India, shortens the window of opportunity for a managed transition to alternative fuels even further. Hence, irrespective of the actual amount of oil remaining in the ground, peak production will occur soon. Therefore, the need for starting to supplement oil as the primary transportation fuel is urgent because an orderly transition to develop petroleum substitutes will take time and careful planning.

1.5.2 Natural Gas

According to BP (2013) the total proven world natural gas reserves at the end of 2012 were 187.3 trillion m^3. Considering the production rate of gas in 2012, with no increase in production thereafter, these reserves would last for 55.7 years. However, production of natural gas has been rising at an average rate of 2.7% over the past 5 years. If production continues to rise because of additional use of CNG for transportation and increased power production from natural gas, the reserves would last for fewer years. Of course, there could be additional new discoveries. However, even with additional discoveries, it is reasonable to expect that all the available natural gas resources may last from about 50 to 80 years, with a peak in production occurring much earlier.

1.5.3 Coal

Coal is the largest fossil resource available to us and the most problematic from environmental concerns. From all indications, coal use will continue to grow for power production around the world because of expected increases in China, India, Australia, and other countries. From an environmental point of view this would be unsustainable unless advanced "clean coal technology" (CCT) with carbon sequestration is deployed.

CCT is based on an integrated gasification combined-cycle (IGCC) that converts coal to gas that is used in a turbine to provide electricity with CO_2 and pollutant removal before the fuel is burned (Hawkins et al., 2006). According to an Australian study (Sadler, 2004), no carbon capture and storage system is yet operating on a commercial scale, but may become an attractive technology to achieve atmospheric CO_2 stabilization.

According to BP, the proven recoverable world coal resources were estimated to be 861 billion tons at the end of 2012 with a reserve to production ratio (R/P) of 107 years. The BP data also shows that coal use increased at an average rate of 3.7% from 2007 to 2012, the largest increase of all fossil resources. Since more than 75% of China's electricity-generating capacity is based on coal and both China and India are continuing to build new coal power plants, it is reasonable to assume that coal use will continue to increase for at least some years in future. Therefore, the R/P ratio will decrease further from the present value of 107 years. The R/P ratio will decrease even more rapidly when clean coal technologies such as coal gasification and liquefaction are utilized instead of direct combustion.

1.5.4 Summary of Fossil Fuel Reserves

Even though there are widely differing views and estimates of the ultimately recoverable resources of fossil fuels, it is fair to say that they may last for around 50–100 years with a peak in production occurring much earlier. However, a big concern is the climatic threat of additional carbon that will be released into the atmosphere. According to the estimates from the IEA, if the present shares of fossil fuels are maintained up to 2040 without any carbon sequestration, a cumulative amount of approximately 1000 gigatons of carbon will be released into the atmosphere (based on Figure 1.7). This is especially troublesome in view of the fact that the present total cumulative emissions of about 500 gigatons of carbon have already raised serious concerns about global climate change.

1.5.5 Nuclear Resources

Increased use of nuclear power presents the possibility of additional carbon-free energy use and its consequent benefit for the environment. However, there are significant concerns about nuclear waste and other environmental impacts, the security of the fuel and the waste, and the possibility of their diversion for weapon production.

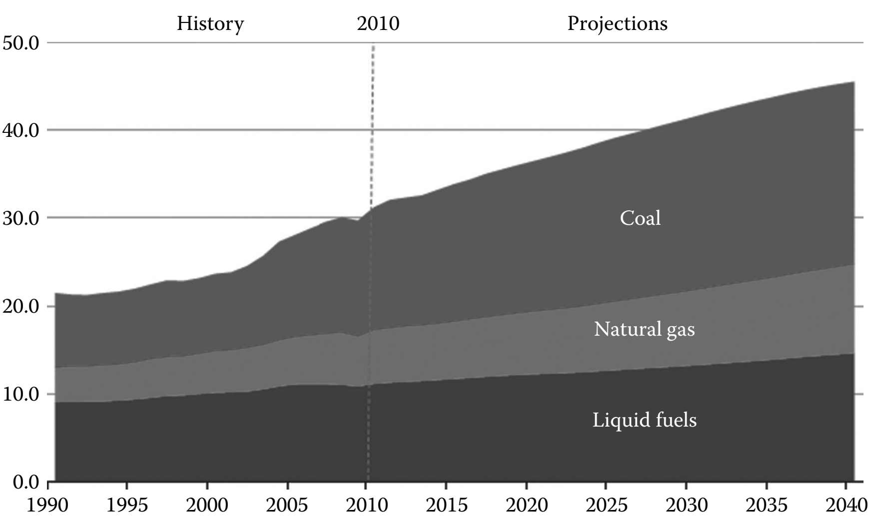

FIGURE 1.7
World energy-related CO_2 emissions by fuel (billion metric tons). (Data and forecast from IEA, *World Energy Outlook 2013*, International Energy Agency, Paris, France, 2013.)

Nuclear fission provided 14% of the electricity in the world in 2011 (IEA, 2013) and the worldwide nuclear capacity in 2011 was 375 GW (IAEA, 2011). Although a number of countries have decided to not build additional nuclear power plants after the Fukushima accident, nuclear power capacity is expected to continue to grow mainly because of the ongoing and planned construction in China and some other countries. IAEA estimates that the worldwide nuclear power capacity will increase at an average rate of 1.5%–2.7% until 2035 (IAEA, 2011). At present, uranium is used as the fissile material for nuclear power production. Thorium could also be used for nuclear fission; however, to date nobody has developed a commercial nuclear power plant based on thorium. Terrestrial deposits of both uranium and thorium are limited and concentrated in a few countries of the world. The International Atomic Energy Agency (IAEA) estimates the total identified recoverable uranium reserves in the world to be about 5 million tons which increase to about 7 million tons if the price of uranium goes up to $264/kg U (Figure 1.8). Additionally, there are nonconventional uranium resources, such as sea water which contains about 3 parts per billion uranium and some phosphate deposits (more than half of them in Morocco) which contain about 100 parts per million uranium. These resources are potentially huge; however, their cost effective recovery is not certain (Figure 1.9).

For generating 1 TWh of electricity from nuclear fission, approximately 22 tons of uranium are required (UNDP, 2004). Based on the 2011 world capacity of 375 GW, the identified reserves will last about 97 years if there is no change in the generation capacity. At an average annual growth rate of 2%, the uranium reserves of 7 million tons will last for about 60 years. This estimate does not consider regeneration of spent fuel. At present, nuclear fuel regeneration is not allowed in the United States. However, that law could be changed in future. Development of breeder reactors could increase the time period much further. The major impediment may be economic viability. Nuclear fusion could potentially provide a virtually inexhaustible energy supply; however, it is not expected to be commercially available in the foreseeable future.

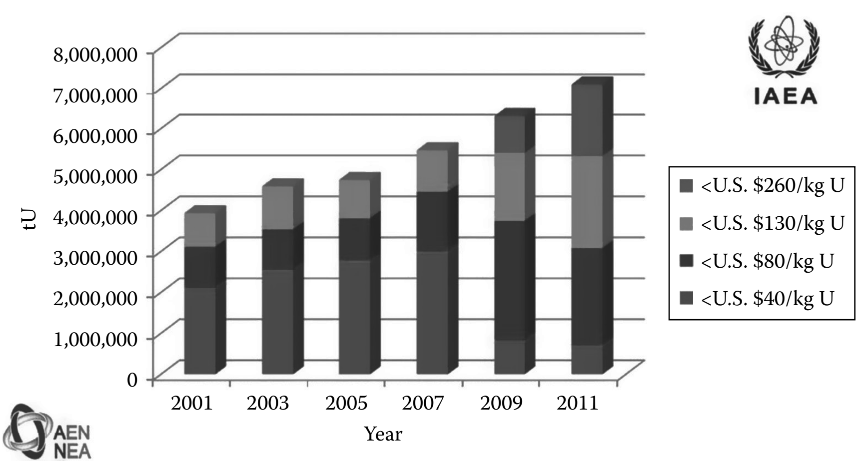

FIGURE 1.8
World identified recoverable uranium resources based on the price of uranium. (From IAEA, *Uranium: Resources, Production and Demand* (*The Red Book*), IAEA, Vienna, Austria, 2011.)

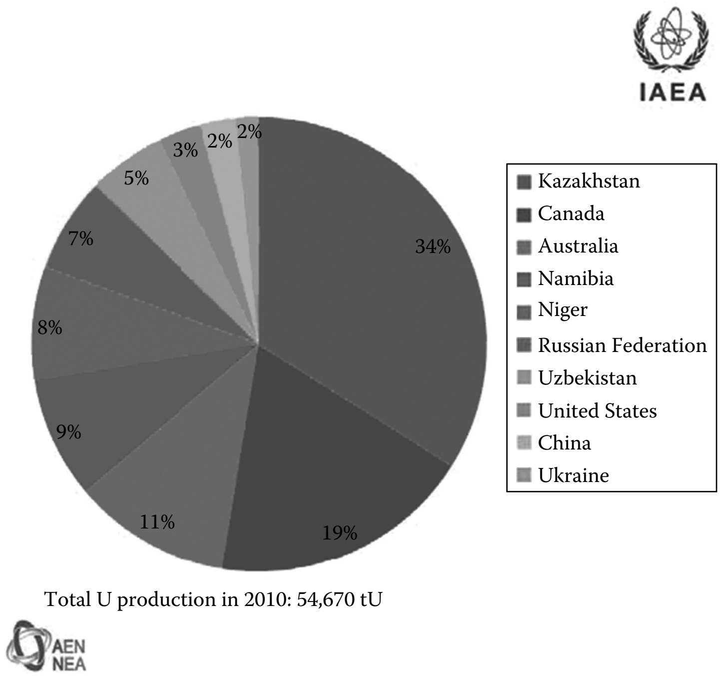

FIGURE 1.9
Top 10 uranium producing countries in 2010. (From IAEA, *Uranium: Resources, Production and Demand* (*The Red Book*), IAEA, Vienna, Austria, 2011.)

1.6 Present Status and Potential of Renewable Energy

According to the data in Table 1.5, 13.2% of the world's total primary energy supply (TPES) came from RE in 2011. However, approximately 75% of the RE supply was from biomass, and in developing countries it is mostly converted by traditional open combustion, which is very inefficient. Because of its inefficient use, biomass resources presently supply only about 20% of what they could if converted by modern, more efficient, available technologies. As it stands, biomass provides only about 10% of the world total primary energy

TABLE 1.5
2011 Fuel Shares in World Total Primary Energy Supply

Source	Share (%)
Oil	31.4
Natural gas	21.3
Coal	28.9
Nuclear	5.2
Renewables	13.2

Source: IEA, *World Energy Outlook 2013*, International Energy Agency, Paris, France, 2013.

which is much less than it's real potential. The total technologically sustainable biomass energy potential for the world is 3–4 TW_e (UNDP, 2004), which is about 80% the entire present global electricity-generating capacity of about 5 TW_e.

In 2011, shares of biomass and hydropower in the total primary energy mix of the world were about 10% and 2.3%, respectively. All of the other renewables, including solar thermal, solar PV, wind, geothermal and ocean combined, provided only about 1% of the total primary energy. During the same year, biomass combined with hydroelectric resources provided almost 50% of all the primary energy in Africa. However, biomass is used very inefficiently for cooking in these countries. Such use has also resulted in significant health problems, especially for women. As of 2012, renewable energy contributes more than 40% of their total energy needs in 4 countries (Nigeria, Norway, Brazil, and Sweden) and more than 20% in 10 countries listed in Table 1.6 (Finland, Indonesia, India, Colombia, Chile, and Portugal). Other countries that provide significant shares of their energy from RE but <20% include, New Zealand (19.9%), Canada (18.4), Thailand (18.3%), Romania (15.2%), and Germany (14.2%).

Table 1.7 shows the share of renewable energy in 2011 and projections to 2020 and 2035. Keeping in mind that the future projections are only as good as the assumptions they are based on, and the energy situation is in a flux because of the impact on environment which is a major reason for the global climate change, IEA developed three scenarios for the future projections: (1) Current Energy Policies, (2) New Energy Policies (policies that have already been developed by major countries as of 2012), and (3) 450 Scenario, which assumes that policies around the world will be strengthened to limit the global temperature rise to 2°C or global atmospheric CO_2 concentrations to 450 ppm. Although there is considerable uncertainty about future policies, it is very likely that the future energy developments will lie somewhere in between the last two scenarios. According to these projections, the share of renewable energy will rise to as much as 18%–26% of the global primary energy and 31%–48% of the electricity-generating capacity by 2035. Based on the trends in the development and deployment of wind power and solar power in the last decade, there is reason to believe that values close to 450 scenario are achievable.

TABLE 1.6

Share of Renewable Energy in 2012 TPES for Top 10 Countries

Country	% Share of Renewables in TPES
Nigeria	80.5
Norway	47.2
Brazil	42.8
Sweden	40.0
Finland	30.6
Indonesia	26.2
India	24.3
Colombia	23.5
Chile	22.7
Portugal	22.5
New Zealand	19.9
Canada	18.4
Thailand	18.3
Romania	15.2
Germany	14.2
World	12.9

Source: Enerdata, *Enerdata Energy Statistical Yearbook 2013*, 2013.

TABLE 1.7

Share of Renewable Energy in 2011 and Projections for 2020 and 2035 Based on New Policies and 450 Scenario

		New Policies		450 Scenario	
	2011	2020	2035	2020	2035
Primary energy demand (MTOE)	**1,727**	**2,193**	**3,059**	**2,265**	**3,918**
United States	140	196	331	215	508
Europe	183	259	362	270	452
China	298	392	509	405	690
Brazil	116	148	207	150	225
Share of renewables in total primary energy (%)	*13*	*15*	*18*	*16*	*26*
Electricity generation (TWh)	**4,482**	**7,196**	**11,612**	**7,528**	**15,483**
Bioenergy	424	762	1,477	797	2,056
Hydro	3,490	4,555	5,827	4,667	6,394
Wind	434	1,326	2,774	1,441	4,337
Geothermal	69	128	299	142	436
Solar PV	61	379	951	422	1,389
CSP	2	43	245	56	806
Marine	1	3	39	3	64
Share of total generation (%)	*20*	*26*	*31*	*28*	*48*
Heat demand (MTOE)	**343**	**438**	**602**	**446**	**704**
Industry	209	253	316	248	328
Buildings and agriculture	135	184	286	198	376
Share of total final demand (%)	*8*	*10*	*12*	*10*	*16*
Biofuels (mboe/day)	**1.3**	**2.1**	**4.1**	**2.6**	**7.7**
Road transport	1.3	2.1	4.1	2.6	6.8
Aviation	0	0	0.1	0	0.9
Share of total transport (%)	*2*	*4*	*6*	*5*	*15*
Traditional biomass (MTOE)	**744**	**730**	**680**	**718**	**647**
Share of total bioenergy (%)	*57*	*49*	*37*	*47*	*29*
Share of renewable energy demand (%)	*43*	*33*	*22*	*32*	*17*

Source: IEA, *World Energy Outlook 2013*, International Energy Agency, Paris, France, 2013.

1.6.1 Wind Power

Wind energy technology has progressed significantly over the last two decades. The technology has been vastly improved and capital costs have come down to as low as $1000/kW. At this level of capital costs, wind power is already economical at locations with fairly good wind resources. Therefore, the average annual growth in worldwide wind energy capacity from 2001 to 2012 was over 25% (Figure 1.10). The average growth in the United States over the same period was 37.7%. The total worldwide installed wind power capacity which was 24 GW in 2001 (Figure 1.10), reached a level of 282 GW in 2012 (WWEA, 2013). The countries with the largest wind capacity in 2012 include China (75 GW), United States (60 GW), Germany (31 GW), Spain (23 GW), and India (18 GW) (Figure 1.11). The total theoretical potential for onshore wind power for the world is around 55 TW with a practical potential of at least 2 TW (UNDP, 2004), which is about 40% of the entire present worldwide generating capacity. The offshore wind energy potential is even larger.

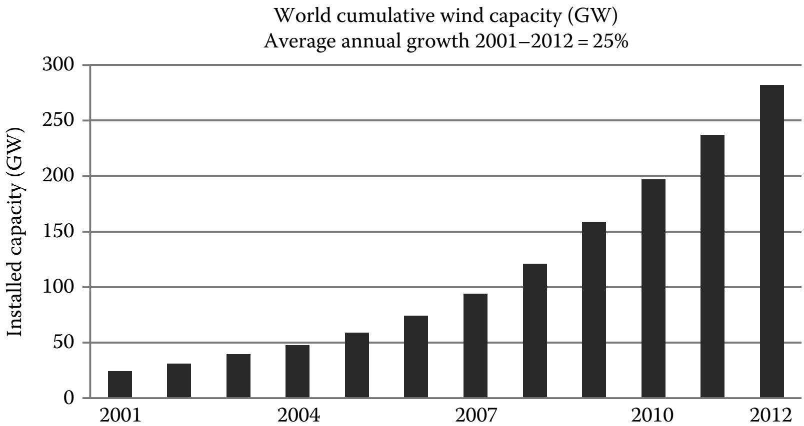

FIGURE 1.10
World wind energy installed capacity and growth rates. (Data from WWEA, World Wind Energy Association, 2012, http://www.wwindea.org/webimages/WorldWindEnergyReport2012_final.pdf.)

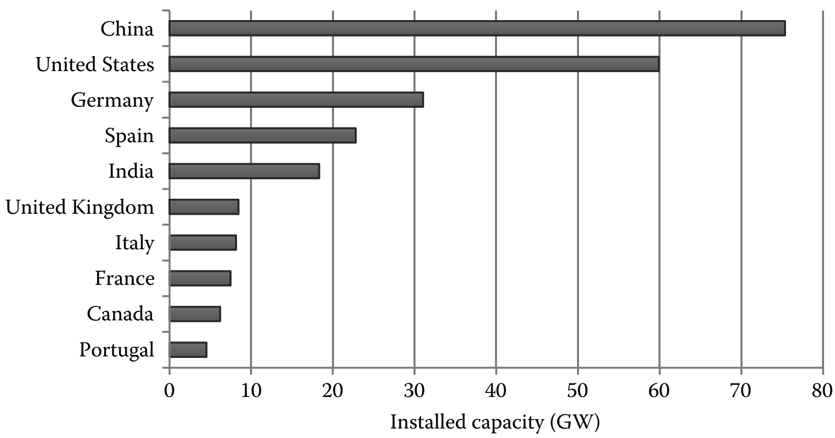

FIGURE 1.11
Top 10 countries with installed wind power capacity. (Data from WWEA, World Wind Energy Association, 2012, http://www.wwindea.org/webimages/WorldWindEnergyReport2012_final.pdf.)

1.6.2 Solar Energy

The amount of sunlight striking the earth's atmosphere continuously is 1.75×10^5 TW. Considering a 60% transmittance through the atmospheric cloud cover, 1.05×10^5 TW reaches the earth's surface continuously. If the irradiance on only 1% of the earth's surface could be converted into electric energy with a 10% efficiency, it would provide a resource base of 105 TW, while the total global energy needs for 2040 are projected to be about 8–9 TW. The present state of solar energy technologies is such that solar cell efficiencies have reached over 40% and solar thermal systems provide efficiencies of 40%–80%. With the present rate of technological development these solar technologies will continue to improve, thus bringing the costs down, especially with the economies of scale.

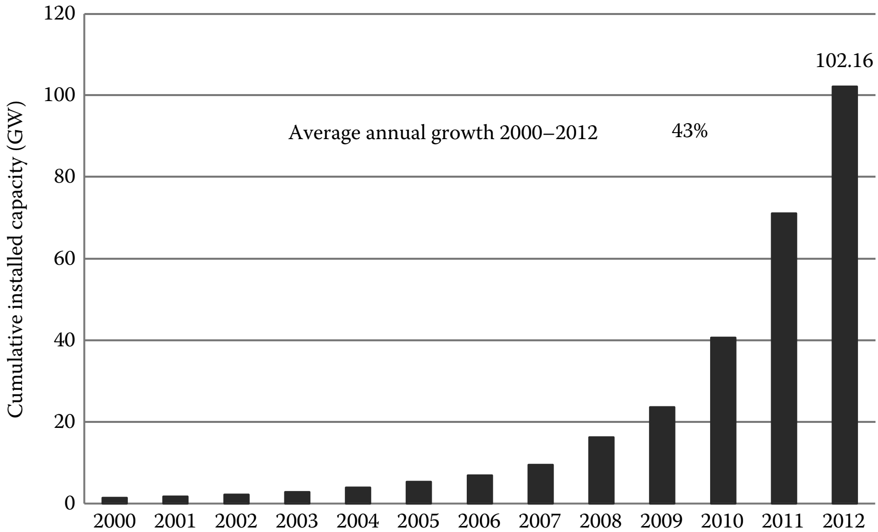

FIGURE 1.12
World solar PV production, 2000–2012 (GWp). (From EPIA, European Photovoltaic Industries Association, 2012, www.epia.org.)

Solar PV panels have come down in cost from about \$30/W to about \$0.50/W in the last three decades. At \$0.50/W panel cost, the overall system cost is around \$2/W, which is already lower than grid electricity in the Caribbean island communities. Of course, there are many off-grid applications where solar PV is already cost-effective. With net metering and governmental incentives, such as feed-in laws and other policies, grid-connected applications such as building integrated PV (BIPV) have become cost-effective even where grid electricity is cheaper. As a result, the worldwide growth in PV production has averaged over 43%/year from 2000 to 2012 and 61% from 2007 to 2012 (Figure 1.12) with Europe showing the maximum growth.

Solar thermal power using concentrating solar collectors was the first solar technology which demonstrated its grid power potential. A 354 MW_e concentrating solar thermal power (CSP) plant has been operating continuously in California since 1988. Progress in solar thermal power stalled after that time because of poor policy and lack of R&D. However, the last 10 years have seen a resurgence of interest in this area and a number of solar thermal power plants around the world are under construction. The largest CSP plant with a capacity of 400 MW came on line in Nevada in February 2014. The cost of power from these plants (which is so far in the range of 12–16 U.S. cents/kWh_e) has the potential to go down to 5 U.S. cents/kWh_e with scale-up and creation of a mass market. An advantage of solar thermal power is that thermal energy can be stored efficiently and fuels, such as, natural gas or biogas may be used as back up to ensure continuous operation. If this technology is combined with power plants operating on fossil fuels, it has the potential to extend the time frame of the existing fossil fuels.

Low temperature solar thermal systems and applications have been well developed for quite some time. They are being actively installed wherever the policies favor their deployment. Figure 1.13 gives an idea of the rate of growth of solar thermal systems in the world. In 2011, approximately 234 GW_{th} solar collectors were deployed around the world, a vast majority (65%) of those being in China (IEA, 2013) (Figure 1.14).

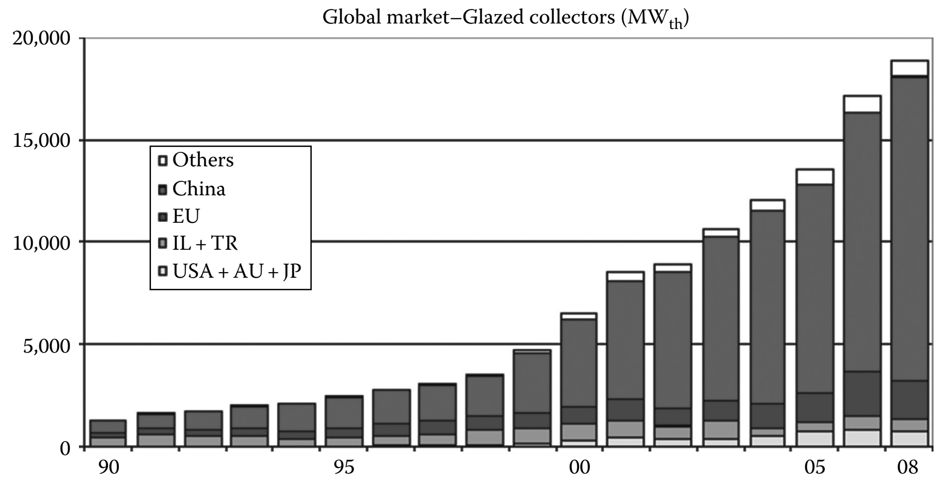

FIGURE 1.13
Deployment of solar heat (glazed) collectors, MW_{th}. (From ESIF, IEA SHC.)

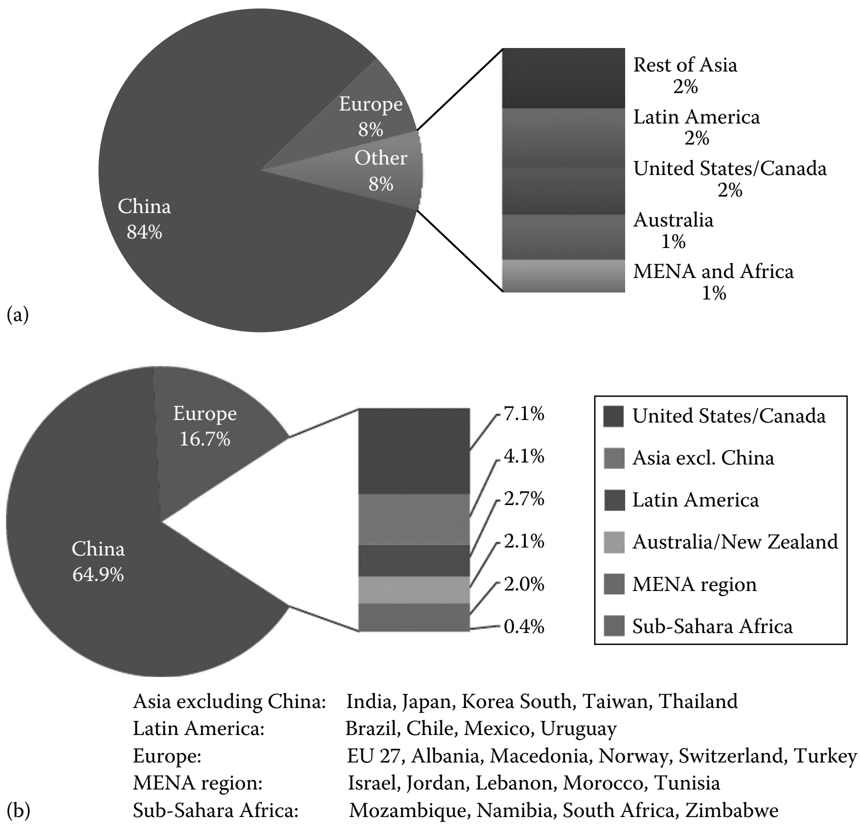

FIGURE 1.14
Worldwide distribution of solar thermal collector markets (a) glazed collectors and (b) total glazed and unglazed in 2012. (From Mauthner, F. and Weiss, W., Solar heat worldwide—Markets and contribution to energy supply 2011, IEA Solar Heating and Cooling Program, Paris, France, May 2013.)

1.6.3 Biomass

Although theoretically harvestable biomass energy potential is of the order of 90 TW, the technical potential on a sustainable basis is of the order of 8–13 TW or 270–450 EJ/year (UNDP, 2005). This potential is 1.6–2.6 times the present electricity-generating capacity of the world. It is estimated that by 2025, even the municipal solid waste (MSW) could generate up to 6 EJ/year.

The biggest advantage of biomass as an energy resource is its relatively straightforward transformation into transportation fuels. Biofuels have the potential to replace as much as 75% of the petroleum fuels in use for transportation in the United States (Worldwatch, 2006). This is especially important in view of the declining oil supplies worldwide. Biofuels will not require additional infrastructure development. Therefore, development of biofuels is being viewed very favorably by governments around the world. Biofuels, along with other transportation options such as electric vehicles and hydrogen, will help diversify the fuel base for future transportation. Table 1.8 and Figure 1.15 show the global production of biofuels from 2001 to 2011. United States, Brazil, and Europe are the top producing countries and region of the world. Biofuel production grew more than five times in 10 years, although it started from a much

TABLE 1.8
Total Biofuels Production (1000 bbl/day)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
United States	115.7	140.3	183.9	223.3	260.6	335.0	457.3	649.7	747.1	889.8	971.7
Brazil	197.6	216.9	249.4	251.7	276.4	307.3	395.7	486.3	477.5	527.1	438.1
Europe	21.2	29.3	39.3	48.9	76.8	123.9	153.8	198.1	233.2	255.2	250.5
Asia	3.1	8.3	17.2	21.1	28.2	44.9	49.2	75.6	93.8	99.8	118.2
Rest of the world	5.3	8.6	9.6	9.8	14.2	29.6	47.3	67.7	83.8	93.3	118.8
World	342.9	403.5	499.4	554.8	656.3	840.6	1,103.3	1,477.3	1,635.4	1,865.4	1,897.2

Sources: Enerdata, *Enerdata Energy Statistical Yearbook 2013*, 2013; IEA, *World Energy Outlook 2013*, International Energy Agency, Paris, France, 2013.

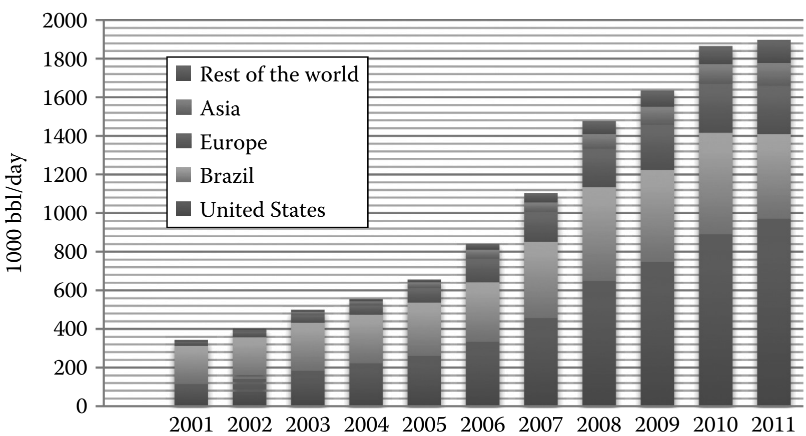

FIGURE 1.15
World biofuel production, 2001–2011. (From IEA, *World Energy Outlook 2013*, International Energy Agency, Paris, France, 2013.)

smaller base. In 2005, the world ethanol production had reached about 36 billion L/year while biodiesel production topped 3.5 billion L during the same year.

The present cost of ethanol production ranges from about €0.25 to about €1/gasoline equivalent L, as compared to the wholesale price of gasoline which is between €0.40 and €0.60/L (Figure 1.16). Biodiesel costs, on the other hand, range between €0.20 and €0.65/L of diesel equivalent (Figure 1.17). Figure 1.18 shows the feedstock used for these biofuels. An important consideration for biofuels is that the fuel not be produced at the expense of food while there are people going hungry in the world. This would not be of concern if biofuels were produced from MSW or nonfood forest resources.

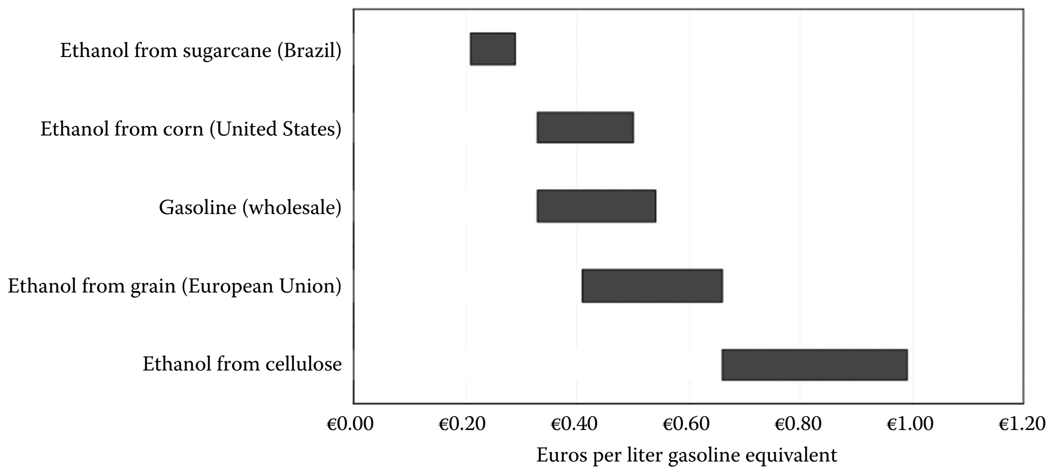

FIGURE 1.16
Cost ranges for ethanol and gasoline production, 2006. (From IEA, Reuters, DOE.)

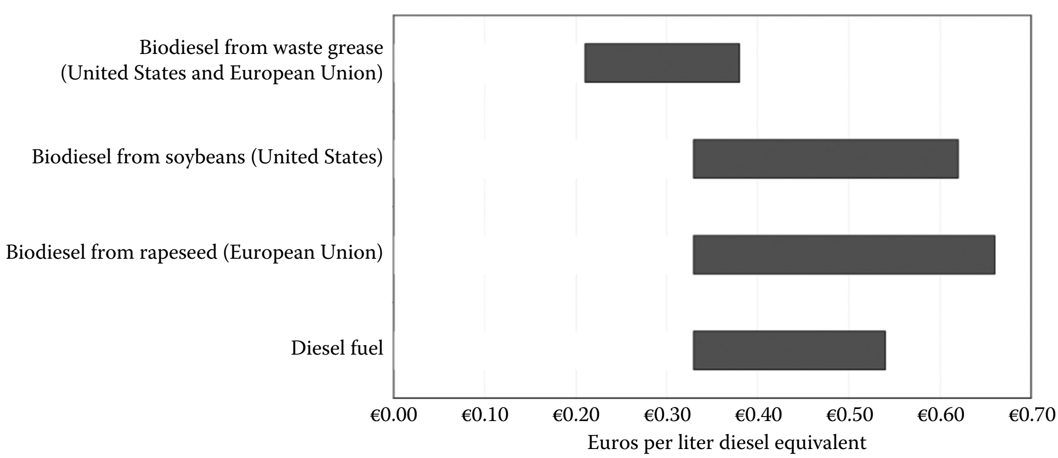

FIGURE 1.17
Cost ranges for biodiesel and diesel production, 2006. (From IEA, Reuters, DOE.)

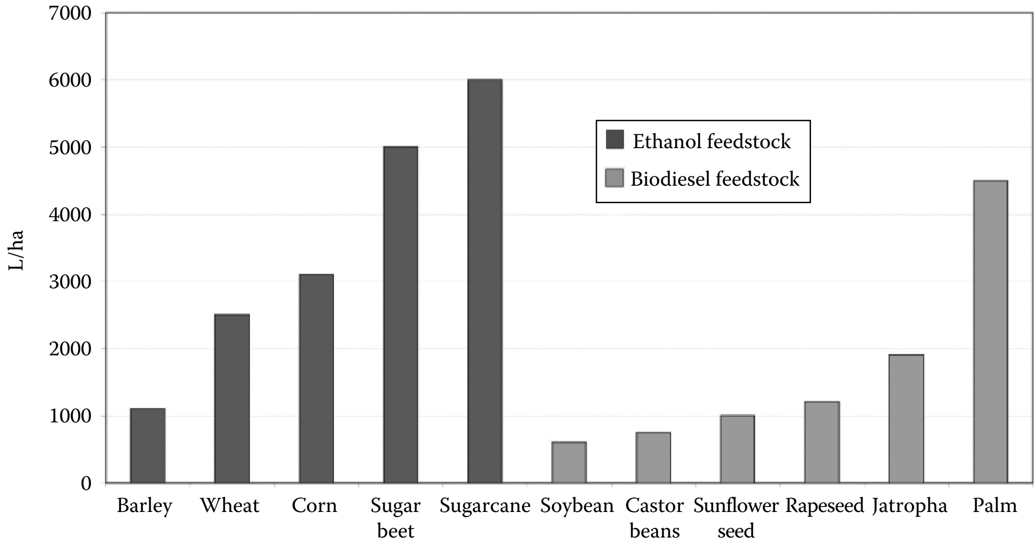

FIGURE 1.18
Biofuel yields of selected ethanol and biodiesel feedstocks. (From Hunt, S. and Forster, E. 2006. *Biofuels for Transportation: Global Potential and Implications for Sustainable Agriculture and Energy in the 21st Century.* Worldwatch Institute, Washington, DC.)

According to the Worldwatch report, a city of one million people produces about 1,800 tons of MSW and 1,300 tons of organic waste every day, which using the present-day technology could produce enough fuel to meet the needs of 58,000 persons in the United States, 360,000 in France, and nearly 2.6 million in China at current rates of per capita fuel use (Worldwatch, 2006).

1.6.4 Summary of Renewable Energy Resources

By definition, the term "reserves" does not apply to renewable resources. So we need to look at the annual potential of each resource. Table 1.9 summarizes the resource potential and the present costs and the potential future costs for each renewable resource.

As in the case of other new technologies, it is expected that cost competitiveness of the renewable energy technologies will be achieved with R&D, scale-up, commercial experience, and mass production. The experience curves in Figure 1.19 show industry-wide cost reductions in the range of 10%–20% for each cumulative doubling of production for wind power, photovoltaics, ethanol, and gas turbines (UNDP, 2004). Similar declines can be expected in solar thermal power and other renewable technologies. As seen from Figure 1.19, wind energy technologies have already achieved market maturity, and PV technologies are well on their way. Even though concentrating solar thermal power (CSP) is not shown in this figure, a GEF report estimates that CSP will achieve the cost target of about $0.05/kWh by the time it has an installed capacity of about 40 GW (GEF, 2005). As a reference point, wind power achieved that capacity milestone in 2003.

TABLE 1.9

Potential and Status of Renewable Energy Technologies

Technology	Annual Potential	Operating Capacity 2005	Investment Costs U.S. $/kW	Current Energy Cost	Potential Future Energy Cost
Biomass energy	276–446 EJ Total or 8–13 TW MSW ~ 6 EJ				
Electricity		~44 GW	500–6,000/kW_e	3–12 cents/kWh	3–10 cents/kWh
Heat		~225 GW_{th}	170–1,000/kW_{th}	1–6 cents/kWh	1–5 cents/kWh
Ethanol		~36 billion lit.	170–350/kW_{th}	25–75 cents/lit. (ge)[a]	$6–$10/GJ
Biodiesel		~3.5 billion lit.	500–1,000/kW_{th}	25–85 cents/lit. (de)[b]	$10–$15/GJ
Wind power	55 TW Theo. 2 TW Practical	59 GW	850–1,700	4–8 cents/kWh	3–8 cents/kWh
Solar energy	>100 TW				
Photovoltaics		5.6 GW	5,000–10,000	25–160 cents/kWh	5–25 cents/kWh
Thermal Power		0.4 GW	2,500–6,000	12–34 cents/kWh	4–20 cents/kWh
Heat			300–1,700	2–25 cents/kWh	2–10 cents/kWh
Geothermal	600,000 EJ useful resource base				
Electricity	5,000 EJ economical in 40–50 years	9 GW	800–3,000	2–10 cents/kWh	1–8 cents/kWh
Heat		11 GW_{th}	200–2,000	0.5–5 cents/kWh	0.5–5 cents/kWh
Ocean energy					
Tidal	2.5 TW	0.3 GW	1,700–2,500	8–15 cents/kWh	8–15 cents/kWh
Wave	2.0 TW		2,000–5,000	10–30 cents/kWh	5–10 cents/kWh
OTEC	228 TW		8,000–20,000	15–40 cents/kWh	7–20 cents/kWh
Hydroelectric	1.63 TW Theo.				
Large	0.92 TW Econ.	690 GW	1,000–3,500	2–10 cents/kWh	2–10 cents/kWh
Small		25 GW	700–8,000	2–12 cents/kWh	2–10 cents/kWh

Sources: Data from UNDP, World Energy Assessment: Energy and the Challenge of Sustainability, 2004. Updated from other sources: Worldwatch, Biofuels for transportation—Global potential and implications for sustainable and energy in the 21st century, Report prepared for the German Federal Ministry for Food, Agriculture and Consumer Protection, Worldwatch Institute, Washington, DC, 2006; World Wind Energy Association Bulletin, 2006, www.wwindea.org; Photovoltoaic Barometer; EPIA, European Photovoltaic Industries Association, 2012, www.epia.org; World Geothermal Power Generation 2001–2005; GRC Bulletin; International Energy Annual; U.S. DOE-EIA.

Note: ge, gasoline equivalent liter; de, diesel equivalent liter; kWe, kilowatt electrical power; kWth, kilowatt thermal power.

1.7 Role of Energy Conservation

Energy conservation can and must play an important role in future energy strategy, because it can ameliorate adverse impacts on the environment rapidly and economically. Figures 1.20 and 1.21 give an idea of the potential of energy efficient improvements. Figure 1.20 shows that per capita energy consumption varies by as much as a factor of 3

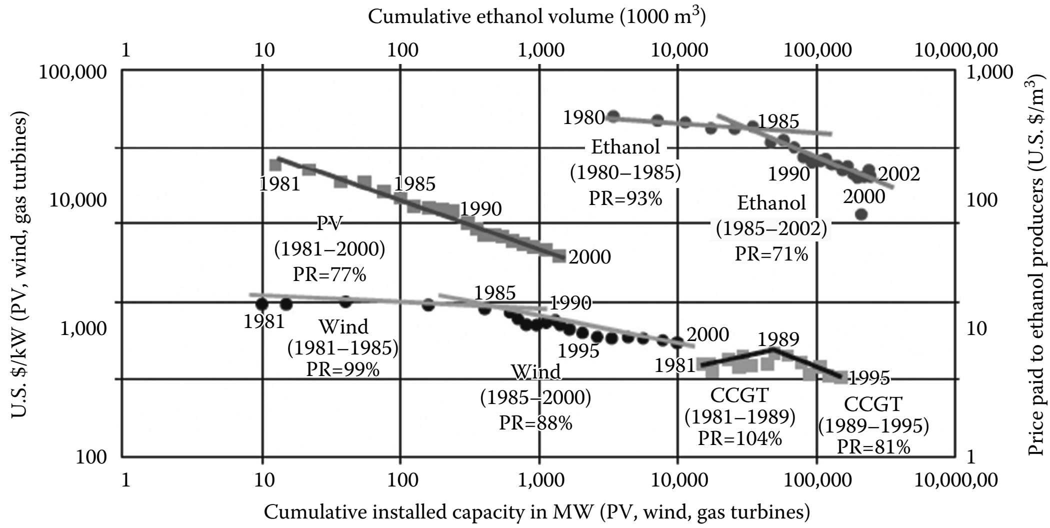

FIGURE 1.19
Experience curves for wind, PV, ethanol and gas turbines. (Adapted from UNDP, World Energy Assessment: Energy and the Challenge of Sustainability, 2004. For wind turbines: Neij, L. et al., Experience curves: A tool for Energy Policy Assessment, March 2003; For gas turbines: Claeson Colpier, U. and Cornland, D., *Energy Policy*, 30, 209, 2002; For photovoltaics: Parente, V. et al., *Prog. Photovolt. Res. Appl.*, 10(8), 571, 2002; For ethanol: Goldemberg, J. et al., *Biomass Energy*, in press.)

between the United States and some European countries with almost the same level of Human Development Index (HDI). Even taking just the OECD European countries combined, the per capita energy consumption in the United States is twice as much. It is fair to assume that the per capita energy of the United States could be reduced to the level of OECD Europe of 4.2 kW by a combination of energy efficiency improvements and changes in the transportation infrastructure. This is significant because the United States uses about 25% of the energy of the whole world. The present per capita energy consumption in the United States is 284 GJ, which is equivalent to about 9 kW/person, while the average for the whole world is 2 kW. Board of Swiss Federal Institutes of Technology has developed a vision of a 2 kW per capita society by the middle of the century (UNDP, 2004). The vision is technically feasible. However, to achieve this vision will require a combination of increased R&D on energy efficiency and policies that encourage conservation and use of high efficiency systems. It will also require some structural changes in the transportation systems. According to the 2004 World Energy Assessment by UNDP, a 25%–35% reduction in primary energy in the industrialized countries is achievable cost effectively in the next 20 years, without sacrificing the level of energy services. The report also concluded that similar reductions of up to 40% are cost effectively achievable in the transitional economies and more than 45% in developing economies. As a combined result of efficiency improvements and structural changes such as increased recycling, substitution of energy intensive materials, etc., energy intensity could decline at a rate of 2.5%/year over the next 20 years (UNDP, 2004).

McKinsey and Company conducted a comprehensive study of the energy conservation potential in United States in 2020. Figure 1.22 shows the potential in various sectors including the average cost of savings. According to this figure, the total U.S. economical potential of energy conservation to 2020 is 9500 trillion Btu or 25 GTOE.

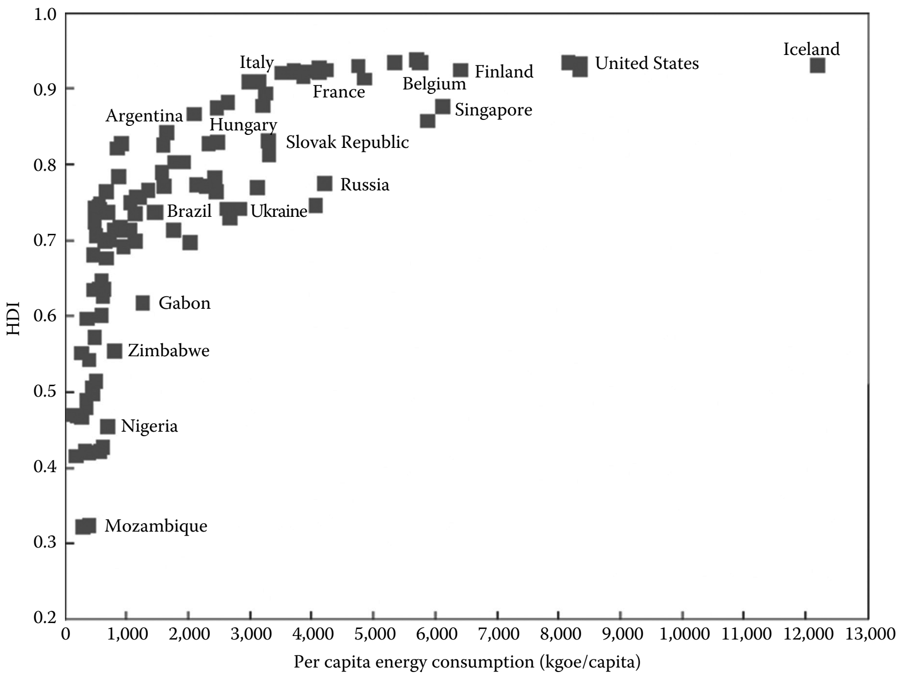

FIGURE 1.20
Relationship between Human Development Index (HDI) and per capita energy use, 1999–2000. (From UNDP, World Energy Assessment: Energy and the Challenge of Sustainability, 2004.)

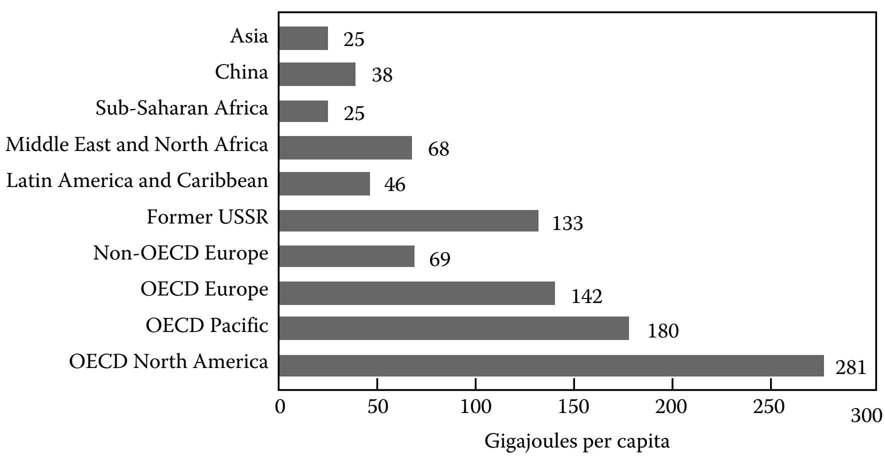

FIGURE 1.21
Per capita energy use by region (commercial and noncommercial) 2000. (From UNDP, World Energy Assessment: Energy and the Challenge of Sustainability, 2004.) *Note:* Asia excludes Middle East, China, and OECD countries; Middle East and North Africa comprises Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates, and Yemen; Latin America and Caribbean excludes Mexico; OECD Pacific comprises Australia, Japan, Korea, and New Zealand; Former USSR comprises Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyztan, Latvia, Lithuania, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan; Non-OECD Europe comprises Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Gibraltar, Macedonia, Malta, Romania, and Slovenia; OECD North America includes Mexico.

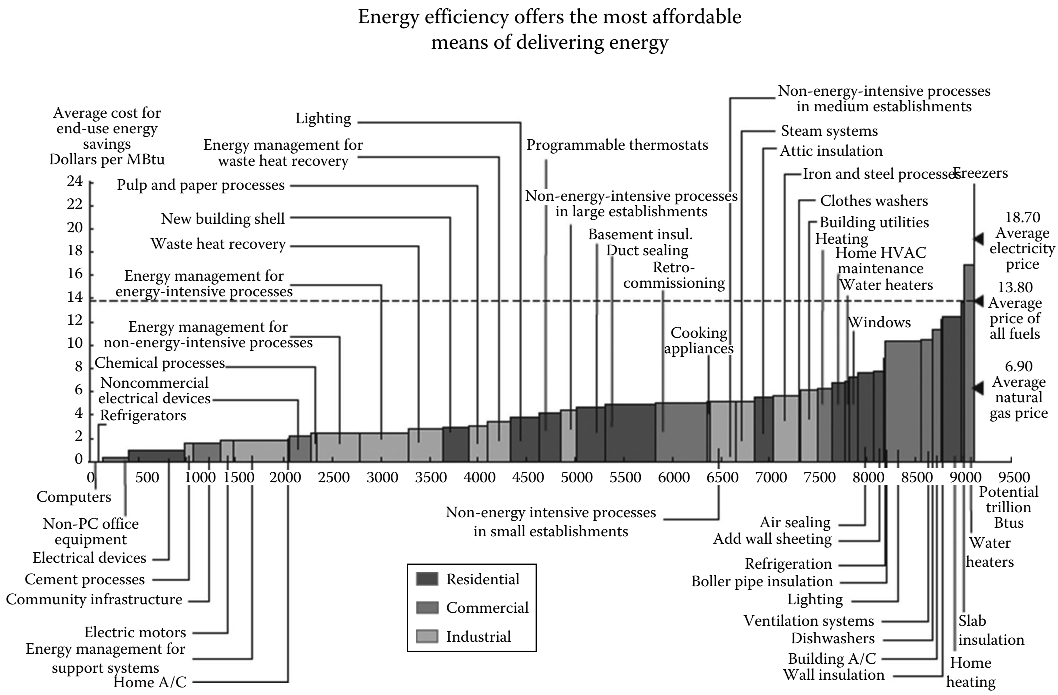

FIGURE 1.22
Energy saving potential of various sectors and cost of savings as compared to the price of electricity. (From Granade, H. et al., Unlocking energy efficiency in the U.S. economy, *2010 EIA Energy Conference*, Washington, DC, April 2010, www.eia.gov/conference/2010/session9/granade.pdf.)

Rocky Mountain Institute in Colorado, estimates that the total potential of energy savings due to efficiency improvements in the industry sector in United States by 2050 could be as much as 30% of energy use under the business as usual scenario (see Figure 1.23).

Improving energy efficiency across all sectors of the economy should become a worldwide objective (Energy Commission, 2004). It should be noted, however, that free market price signals may not always be sufficient to effect energy efficiency. Hence, legislation on the state and/or national level for energy efficiency standards for equipment in the residential and commercial sector may be necessary. There is considerable debate whether incentives or mandates are the preferred way to improve energy efficiency. Such measures may be necessary because surveys indicate that consumers consistently rank energy use and operating costs quite low on the lists of attributes they consider when purchasing an appliance or construct a building. Incentives may be the preferred option provided they induce decision makers to take appropriate action.

Figure 1.24 shows the projected energy savings from upgraded standards for products installed in the years 2010–2020. Outside the United States, over 30 countries have also adopted minimum energy performance standards. These measures have been shown to be economically attractive and can provide an appreciable reduction in adverse environmental impacts.

This handbook describes energy efficient improvements achievable with available technologies. The challenge is to adopt policies that accelerate the adoption of these technologies all over the world.

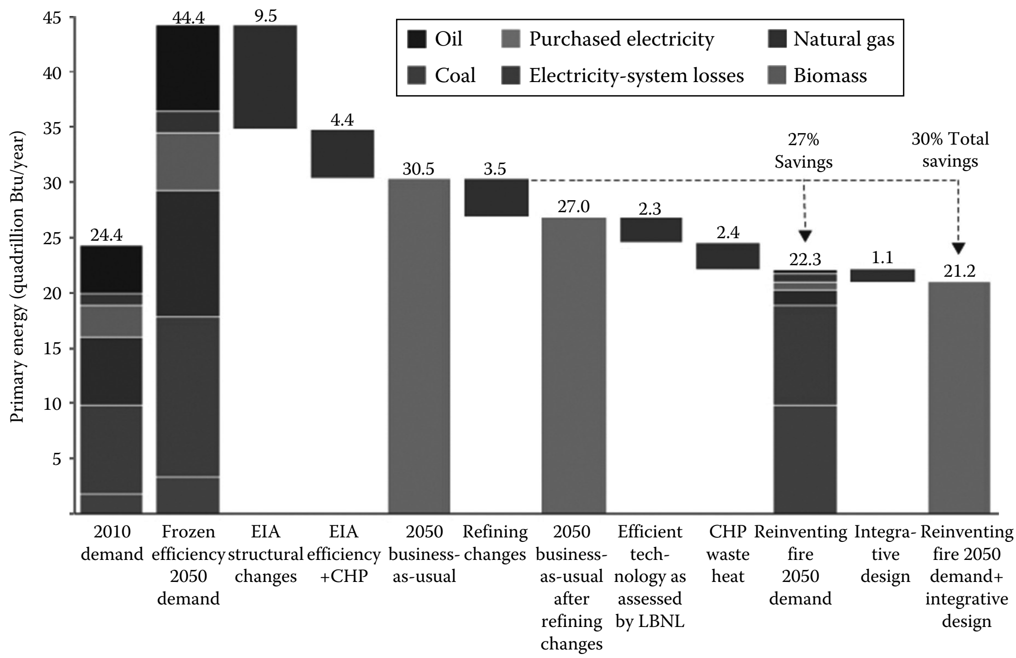

FIGURE 1.23
U.S. industry energy savings potential (2010–2050) as a percentage of the total industrial energy use in business as usual scenario. (From Rocky Mountain Institute, U.S. Industry Energy savings potential, 2010–2050, in: *Reinventing Fire: Bold Business Solutions for the New Energy Era*, RMI, Snowmass, CO, 2012, http://www.rmi.org/RFGraph-US_industry_energy_saving_potential; www.RMI.org./ReinventingFire.)

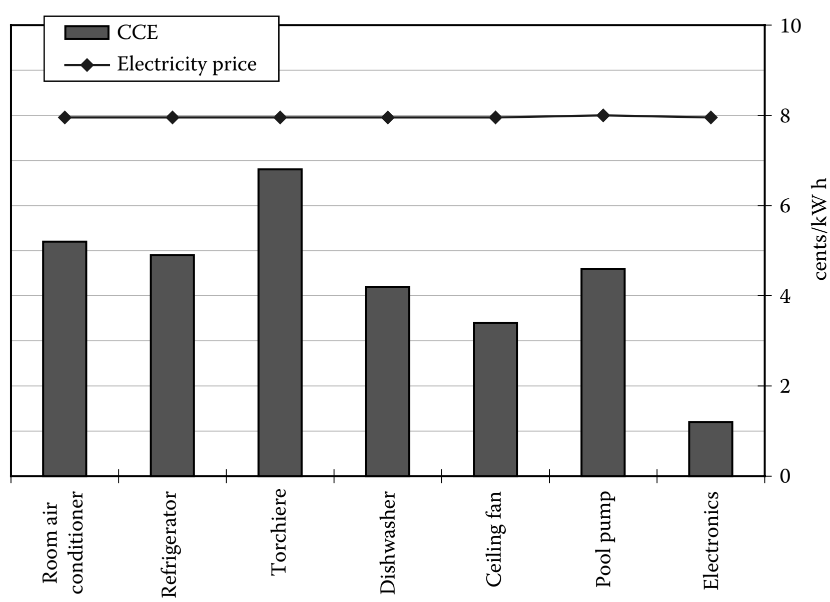

FIGURE 1.24
Comparison of cost of conserved energy for 2010 standards to projected electricity price in the residential sector.

1.8 Forecast of Future Energy Mix

As explained in this chapter, it is clear that oil production will peak in the near future and will start declining thereafter. Since oil comprises the largest share of world energy consumption, a reduction in availability of oil will cause a major disruption unless other resources can fill the gap. Natural gas and coal production may be increased to fill the gap, with the natural gas supply increasing more rapidly than coal. However, that will hasten the time when natural gas production also peaks. Additionally, any increase in coal consumption will worsen the global climate change situation. Although CO_2 sequestration is feasible, it is doubtful that there will be any large-scale application of this technology for existing plants. However, all possible measures should be taken to sequester CO_2 from new coal-fired power plants. Nuclear power does not produce CO_2, however, it is doubtful that nuclear power alone will be able to fill the gap. Forecasts from IAEA show that nuclear power around the world will grow at a rate of 1.2%–2.7% over the next 25 years (IAEA, 2013). This estimate is in the same range as that of IEA.

Based on this information it seems logical that the RE technologies of solar, wind, and biomass will not only be essential but will hopefully be able to fill the gap and provide a clean and sustainable energy future. Although wind and photovoltaic power have grown at rates of over 30%–35%/year over the last few years, this growth rate is based on very small existing capacities for these sources. There are many differing views on the future energy mix. The IEA gives forecasts based on different policy scenarios. Figure 1.25 shows the growth in primary energy demand and the corresponding CO_2 emissions for the

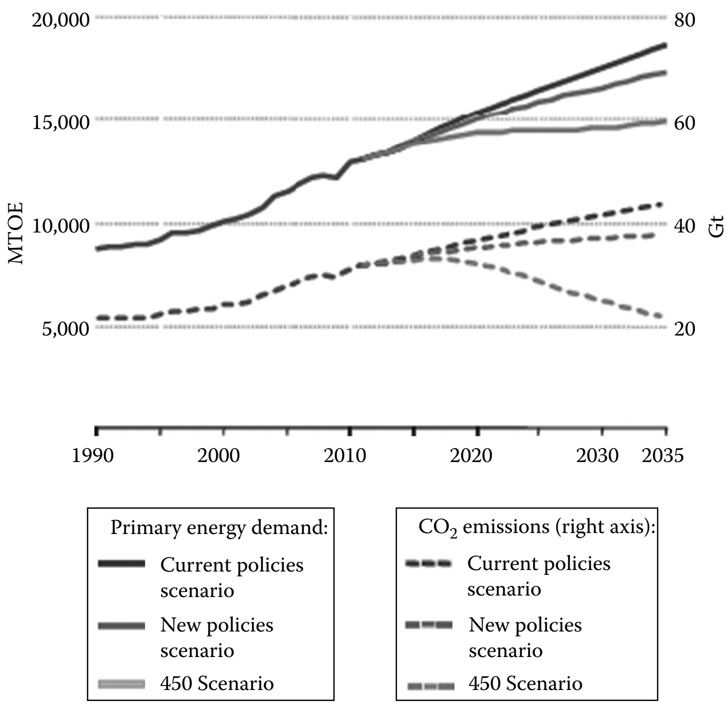

FIGURE 1.25
World primary energy demand by fuel types. (According to IEA, *World Energy Outlook 2013*, International Energy Agency, Paris, France, 2013.)

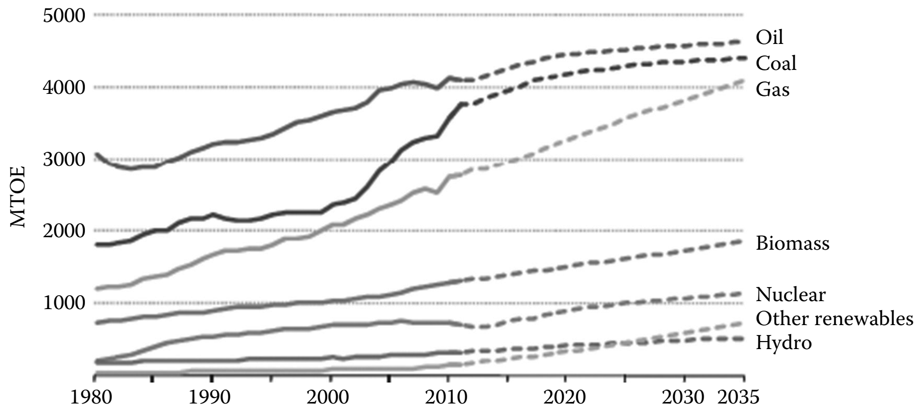

FIGURE 1.26
World primary energy demand by fuel in new policy scenario. (From IEA, *World Energy Outlook 2013*, International Energy Agency, Paris, France, 2013.)

three scenarios. Figure 1.26 shows the demand by fuel type in the "New Policy Scenario," in which renewable energy will provide 18% of the primary energy demand by 2035. However, in the "450 Scenario," renewable energy share goes up to 26% by 2035. This estimate is close to the estimate by the German Advisory Council on Global Change (WBGU), which performed a detailed analysis on combating global climate change with an orderly transition to increased energy efficiencies and increased use of renewable energy. WBGU estimates that as much as 50% of the world's primary energy in 2050 will come from renewable energy, increasing to 80% by 2100 (Figure 1.27). However, to achieve that level of RE use by 2050 and beyond will require a global effort on the scale of Apollo Project.

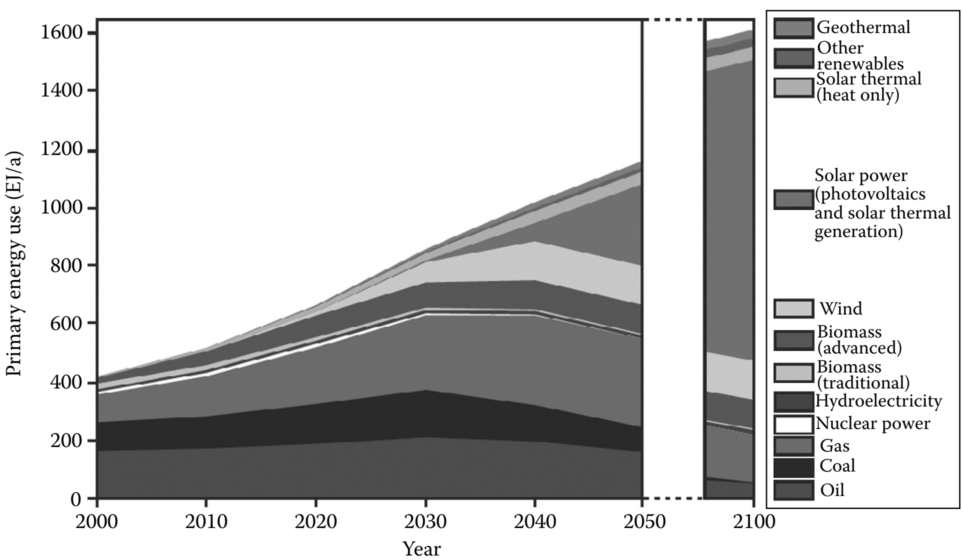

FIGURE 1.27
The global energy mix for year 2050 and 2100. (According to WBGU, World in transition—Towards sustainable energy systems, German Advisory Council on Global Change, Berlin, Germany, 2003, Report available at http://www.wbgu.de.)

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2

Sound Finance Policies for Energy Efficiency and Renewable Energy

Michael Curley

CONTENTS

This chapter presents examples that illustrate the economics of energy efficiency and renewable energy systems. Further sections of this chapter delve more deeply into United States and international financial energy policies.

Financial policy for energy efficiency and renewable energy technology is simply based on comparing the cost of the device with the monetary savings resulting from its deployment. In the present setting, the cost of power from the renewable energy system must be less than the cost of power from fossil fuels in order to be economically competitive.

The problem, of course, is that, at this stage in the development of civilization, these events seldom occur naturally. In most cases, the cost of energy efficiency devices exceeds the savings. Likewise with renewable energy: it usually costs more than fossil energy.

If you want people to buy energy efficient "on-demand" (tankless) water heaters, for example, which cost, let's say, $800 more than the conventional system, then the energy savings must be more than $800 over a reasonable period of time.

Same sort of thing is true about renewable energy. There is a gentleman who owns property on Lake Chautauqua in New York. He recently installed a geothermal heating system that cost him $60,000. The man wrote a check for $60,000! The savings on his electricity bill is $1000/month. He is very proud of the fact that—using straight accounting numbers—he will get his money back in 60 months, or 5 years.

Not many of us can write a check for $60,000. So, let us drop our example down an order of magnitude to $6000. Say we are offered a geothermal system for that sum that will save us $100 a month on our energy bill. Would you write a check for $6000? Would you be willing to wait 5 years to get your money back? Most people would not. Furthermore, if you put the $6000 into a CD at 3% for 5 years you would have $6955.64. So it's not really just $6000 that you're out; it's $6955.64. It will take you more than 5 years to break even. Closer to six.

Instead, you could get a $6000 second mortgage for 5 years at 7%? If so, you would be paying the bank $118.81 a month while you are saving only $100. In other words you'd be losing $18.81 a month for 5 years. So at the end of the 5 years, you'd still be out $1216.* You'd still have to wait another 13 months to break even.

The point here is that very, very few people will wait 60 or 73 months to get their renewable energy investment back. Likewise, people who buy energy efficiency devices don't want to wait several years to get their money back. So, if people want to get serious about energy efficiency and renewable energy they must—if a government or financial institution—create finance programs that deliver the goods at prices below the expected savings. If they are businesses or NGOs, they must seek out these programs and lobby their state, federal, and local legislators to create such programs.

When the wealthy gentleman in Chautauqua signed his $60,000 check and started saving his $1,000 a month, he was probably unaware that in several states other than New York there were government programs that would have financed his geothermal project for about $375 a month with $0 down. This means that in month one he would have spent $375, but saved $1,000.

In our lesser example, the county would have financed our $6,000 project and charged us $37.50 a month, meanwhile we would be saving $100 a month. Don't you think that many, many more people are likely to take on renewable energy projects when the savings kick-in on day one? So, now we just have to figure out how to design finance programs that do just that.

2.1 Some Sound Finance Principles for Creating Effective Finance Programs

Here are seven sound principles of finance for energy efficiency and renewable energy. First, we will list them and then discuss them individually.

1. *Leverage*: Leverage money. The most important word in improving environmental quality is "leverage."
2. *Guaranties*: Never make loans; guaranty them.
3. *Term*: Finance assets over the full term of their service lives.
4. *Subsidies*: Stop general subsidies, which waste billions of dollars. Target subsidies only to those who need them.
5. *Grants*: Never give grants unless absolutely necessary.

* Discounting at 3%.

6. *Cost/benefit analyses*: Make financial decisions based on strict cost/benefit analyses. Get politics and chance out of the decision making matrix.
7. *Full-cost pricing*: Insist on full-cost pricing of environmental services. Full cost pricing will drive technological innovation. In turn, new technologies will drive down costs.

2.1.1 Leverage

Many people think that leverage is some black art practiced by the charlatans on Wall Street. It's not. It's something we all use every day. We just don't call it that. For example, if you buy a $250,000 home with a $50,000 down payment and a $200,000 mortgage, you will have achieved a 5:1 leverage on your home purchase. If you can get away with putting only $25,000 down and get a $225,000 mortgage, then you'll have achieved a 10:1 leverage ratio. Sounds sinister to you? Of course not.

Same is true if you buy a $20,000 car with a $2,000 down payment and finance the balance. You will have achieved a 10:1 leverage again on this transaction. When car dealers get desperate, they often offer cars with no money down. In that case you can achieve infinite leverage. Black magic? No. Not even life in the fast lane. As a matter of fact, leverage is pretty common.

In these examples, the institution that provided the leverage was a bank. Think instead of the U.S. bond market, which was estimated to be $35.2 trillion in the second quarter of 2011 by the Securities Industry and Financial Markets Association, or the international bond market, which is close to $90 trillion. As far as energy efficiency and renewable energy projects are concerned, these international capital markets can provide almost a limitless source of funds.

Now, what's the impact on the projects—or in our examples, the homebuyer or the car buyer? Ask yourself this: if two car dealers offered you the same vehicle with financing for the same term at the same rate of interest but one wanted $4000, or 20%, down and the other wanted $0 down, which would you choose? Exactly! The one with the greatest leverage. And that is precisely why it is so important to design renewable energy and energy efficiency programs with the greatest possible leverage.

2.1.2 Guaranties

The best way to achieve truly extraordinary leverage is to use financial guaranties instead of making direct loans. Let us illustrate this by comparing four most common types of government finance programs: grants, subsidized loans, market-rate loans, and guaranties. To do this, we will set up a little game.

2.1.2.1 Rules of the Game

1. Government contributes $100,000,000 to the New Energy Fund (NEF)
2. Project size: $5,000,000
3. Term: 5 years
4. Payment terms: Level Principal Method
5. Interest rate on subsidized loans = 0%

6. Interest rate on market-rate loans = 10%
7. Interest rate on guaranty fund = 5%
8. Leverage ratio* paradigm†:

Number of Loans	Coverage (%)
0–20	100
20–30	90
30–40	80
40–50	70
50–60	60
60–70	50
70–80	40
80–90	30
90–100	20
100+	10

In our game, the legislature gives your finance agency $100 million and tells you to use it to finance as many energy efficiency and renewable energy projects as possible. So, you look at a grant program, a subsidized loan program, a market-rate loan program and a loan guaranty program.

The following table compares the effectiveness of these four financing techniques.

Year	0	1	2	3	4	5	6	7	8	9	10
Comparison of NEF financing schemes											
Total grants made	20	0	0	0	0	0	0	0	0	0	0
Total subsidized loans made	20	24	28	34	41	49	55	61	68	74	81
Total market rate loans made	20	26	33	42	53	66	79	93	109	126	145
Total guaranties issued	20	27	34	45	60	80	94	119	180	435	543

Let's turn these project numbers into project costs by multiplying the number of projects by $5 million:

Grants	20	$100,000,000
Subsidized loans	81	$405,000,000
Market-rate loans	145	$725,000,000
Loan guaranties	543	$2,715,000,000

Just look at that! $2,715,000,000 worth of energy projects! 543 projects financed! All for the same $100,000,000 that bought you 20 grant projects!

* In this example, the leverage is the ratio of guaranteed loans outstanding to money in the bank pledged to cover them.

† Estimating coverage between the minimum (>20) and the maximum (<100) loans is a totally inexact science; but what is presented certainly suffices for our illustrative purposes.

Loan guaranty programs are so efficient because they incorporate leverage. Leverage, as you already know, is the ability to increase the effect of the use of money. The same sum of money ($100,000,000) was used in each financing scheme. Under the subsidized loan program, there was modest leverage because the funds were paid and could be re-loaned for another project. Thus, the same amount of money could be used twice. This is leverage.

In market rate loan program, there was additional leverage because not only was the $100,000,000 of principal repaid, but 10% interest was also paid each year. So, this increased the leverage.

With loan guaranties, even greater leverage occurs because of the principle of insurance. A guaranty is the same as an insurance policy.

A loan guaranty program insures "prompt and full payment" of debt. It works just like an insurance policy. With $100,000,000, a fund such as the NEF should easily be able to guaranty over $1,000,000,000 of projects at any one time, because of the extreme unlikelihood that more than 10% of its projects would ever go into default at any one time. Thus, if the NEF were to guaranty commercial bank loans for $1,000,000,000 of projects, and 10% or $100,000,000 of them were to default, the NEF could still make good on its guaranties by paying the banks holding the defaulted $100,000,000 held in their reserve account.

Thus, from the point of view of a government wishing to finance energy efficiency or renewable energy projects, the creation of a loan guaranty program would be—by far—the most effective use of its funds.

2.1.3 Term

When most people talk about "low-cost" government finance programs they are almost always referring to a low interest rate. The world's most successful environmental finance program, the Clean Water State Revolving Fund (SRF) at EPA, routinely offers low-cost financing, which—to them and their borrowers—means loans with low interest rates. In SRF's case they offer loans at about 50% of market rates. So, if the market rate on a 20-year, AAA/Aaa tax-exempt municipal bond is 4%, an SRF will offer loans at 2%. If the market rate is 6%, SRFs will finance at 3%, and so on.

Now, to be able to offer sub-market rate loans requires the SRFs to subsidize such loans. This is an egregious waste of money. Here's why.

The reason for the low rates/subsidies is so that sewer-user fees can be minimized. Right? Now watch this.

The annual payment on a *20-year* loan of $1 million at *2%* is $61,157.

The annual payment on a *30-year* loan of $1 million at *4%* is $57,830.

Even if the 30-year market rate is a bit higher, say 4.5%, the annual payment is $61,392, which is only $235 higher. That's $235 a year—not a month—on a $1,000,000 loan. Peanuts!

The point here is that you can have a much more effective program if you lengthen the term rather than subsidizing an interest rate. Furthermore, you save all of the money wasted on the needless subsidies.

Now we will compare annual payments on identical loans with different terms. We will do so with both types of loans: level principal payment loans and level payment loans.

The following table sets forth the first years' annual payments on a $100 loan at several different interest rates over several different terms. The first table deals with level principal payment loans. The second deals with level payment loans.

Interest Rates	0%	5%	10%	15%	20%
Term					
1 year	$100	$105	$110	$115	$120
2 years	$50	$55	$60	$65	$70
3 years	$33	$38	$43	$48	$53
4 years	$25	$30	$35	$40	$45
5 years	$20	$25	$30	$35	$40
10 years	$10	$15	$20	$25	$30
20 years	$5	$10	$15	$20	$25
30 years	$3	$8	$13	$18	$23
40 years	$2.50	$7.50	$12.50	$17.50	$22.50

Please note the hugely significant impact that term has on the annual debt service payments for these loans.

And, now we turn to the level payment method.

The impact of term on annual debt service payments is as significant when the level payment method is used as when the level principal payment method is used.

Interest Rates	0%	5%	10%	15%	20%
Term					
1 year	$100	$105	$110	$115	$120
2 years	$50	$54	$58	$62	$65
3 years	$33	$37	$40	$44	$47
4 years	$25	$28	$32	$35	$39
5 years	$20	$23	$26	$30	$33
10 years	$10	$13	$16	$20	$24
20 years	$5	$8	$12	$16	$21
30 years	$3	$7	$11	$15	$20
40 years	$2.50	$6	$10	$15	$20

A final word about lengthening term. How long is too long? The answer—which is an axiom of public finance—is that assets should be financed over terms commensurate with their service lives. Home insulation, for example, lasts as long as the home it insulates: so 30 years. I understand solar panels last 20 years. So, finance them over 20 years. Geothermal projects last forever, almost. So, again, 30 years should be no problem.*

2.1.4 Subsidies

When a normal person thinks of subsidies, one usually thinks of helping the poor pay for things they can't afford. Right? Well, in the energy infrastructure game, being poor has

* Although many assets have service lives longer than 30 years, the municipal bond market thins out considerably beyond that period. So, better to sell into a 30-year market with lots of buyers than a 30-plus-year market with relatively few.

nothing to do with subsidies…most of the time. Take the case of Loudoun County, Virginia, which has the highest Median Household Income (MHI) in the country. Their MHI was about $119,000 in 2011. That was the *median*. That means that 50% of the households earned *more than $119,000*. Let us now imagine the household with the absolute highest income in Loudoun County. Would it surprise you to learn that the families receive subsidies from the Commonwealth of Virginia? Well, they do.

A very wise mentor of mine breaks down subsidies into two main categories. The first is "general, supply-based subsidies." That's what you see in Loudoun County. The second category is "targeted, demand-based subsidies."

Think of a young family out west who lives in a double-wide, have household income of about $22,000 a year, has two young children, one with asthma, and lives in a valley that in terms of air quality is classified as a nonattainment area because of the wood smoke that hangs constantly over their valley like the sword of Damocles. The only heat the young couple has in their home is an old wood stove. When it gets cold, they have to light it. But when they light it, they are slowly killing their little girl with asthma. A few years ago, there was a $1500 tax credit program for—among other things—replacing old wood stoves. Now, our young couple can't use a tax credit. They don't pay taxes. Their income is too low. The tax credit is useless to them. On the other hand, their wealthy neighbors with weekend cabins on the tops of the mountains can use it. But not people, like our young couple, who really need help. So, instead of this wasteful general subsidy, how about a 100% cash rebate (subsidy) for people: (1) living in nonattainment areas, (2) below the poverty line, (3) with no other source of home heat, and (4) with a resident with a pulmonary ailment. Now, these exceedingly narrow criteria may be a bit over the top; but you see what we mean by a "targeted, demand-based" subsidy.

Now let us show you how truly wasteful general, supply-based subsidies are, by illustrating the point with the most infamous example of all: the tax-exempt municipal bond.

In 1895, the U.S. Supreme Court ruled that the Congress had no power under the Constitution to tax the interest on state or local debt.* In 1913, this position became statutory.

In the municipal bond market, the rule of thumb is that the best (AAA/Aaa) municipal bonds should have interest rates of about 75% of United States.† Treasury bonds of the same term. So let us envision an interest rate environment where, say, 20-year treasuries carried an 8% interest rate. Under these circumstances, you would expect AAA/Aaa tax-exempt municipal bonds to carry a rate of about 6%. Now, let us say that the 8% Treasury was bought by the richest householder in Loudoun County. We'll call her Ms Loudoun. If she bought $10,000 of these bonds, she would receive $800 a year in interest. Being in the 35% tax bracket, Ms Loudon would pay $280 in federal income taxes, and so have net earnings of $520.

Now, let us say, instead, that Ms Loudoun bought $10,000 of tax-exempt bonds at a 6% interest rate issued by the Commonwealth of Virginia. In this latter case, Ms Loudoun would receive $600/year in interest. Because this interest is exempt from federal income taxation, Ms Loudon gets to keep the whole $600. She doesn't pay a penny of that $600 in taxes.

So, we now know that if Ms Loudon bought the 6% tax-exempt bond, she would be $80 better off than if she had bought the 8% Treasury and paid taxes on it.‡

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* This case, *Pollock vs. Farmers' Loan & Trust Co.*, was effectively overruled by the Supreme Court in 1988 in *South Carolina vs. Baker*. But the statutory prohibition remains intact.

† As of this writing, as the damage from the sub-prime mortgage crisis is still being felt in the financial markets, this 75% ratio isn't true. Today it's about 120%. But the 75% number is a decent historical ratio.

‡ Some Ms Loudouns might choose to forego the extra $80 because treasuries are a safer investment than munis. Or at least, that's how the story goes on Wall Street.

But what about the $280 that the U.S. Treasury *didn't get, that they missed out on*. Let's look at it this way. There are 535 members of Congress. Each one receives a salary of $174,000/year. That means there should be $93,090,000 in the Congressional payroll account at the beginning of the fiscal year. Let us say that this account is $280 short because Ms Loudon opted not to buy the treasury bond. If this were really the case, panic would sweep Capitol Hill! Congress would undoubtedly immediately pass a bill to raise some tax by $280 to make up the shortfall. Who would pay that tax? You and I would—as would the poorest tax-paying family in Buffalo County, South Dakota, the poorest county (by MHI)* in the country.

Targeted subsidies for our poor young couple with the sick little girl? Yes.

General subsidies for Loudon County and our wealthy cabin owners? No.†

2.1.5 Grants

Grants are subsidies. So they should only be used in relatively rare circumstances. And, as we learned earlier, they should be tightly targeted.

The four legitimate uses of grants are as follows:

1. *Paying for environmental services that are not affordable, either to individuals or communities*: Remember our young couple with the sick little girl. They desperately needed to buy a new wood stove to keep their home warm and their baby daughter healthy. What form of government assistance was available to them? A tax credit, which they were too poor to use. What did they need? A grant. Either a 100% grant, or something very close to 100%. That is an example of a good use of grants for individuals.

   A good example of a sound community grant is in the case of the USDA water and wastewater program. Here, when the USDA sees that a project costs a significant share of MHI and will make rates higher than in surrounding districts, then the USDA uses grant money to buy down the cost of the project to levels where it will be affordable to the average ratepayer. Targeted grants for communities. Good finance policy.

2. *Inducing people or businesses to make environmental improvements that they are not legally required to do*: When the American Reinvestment and Recovery Act (ARRA) was passed in 2009 to help us get out of the sub-prime mortgage disaster, renewables were just beginning to be a major buzzword. ARRA included substantial grant funds for those who would reduce their carbon footprint by installing solar panels. No one was required to install any kind of renewable or energy saving devices. So, the government paid them to do so. Good idea.

   Cover crops are another good example. After crops are harvested, a large amount of nitrogen remains in the soil. Over the Winter, with snows and rain on the now-bare soil, much of this nitrogen migrates to the nearest water body where it pollutes it. Cover crops are planted after the main crop is harvested. Their sole purpose is to sop up nitrogen left over in the soil to prevent it from polluting any streams or ponds. In the United States, we pay (i.e., give grants to) farmers who will plant cover crops. These grants come out of the "farm bills" that the Congress passes to maintain its elaborate scheme of subsidies for agriculture. In Germany,

* The MHI in Buffalo County, South Dakota is $12,692.
† Although the probability of ending tax-exempt bonds is close to zero.

they have a cover crop program too. It is also a grant program, but in Germany the grants come from a special tax that is collected each year. The point here is that planting cover crops is a good thing. But doing so is entirely voluntary. There is no law—anywhere—requiring farmers to plant cover crops. So, we should use grants to persuade them to do so.

3. *Creating or commercializing new environmental technologies.* Until most recently, it was not cost-effective to install solar panels. Even with generous government financing programs, the monthly cost of the panels exceeded the savings in electricity from the panels. In order to jump-start the solar industry, the U.S. Department of Energy started a grant (i.e., a subsidy program) for solar panel manufacturers. China did the same. However, the Chinese subsidies were so large that the Chinese manufacturers were able to sell their solar panels below the cost of production. The Chinese government created subsidies so that their manufacturers could export all over the world, creating thousands of good manufacturing jobs in China in the process. The United States, European Union, and China are now embroiled in a trade fight over this issue. Regardless of the trade issue, using grants to jump-start new, needed, environmental technologies is a very good idea.
4. *Environmental/Energy Education*: Giving out smallish grants is a good way to get community groups to take an avid interest in energy efficiency and the environmental issues such as climate change. This is especially so for poorer groups that can't readily raise funds for projects themselves. Maryland has a grant fund called the Chesapeake and Atlantic Coastal Bays Trust Fund, which most natives call the "green fund." This fund is relatively small but it gives out grants to community groups for such activities as streambed restoration, tree plantings and the like. Educating people about the value of the environment and the steps necessary to protect it is certainly a valid expenditure of public funds. And, in this case, it really needs to be grant funds.

2.1.6 Cost/Benefit Analyses

Cost/benefit analyses are extremely important for two allied reasons. First, to make sure money for projects or energy efficiency devices is wisely spent, and second, to convince the public of the same, so that they will support these types of programs.

In the field of financing water and wastewater facilities, these analyses can get complicated. They involve the collection of empirical data from the general public, which, in some less-developed countries, is not easy to come by. But for energy efficiency devices and renewable energy, they are quite simple—at least in theory.

In the case of energy efficiency devices, the benefit is the number of kilowatt hours saved. In the case of renewables, it is the number of kilowatt hours generated.

The cost, for energy efficiency devices, is the price of the device paid over the service life of the device at the lowest possible rate of interest.

This is easy for such devices as light bulbs. You know the four critical pieces of information to complete the cost/benefit analysis. You know the lumens the bulb will put out. You know the watts the bulb uses per hour. You know the service life of the bulb in hours (at least as estimated by the manufacturer). And you know the cost of the bulb. With these four pieces of information you can conduct a cost/benefit analysis on these bulbs and thus compare them to get the best value.

The cost for renewables is the installed cost of generating a kilowatt *hour* of electricity. This is a little different. Most people rate installed power by the kilowatt, not the kilowatt hour. But many renewables, such as wind or solar, don't generate power on a constant basis. They generate intermittently. Here is a very simplified example, omitting, among other things, the cost of maintenance.

Let us say two homeowners, one in Buffalo, New York, the other in Las Vegas, Nevada, each purchase a 4 kW solar array at an installed cost of $5/W, or $20,000/W. Let us say they each finance them for a 20-year term at an interest rate of 5% for an annual payment of $1605. Las Vegas has an average of 3825 h/year of sunlight. So, our homeowner in Las Vegas is paying $0.42/kW h.

On the other hand, Buffalo gets 2207 h of sunlight a year. So, our Buffalo homeowner pays $0.73/kW h.

So, you see why we need to use kilowatt HOURS, not just kilowatts to rate renewable energy projects.

2.1.7 Full Cost Pricing

As you already know, environmental utility costs are heavily subsidized. This does no one any good. If there are poor people who cannot afford their water or sewer bill, there are several strategies to effectively and compassionately deal with that.

Now the rest of the ratepayers who *can* afford the full cost of their service should definitely pay for it. No one likes to pay more. No board member or politician likes to raise rates. But rates can be raised gradually. (And when raising rates over, say, 5 years, the authorizing resolution should be passed today for all forthcoming increases. This will save the board and/or politicians the anguish of having to go back to the people every year for more money.)

Raising rates, whether to full-cost pricing levels, or not, will promote conservation. The higher the rate increase the more people will conserve. Think of raising our gasoline rates to the $7+ a gallon rates they charge in Europe. People would definitely find ways to drive less. Car manufacturers would smarten up too. Ditto when you raise power rates. People find ways to use less.

Finally, higher rates will also drive innovation, which will have the eventual effect of lowering costs. Take the example of installing a technology that costs $10 million at a system with full-cost pricing, that is, no subsidies. Engineers and scientists will know that if they can create a technology that does the same or better job at the same or lower cost, they can get into the game without being trumped by some hidden subsidy.

So, these seven principles should be used to guide the creation of any finance programs for renewable energy or energy efficiency.

Now that you know how to spend money most efficiently, please consider a few more principles—these to raise the money that you will spend most efficiently.

1. Raise money from many small charges, fees or taxes—not one big one. Many small sources of money are more stable than one large one. A small tax or surcharge on vehicle registration based on its fuel consumption. A carbon tax loaded into electricity bills.
2. Once collected, put all the environmental money in one basket. Do not fragment or piddle it away.

3. Change behavior while raising money. Do not tax all equally; tax the polluters more while rewarding energy efficiency and green practices. The vehicle/fuel consumption surcharge discussed earlier and the carbon tax will send effective messages to consumers, car manufacturers, and power companies.
4. Use "dedicated revenue streams" (such as annual taxes or fees) to finance capital, not operational, expenses. Such revenue streams that derive from charges like the vehicle/fuel consumption and carbon tax are highly regular and predictable. As such, they constitute an excellent, high quality source of repayment for bonds issued to finance energy efficiency and renewable energy projects. With proper structuring, they can be used to achieve the highest, AAA, ratings on bonds, which result in the lowest possible interest rates. Furthermore, these solid revenue streams don't actually even need to be used to repay bonds to achieve AAA ratings! They can just be pledged to repayment! In other words, let us take the example of a small business energy efficiency/renewable energy program. Small businesses are not known for stellar credit ratings. Moreover, since many small businesses rent their premises, there is no real property that can be used as collateral. In this case, a bond containing a portfolio of uncollateralized loans to small businesses would get either no rating or a triple zilch rating. In this case, the bonds could be structured with the loan receivables as the primary source of repayment and the revenue stream as a secondary source of repayment, that is, the revenue stream would be called upon if, and only if, a small business defaulted on its loan.
5. Make it as painless as possible. At the federal level, raising the rates on a general tax—like the income tax—will set up howls of protest across the country. It will mobilize armies of lobbyists in Washington who will roam the halls of Congress wheedling and bullying the members to oppose it. At the state level, the same phenomenon will occur if there is an income tax increase proposal or a real property tax increase proposal. Virtually, every newspaper in the state will editorialize against it. And the lobbyists will mob the state legislature. The more opposition, the less likely that an effective environmental finance program will be adopted.

The title of this chapter is "Sound Finance Policies for Energy Efficiency and Renewable Energy." These seven principles should be used not only to design programs that spend money on energy efficiency and renewable energy projects in a highly efficient manner, but also on how to raise money for such programs in a highly efficient manner as well.

3

State and Federal Policies for Renewable Energy

Christopher Namovicz

CONTENTS

3.1 Tax Incentives

Tax incentives have provided a key form of direct subsidy to renewable energy and energy efficiency in the United States at both the state and federal levels. These incentives can take several forms, including deductions from taxable income or a credit against tax liability. In addition, tax credits can be applied to the initial purchase or investment in a particular technology, or to the ongoing utilization of a technology or production of a covered commodity. In some cases, lower efficiency investments can be subject to additional taxes.

3.1.1 Investment

Renewable energy and energy efficient technologies are typically characterized by higher upfront costs resulting in significantly reduced fuel and/or operating costs (although not all technologies fit this characterization, e.g., biomass energy can involve substantial ongoing costs for fuel and operations). Many early policy incentives at both the Federal and state levels were intended to reduce the acquisition cost of these technologies, frequently through the use of tax credits proportional to capital investment costs. In some cases, such as some of the early deployment of wind generating technology in California during 1980s, it was believed that investment incentives provided insufficient incentive for high-quality technology or projects that would continue to operate once the initial incentive had been fully realized by the project owner. Such failures, however, may also be attributed to insufficient technology qualification measures, such as technology criteria or screening.[1]

Despite the apparent shortcomings of investment incentives in the early U.S. wind industry, these continue to see widespread use in both federal and state policies for other renewable energy and energy efficiency technologies.

Federal tax incentives proportional to the investment in renewable energy technologies played a significant role in the early adoption of these technologies during the 1980s. Originally adopted as part of the Energy Tax Act of 1978, permanently set at 10% for solar and geothermal facilities by the Energy Policy Act of 1992 (EPACT 92), and currently 30% for solar facilities through 2016, the investment tax credit directly offsets federal corporate income tax liability in proportion to the initial investment cost of the covered technology.[2] Current federal law also allows technologies eligible to receive the production tax credit (PTC) (see the following section) to instead receive a 30% investment tax credit. In addition, most renewable electricity generating technologies are also able to benefit from preferential federal tax depreciation allowance schedules. The Modified Accelerated Cost Recovery Schedule allows much faster depreciation of renewable generation investment costs than is allowed for other generation technologies, using a 5-year schedule rather than a 15- or 20-year schedule for combustion turbines or other thermal plants.[3]

Some states also have or have had tax incentives on the investment in renewable energy or energy efficiency. Additional investment tax credits in California during the 1980s, along with other policies such as the Public Utilities Regulatory Policy Act discussed in Section 3.2.2, helped spur the early adoption of wind and solar thermal generating capacity in that state.[4] Several states currently offer substantial investment tax credits to preferred renewable energy technologies, such as photovoltaic (PV) systems.[5] These credits, however, are not uniformly offered, vary significantly among states that do offer them, and may apply to electric generating technologies or to facilities that produce renewable fuels, such as ethanol. Rebates or exemptions from state-imposed sales taxes on both renewable technologies and energy-efficient appliances and equipment also offer a mechanism to reduce the first-cost of adopting these technologies by the end-user. Availability of such programs varies significantly among states, as do the sales-tax rates and the value and timing of a rebate or exemption where offered.[5] Sales-tax rebates may also, or instead, apply to a renewable fuel, such as biofuel. In this context, such a program may have an effect closer to that of a production incentive rather than an investment incentive. Certain vehicles with low gas mileage will incur a "gas guzzler" tax, which acts as a disincentive for low-efficiency technology investment.

3.1.2 Production/Utilization

Production-based tax incentives provide a tax credit proportional to the quantity of commodity, such as electric generation, produced or sold in a given year. Since production-based incentives reward project performance, they should tend to transfer project performance risk to the project owner, rather than the taxing authority, and without the need for extensive qualification criteria or screening of each project or technology. However, technologies that do not produce easily marketable (and hence taxable) output, such as most energy efficiency technologies, or where the output is generally consumed on-site (without a third-party transaction), such as on-site PV, may be not be amenable to a production-based incentive. In these cases, there may not be a sufficiently auditable record of production or the establishment of such an auditable record (such as internal metering of PV output) may add unwanted cost to a project.

The PTC for renewable electricity, Section 45 of the U.S. Internal Revenue Code, established by EPACT 92 and subsequently modified, provides an inflation-adjusted payment, 2.3¢/kW h in 2013, for the third-party electricity sales from the plant during the first 10-years of operation. The range of technologies eligible for the tax credit has been expanded since its inception, and now includes wind, several types of biomass resources, geothermal, and landfill-gas. However, some technologies do not receive the full credit amount or the same 10-year claim period.[6] The PTC has generally been credited with contributing to the significant growth in U.S. wind power since 1998. Having been allowed to expire and subsequently extended several times, the credit expired for projects starting development after December 31, 2013.[7] A number of states also offer tax credits on the production of preferred renewable energy sources.[5]

A tax credit of $1.00/gal for biodiesel and $0.50/gal for other qualified alternative fuels, including certain biomass-derived fuels, expired at the end of 2013.[8] A number of states also have tax credits for the production of ethanol or other renewable fuels. These credits may reduce income tax liability or, like the federal credit, be applied to a motor fuels tax (in effect, a sales-tax rebate). State programs vary by credit amount as well as by restrictions on local origin of the fuel.[5]

3.2 Regulatory

Regulatory mechanisms generally establish restrictions on market activity that are intended to result in increased adoption of policy-preferred technologies or limitation on policy-undesired technologies. Costs are typically borne directly by market participants, or by either energy producers, consumers, or both. Although regulatory policy may affect markets in many ways, this section will examine three major types of regulatory intervention: target-based standards, market facilitation or limitation policies, and technology specification standards.

3.2.1 Target-Based Standards

Target-based standards establish a target metric of renewable energy or energy efficiency achievement and require regulated industry to achieve the goal. The most important types of goal-based standards in U.S. energy policy are renewable electricity targets established by the various states, the Renewable Fuels Standard (RFS) for transportation fuels, and automotive fuel efficiency standards established by the federal government.

Renewable electricity targets can take the form of absolute levels of capacity (or generation) or of a specified fraction of some future level of total generation (or capacity). Generally called renewable portfolio standards (RPS), these targets can be targeted for a single future year or can be based on a gradually increasing compliance schedule. Renewable energy goals—found in a few states—can mimic RPS programs, but generally lack enforceability provisions, and thus cannot be considered as regulatory policy.[9] RPS policies can require absolute compliance by affected utilities, or, as frequently occurs, can allow the accumulation of "renewable energy credits" (RECs) that can facilitate either inter-temporal compliance "banking" (i.e., using RECs earned in 1 year to meet compliance targets in another year) and/or inter-utility or inter-state credit trading (whereby a utility that over-complies may sell RECs to a utility that cannot meet targets with native resources). Most states with RPS policies limit the geographic source of compliance to in-state resources, resources within the electric power pool(s) that service the state, or resources that can be "delivered" to the state or state power pool. The prevailing selling price of RECs may also be used to calibrate a penalty or alternative compliance payment, typically in the form of a price ceiling at which the state will provide RECs (without actual renewable capacity or generation) or otherwise waive actual compliance. Such "safety-valve" prices are generally intended to provide a clear maximum impact on general electricity prices. Other states may have a "safety valve" that explicitly limits compliance based on realized electricity rate impacts, and in some states compliance may also be waived or delayed for other, statutorily sanctioned reasons, such as protecting the financial solvency of affected utilities. Policies among states also show significant variation in resource eligibility, "grandfathering" of existing capacity, and mechanisms to show preferences among eligible technologies, such as awarding "bonus" credits or having differentiated targets for preferred technologies.[5,12]

The federal RFS was established by the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007. It establishes volume-based targets for ethanol and advanced biofuels, increasing each year through 2022. By this year, the RFS will require the use of 36 billion gal of renewable fuel. The law ensures the use of a variety of fuel types by limiting the amount of conventional ethanol (ethanol derived from corn) to be used for compliance and setting volumetric targets for various advanced biofuels. Advanced biofuels include fuels derived from "cellulosic" feedstocks and can include ethanol, biodiesel, "drop-in" fuels, and other qualifying formulations. Compliance is tracked through the use of Renewable Identification Numbers (RINs) assigned to each batch of qualifying fuel entering the market. RINs can be banked or traded to facilitate compliance.[10]

In 1975, the federal government established a target of doubling the fuel efficiency of the automobile fleet within 10 years. To implement this target, the aggregate sales of each manufacturer selling cars in the U.S. market had to achieve a set schedule for Corporate Average Fuel Economy (CAFE). In 2007, the law was updated, and, in 2012, regulations were issued to establish a target of over 40 miles/gal for passenger cars and light duty trucks by 2021 on a gasoline energy equivalent basis, potentially increasing to over 49 miles/gal by 2025.[11] With the current regulation, compliance for any given manufacturer is facilitated through credit banking and trading provisions. That is, excess credits earned in 1 year may be used to cover a shortfall in another year, or may be traded to another manufacturer to help cover their shortfall. Provisions to support the adoption of electric drive train vehicles may be adopted outside of the construct of the CAFÉ program.

3.2.2 Market Facilitation or Restriction

Regulatory policy can also be used to facilitate or hinder a preferred or undesirable renewable energy or energy efficiency technology from participating in the market. Facilitation can take many forms, including the target-based and technology-specification approaches discussed in Sections 3.2.1 and 3.2.3. Other types of market facilitation can require nondiscriminatory or even preferential market treatment of preferred technologies. Such policies operating at the federal or state level can include "feed-in tariff" (FIT) laws, net metering requirements, and interconnection standards.

In 1978, the Congress passed the Public Utilities Regulatory Policy Act (PURPA), which established the requirement that electric utilities must interconnect (i.e., accept generation feed from) small qualifying facilities that either co-generate process heat and electricity (combined heat and power or CHP) or utilize certain renewable resources.[12]

Furthermore, PURPA established a price floor for the power, known as "avoided cost," subsequently defined to mean the cost of electricity that the utility otherwise would have purchased. PURPA, in theory, established a non-discriminatory framework for adoption of efficient industrial CHP and renewable electricity, established by the federal government, but largely implemented by state regulatory authorities. Some of the non-discriminatory market features that PURPA specifically applied to renewable and CHP facilities were subsequently applied to the broad class of all power generation technologies as federal electricity policy moved toward deregulation of the wholesale power market.[13]

Many states have adopted regulations at the retail/distribution level to require the acceptance of some renewable electricity feeds at an established price floor.[5] Such net-metering laws typically require load serving utilities to facilitate end-user connection of renewable distributed generation technologies (especially solar, but sometimes wind or other renewable or non-renewable technologies) on the customer side of the meter. When instantaneous generation from the local resource exceeds instantaneous customer demand, the meter is allowed to "run backward," effectively causing the utility to purchase the excess generation at the prevailing retail rate. Most states limit the size of the distributed resource, sometimes by customer class, and may also provide limits on the total generation off-set allowed (e.g., the monthly or net annual bill may not be less than zero). Some states have also established limits on the number of customers or level of installed distributed capacity that may participate in net-metering.

More recently, a number of states, localities, and utilities have adopted FITs more similar to those found in Europe.[5] In the FIT model, the utility accepts the renewable feed, as with net metering, but also offers a premium payment over the consumer's retail value of the generation. In some cases, these FIT programs are established by a state or local government, but in other cases, the programs are voluntarily established by the utility itself, and thus may not be, strictly speaking, regulatory policy.

3.2.3 Technology Specification Standards

Another common form of regulatory intervention for renewable and energy efficient technologies is the establishment of minimum product specifications, either as voluntary targets or mandatory limits on product performance. Such standards are seen as an effective approach to improving energy efficiency among individual consumers. Commercial and industrial consumers presumably have significant incentive to optimize energy efficiency for their operations to maintain or improve profitability. However, individuals, while still sensitive to energy prices, may have less motivation to seek out products with higher upfront costs to achieve lower ongoing energy costs. In some cases, market structures may affect consumer decision-making with respect to energy efficiency.

The federal Energy Star program allows qualifying products—ranging from computer equipment to household appliances, to commercial building equipment—to display the "Energy Star" logo on product advertising and packaging.[14] This serves as a proxy for disclosure, in that the consumer is thus aware that the product is "best-in-class" for energy efficiency (although for products not displaying the logo, the consumer cannot tell if this is because the product did not meet the specification or because the manufacturer did not participate in the program). Through the Energy Policy and Conservation Act and its various amendments, the federal government also establishes mandatory energy efficiency specifications, such as minimum levels of energy efficiency, for a wide array of consumer appliances, such as furnaces, air conditioners, light bulbs and fixtures, and kitchen appliances.[15] At the state and local levels, energy efficiency standards may also be incorporated into building codes.

There are both federal and state regulations regarding transportation fuel composition that either directly or indirectly provide incentive for renewable fuels. In addition, the Clean Air Act Amendments of 1990 established a number of fuel specifications, including oxygenation, that vary by region and/or season.[16] Ethanol has emerged as a preferred oxygenate, especially in states with additional ethanol incentives or that have restricted the used of alternatives such as MTBE, but is also incentivized by the RFS. Restrictions on the sulfur content in diesel fuels may also encourage the use of "biodiesel" fuels derived from plant oils, if such fuels can be economically produced.

3.3 Research and Development

Government research and development (R&D) funding for renewable and energy efficiency technologies can support the adoption of these technologies by facilitating cost reductions, higher efficiency, and improved utilization. R&D funding may occur at all stages of the technology development cycle, including basic science, bench-scale technology development, proof-of-concept demonstration, and pilot applications.[17] Government funds may be directed toward government-owned research laboratories, academic institutions, or industry participants. For many projects, especially those developing technologies closer to commercialization, the government will leverage its contributions by requiring substantial cost-sharing (either financial or in-kind) with industry participants.

3.4 Financing

Government-assisted financing has also been used to support renewable energy and energy efficiency, both at the project level and at the manufacturing level. In particular, Section 1703 of the Energy Policy Act of 2005 and Section 1705 of the American Recovery and Reinvestment Act of 2009 established loan guarantee programs,[18] whereby the federal government would act as a third-party guarantor for qualified borrowers using the proceeds for allowed purposes, such as new project development or development of technology manufacturing capability. While no new loans may be authorized under Section 1705 authority, loans for advanced energy technologies (which may include some renewable technologies) may still be authorized under older Section 1703 authority.

The federal government has also provided financial assistance to publicly owned utilities and other governmental entities in the form of a tax-advantage bonding authority.[5] With such bonds, the government may borrow money, repaying only the principal to the bond holders. The bond holder receives interest payments in the form of income tax credits. Programs have been offered for Clean and Renewable Energy Bonds (CREBs) and Qualified Energy Conservation Bonds (QECBs). The CREB program had limited funding and is no longer accepting new project applications.

Several states also offer assistance with project or technology loans. A number of states and localities have also started financing distributed renewable energy projects (such as roof-top PV) using "Property Assessed Clean Energy" (PACE) financing. In PACE financing, the local government (typically) acts as the lender, allowing the project owner to repay the loan through an assessment attached to a property tax bill.

3.5 Other Direct Policy

Other common programs at the state and federal levels include direct payments (such as through grants or awards) and government purchase of these technologies. These mechanisms generally require continuing budgetary support, which may be provided from a dedicated revenue source, or may require periodic affirmation in appropriations process.

A number of states have established system benefit funds dedicated to supporting renewable energy and energy efficiency projects and technologies. Although varying greatly by state, these programs are typically structured to collect revenue based on an additional fee on retail generation or billing, commonly referred to as a systems benefit charge or public benefit fund.[5] As a result of EPACT and subsequent presidential orders, the various agencies of the federal government are required to obtain a share of their energy from renewable sources and reduce their consumption of energy per square foot of facility.[19] Finally, the federal-owned fleet of cars and other vehicles is required to meet requirements for both fuel economy and use of alternative fuels. Several local state governments have also established similar purchase or efficiency requirements for electricity or motor fuels.[5]

3.6 Indirect Policy

Numerous other policies at the state and federal levels, while not designed specifically to address renewable energy and energy efficiency markets, may have a significant or notable impact on these markets. Perhaps most significant among this broad category are efforts to regulate energy or other markets, manage government—or privately—owned lands, and protect the environment.

Efforts at the federal level to introduce competition in wholesale electricity generation markets, as well as in a number of states to introduce competitive retail electricity supply, have created the opportunity for electricity suppliers to sell "green" power—typically electricity produced from renewable, low-emission, or high efficiency technologies.[20] Such programs include competitive supply of clean or renewable power, special pricing for green power by regulated utilities, or the sale of the environmental attributes of renewable power apart from sale of electricity. In addition, the specific design of competitive wholesale markets for generation and transmission can impact the competitiveness of some renewable, especially intermittent resources such as wind.

Environmental regulation at the federal or state level, for air quality, water quality, solid waste disposal, land use, greenhouse gas emissions, and other pollution problems, can have substantial impact on both the cost and value of renewable energy and energy efficiency. The Clean Air Act Amendments of 1990 (CAA) provides the foundation for cap-and-trade regulation of sulfur dioxide, and for emission limits on other pollutants.[21] While these programs do not always directly address the use of renewables or efficiency as a pollution avoidance mechanism, they do not necessarily preclude their use to reduce overall emissions. Other CAA impacts on renewable energy and energy efficiency include reformulated gasoline requirements discussed earlier, which have interacted with state-level groundwater protection efforts to provide a preference (in some states) for ethanol as a preferred fuel additive for CAA compliance. More recently, EPA has begun to use authorities in the CAA to regulate greenhouse gas emissions, which may have a more pronounced, if still indirect, impact on renewable generation resources. As a result of the Resource Conservation and Recovery Act, some landfill operations have been required to install collection and flaring systems to prevent the dangerous build-up of methane-rich gas that results from the decomposition of organic matter in the landfills.[22] These systems have significantly reduced the cost of deploying small generators fueled by this off-gas. Impacts of land management policy at both the Federal and state levels can be significant factors in renewable energy policy, either to encourage or preclude its development on government owned land.

At the state level, a number of states, either working alone or in cooperation with other states, have established policies to control the emissions of greenhouse gases. For example, the California law known as AB32 (for Assembly Bill number 32, its ascension number in the legislative session) implements a number of policies to control or limit carbon emissions.[23] Some of these policies, such as a modification of the state's RPS or the low carbon fuel standard, directly address renewable energy or energy efficiency, while other policies, such as the cap on greenhouse gas emissions, may serve to encourage additional adoption of renewable energy resources and increased energy efficiency. The Regional Greenhouse Gas Initiative is a cooperative agreement among several states in the Northeast to limit greenhouse gas emissions, which may also incentivize renewable generation resources.

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4

Strategies and Instruments for Renewable Energy and Energy Efficiency: Internationally, in Europe, and in Germany

Werner Niederle*

CONTENTS

4.1 Framework for a Sustainable Development of Energy Supply Systems

4.1.1 Political Drivers toward the Transformation of Energy Supply

AGENDA 21, which was adopted at the United Nations Conference on Environment and Development in 1992 in Rio de Janeiro, sets out the requirements for sustainable development. Critical issues for sustainable development in energy supply are the continuous growth in human needs for energy in the face of limited fossil and nuclear resources, and their serious impacts on the environment and the climate.

Per capita consumption of energy varies widely between countries across the world. Cost-effective energy supplies are key to overcoming poverty. About 1.3 billion people have no

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access to electricity, and 2.6 billion are without clean cooking facilities [1]. At the same time, the economic development in countries like China and India increases the global demand for energy, especially for fossil sources. The resources are unequally distributed; much of fossil and nuclear energy resources are in the hands of a few countries. This can present a considerable barrier to the economic development of resource-poor countries.

Costs are a key driver for the choice of energy source. The costs of fossil and nuclear energy supplies cannot be realistically evaluated unless the considerable environmental damage, climate change, and the risk posed by nuclear energy are taken into account. Insufficient attention continues to be paid to the external costs linked with fossil energy. Furthermore, the World Energy Outlook (WEO) reports energy production using fossil and nuclear sources as being supported by subsidies amounting to U.S. $544 billion in 2012 [2]. These must be systematically reduced.

On the other hand, nuclear energy can be seen to be subject to growing constraints to ensure operational safety, which leads to rising costs and therefore calls its economic viability into question. The costs for the use of renewable energy (RE) are falling, due to technological development. In addition to mitigating climate change, dynamic development of RE use offers access to comparably reliable, environmentally sound, and low-risk energy supplies as well as the opportunity for poor countries to develop socially and economically. Furthermore, significant cost-effective potential to save energy through efficient conversion and use exists worldwide and is only partly utilized today.

4.1.2 Successful Promotion of a Sustainable Energy Supply

The transformation of energy supply system requires a number of *framework conditions, instruments, and measures* which are capable of breaking down the decades-old structures of the existing energy supply system and promoting system changes which in part are fundamental. Important, if not an essential prerequisite for such a development in a country or an association of countries, is a basic commitment of government, administration, business, and the population. Generally, there must be a transparent strategy with legally binding development paths. The latter must refer to transparent and soundly calculated indicators with a clear reference to the short- and long-term goals. The development should be monitored continuously to make sure the trajectory is being complied with. The International Energy Agency has proposed general approaches to promoting efficient energy conversion and energy use [3]. In principle they can also be applied to the promotion of RE.

Generally, a set of instruments which specifically address the various market segments is needed. A strategy geared to a single goal, for example, climate protection, will not be sufficient to achieve the manifold sustainable-development goals. The instruments must be continuously adjusted as required for the long-term transformation of the energy system and must be coordinated in order to avoid contradictions between them. They should promote the development and application of the technical basis, encourage the integration of new products into the market, and activate cost reduction potential. One priority, alongside installations for the utilization of RE, should be the development and use of integrative elements such as energy grids, load management, and storage facilities in order to adapt fluctuating wind and solar energy to the given load profiles.

This is being discussed today mainly in the context of electricity supply, but in order to optimize the energy system as a whole, provision of electricity, heating and cooling as well as the energy needs for transport must be considered as a connected system. The implementation of cost-effective efficiency measures should be made mandatory through suitable legal norms, and longer amortization periods should be compensated through suitable support. The transformation of energy supply must be coordinated with the declining energy demand brought on by energy efficiency (EE) measures in order to ensure that the expansion of RE utilizition does not thwart subsequent efficiency measures in, for example, the buildings sector.

Making the energy supply system sustainable involves far-reaching changes. Policymakers, administrations, companies, and citizens must not only accept this transformation, they must also actively support it. International organizations and states committed to this task must therefore establish target-group-specific public relations activities in order to communicate the opportunities and challenges it involves. They must also devise new training and further-training contents to prepare the people and professions charged with this task for tackling it.

4.1.3 International Agreements on the Use of Renewable Energy

The debate about global sustainable development has also had an impact on organizations in the energy sector. Over the last 10 years, various global initiatives and organizations have been established in this context. They include, but are not limited to, those briefly described in the following section.

In 2011, United Nations Secretary-General Ban Ki-moon launched the *Sustainable Energy for All initiative* (SE4ALL). It has three objectives which are to be achieved by 2030: to ensure universal access to modern energy service, to double the global rate of improvement in EE, and to double the share of RE in the global energy mix. The initiative has developed a Global Action Agenda with 11 Action Areas: 7 "sectoral" areas (e.g., modern cooking appliances and fuels, large-scale renewable power, and buildings and appliances), and 4 "enabling" areas (energy planning and policies, business model and technology innovation, finance and risk management, capacity building and knowledge sharing). The initiative seeks to encourage governments and actors to initiate their own specific actions in these areas. Suitable metrics will be established to measure progress toward achievement of the objectives [4].

The proposal to set up an international organization for RE dates back to the United Nations Conference on New and Renewable Sources of Energy held in 1981 in Nairobi. It took three decades of manifold international efforts until on April 4, 2011, the International Renewable Energy Agency (IRENA) was established in Abu Dhabi, United Arab Emirates. By June 2013, 160 participants were registered, including 114 states and the EU as members and 45 states as signatories or in accession. Mandated by its Member States (MS), IRENA serves as a network hub of country, regional and global programs and activities, an advisory resource on planning, policy development and deployment, and as an authoritative, unified global voice for RE [5].

Numerous conferences paved the way for the activities and organizations addressed earlier. The World Summit for Sustainable Development in 2002 in Johannesburg stressed the importance of RE, and the foundation of IRENA was mentioned for the first time in the final declaration of the International Renewable Energy Conference in 2004 in Bonn. This was followed by a series of International Renewable Energy Conferences (IREC) in Beijing, Washington, Delhi, and Abu Dhabi. The 2013 IREC took place in conjunction with the third session of the IRENA Assembly and the Annual World Future Energy Summit during Sustainable Energy Week [6].

Last but not the least, the Renewable Energy Network (REN21) was established as a result of the Renewables 2004 Conference. It is a global network connecting actors from governments, international organizations, industry associations, science and civil society to support exchange of knowledge and data as well as global activities in the field of RE. REN21 annually publishes the Global Status Report, the Global Future Report as well as reports on regional activities and RE policies, and runs several websites [7]. The international activities outlined earlier cooperate closely and assist one another. UN Secretary-General Ban Ki-moon has welcomed IRENA as RE hub within the SE4ALL initiative [8], and the conferences served to discuss and prepare the global activities and were actively supported by REN21. Despite the growing intensity of this exchange, governments must take action themselves to promote RE within their own remit.

4.2 Strategies and Instruments in Europe

The global debate on climate change (e.g., reports by the Intergovernmental Panel on Climate Change [IPCC], Kyoto Protocol) and the dependency of the European Union (EU) on energy imports led to the adoption of the EU Climate and Energy Package in April 2009. It consists of several instruments designed to prevent or reduce greenhouse gas (GHG) emissions and sets three targets for the year 2020: a reduction of GHG emissions by 20% compared to 1990 levels (30% if other industrialized countries set own targets), an energy efficiency (EE) improvement of 20% compared to 2005, and an increase in the use of Renewable Energy (RE) to a share of 20% of gross final energy consumption. In addition, RE's share in the transport sector is to be increased to 10% [9].

4.2.1 European Energy Supply and Dependency on Energy Imports

In 2011, gross primary energy consumption in the 27 EU MS amounted to about 1,698 million tons of oil equivalent (toe), which corresponds to 71,092 terajoules (TJ) and is 6% less than in 2008. Gross final energy consumption saw a decrease of similar magnitude, to about 1103 toe. The energy dependency rate is about 54% of primary energy consumption, that is, more than half of energy consumption comes from imported sources. Consumption and dependency on imports vary greatly between MS. The largest energy consumers are—in line with economic performance—Germany, France, the United Kingdom, Spain, and Italy. As regards dependency on imports, small countries (many of them islands) like Malta, Zyprus, or Luxembourg head the list, but also Ireland, Italy, and Portugal have to import much of their energy requirement. On the other hand, Denmark is a net energy exporter [10].

4.2.2 Renewable Energy Directive (2009/28/EC) of April 23, 2009

Directive 2009/28/EC on the promotion of the use of energy from renewable sources (RE Directive, RED) is one of the instruments of the Climate and Energy Package and entered into force in June 2009 [11]. It establishes a framework for the further development of RE use in the electricity, heating, and transport sectors in the MS of the EU and provides recommendations for the design of the environment for RE promotion and expansion. The RED allocates the overall EU RE development target among the MS by setting MS-specific targets. Its main contents are

- A national action plan and progress reports serve for precise communication between MS, European Commission and European Parliament on progress made to achieve the Directive's goals. The MS submitted their national action plans by June 31, 2010. They contain the energy data structure needed to calculate GHG reduction effects (taking into account savings in consumption due to energy efficiency) and the expected expansion of RE until 2020 with 2-year intermediate values (trajectory). The report also describes the measures and instruments established to comply with the RED. From 2011 to 2019, the MS draw up a progress report every 2 years presenting an interim assessment of the development described in the action plan. The European Commission evaluates these reports and summarizes them in a progress report to the European Parliament and the Council. In the first progress report of March 27, 2013, the European Commission calls for improvements in MS, for example, better framework conditions for expansion of RE, and finds compliance with the trajectory unsatisfactory in some cases. It has even launched infringement proceedings against some MS. However, it also sees a need for further action in its own domain.

- The base data and methods needed to calculate GHG reduction effects.
- For cooperation between MS, the RED defines mechanisms for the statistical transfer of used amount of RE joint support schemes, and joint projects for production of electricity, heating, or cooling. Electricity production projects may also be carried out with non-EU countries. The produced amounts of energy are divided up between the countries involved for the purpose of counting them toward national targets.
- To reduce barriers to RE expansion, the RED addresses in detail the favorable framework conditions for project planning and implementation, access to and operation of grids as well as information and training, and recommends appropriate adjustment of relevant regulations.
- The system for guarantees of origin of renewable electricity defined by Directive 2001/77/EC was further developed and may now be extended to include heating and cooling. The system serves to ensure that the share of RE in electricity, heating or cooling product can be proven to final customers in a transparent and objective manner.
- The RED places great emphasis on sustainable provision of biofuels, addressing the global dimension of relevant markets. As a key requirement, biofuels are only accepted within the scope of the RED, for example, for fulfillment of the RE shares, if their use leads to a 35% GHG emission saving compared to the fossil-fuel reference. From 2017 the saving must be 50%. This aspect is discussed further in the following paragraphs.

The EU-wide *target for the share of RE in transport* applies equally to each MS. In addition to biofuels, fuels, or electricity from other RES may be counted toward this target. Since highly efficient technologies such as batteries and new conversion processes (e.g., power to gas) are still not available at feasible costs, this target has generated considerable pressure toward the production of biodiesel in particular.

The provision and use of biomass for energy production usually has adverse environmental impacts. In addition to other environmental impacts, intensified land use or the use of land previously used otherwise, referred to as land use change (LUC), for example, plowing up of meadows, can increase the eutrophication and acidification of soil and water bodies and lead to correspondingly higher emissions of highly potent GHG. GHG emissions from fossil-fuelled machinery or artificial fertilizers are hardly evitable. Competition with food and feed production is another relevant problem. In tropical countries, and especially in poor countries, the effects from this may be much more pronounced, for example, when food production is displaced to previously virgin rainforest areas (indirect land use change—ILUC). Competition with food production can have serious social consequences in these countries, for example, due to rising food prices [12].

These insights raise serious doubts as to the sustainability of biofuels (especially of biodiesel) or even their positive effects for the climate. Calculated GHG emissions do not yet include the effects of ILUC, as a commonly accepted calculation method does not yet exist. Therefore, the European Commission presented in autumn of 2012 a controversial initial proposal, on the basis of several experts' reports, on how ILUC could be accounted for in reporting under the RED on the promotion of RES [13]. The implementation of the proposal would lead to the situation that a reduction of GHG emissions could no longer be demonstrated for biofuels with a high oil-crop share [14]. This has led to an intense debate about the contribution of food-crop-based biofuels to the target for RE in the transport sector by 2020 under the RED, and for this option, a limitation to the current level is under discussion.

4.2.3 Instruments in EU Member States to Promote Renewable Energy for Electricity Generation

EU MS essentially use two instruments as main support instruments: feed-in payments with fixed tariffs or variable premiums, and quota models with tradable certificates in different variations. In addition, tendering, tax incentives, and mixed schemes are used. The support instruments are constantly changing, and their design and respective frameworks differ markedly between MS. Therefore, a comprehensive description would only have transitory relevance and would go beyond the scope of this contribution. Figure 4.1 shows the main support instruments applied by MS at the end of 2012 [15]. In the subsequent section, the basic schemes are briefly described and evaluated in terms of their economic efficiency.

With the *fixed feed-in tariff*, operators of RE installations receive fixed payments per kW h for the amount of electricity they produce. This makes electricity revenues readily calculable and provides high investment security. However, it eliminates the electricity price signal from being the decisive criterion for the RE installation operator; neither investment nor operating decision will be determined by the real-world shortage situation in the electricity market. With fixed feed-in payments, the speed of expansion can be controlled only indirectly and roughly via the funding rates. Adjusting the payments to the price development is difficult, especially when it is dynamic. Differentiating the payments according to technology may be appropriate, especially in the case of large cost differences, and may reduce or prevent the problem of windfall profits in RE promotion. When long term, the support can be adjusted to reflect the learning curves of RE technologies and windfall profits can be prevented.

With the *premium model*, the installation operator or a trader markets the renewable electricity via a power exchange. In addition to the market prices, RE installation operators are paid a premium per kW h for the amount of electricity produced. The premium is geared to the exchange price (e.g., the average monthly price) and therefore provides an incentive for market-adapted production. The behavior of a market premium model in terms of windfall profits and controllability of the speed of expansion is similar to that of the fixed feed-in payment. The uncertain electricity price reduces certainty for investors, but linkage with a fixed payment as in the case of the market premium provided for in Germany by the EEG limits this effect.

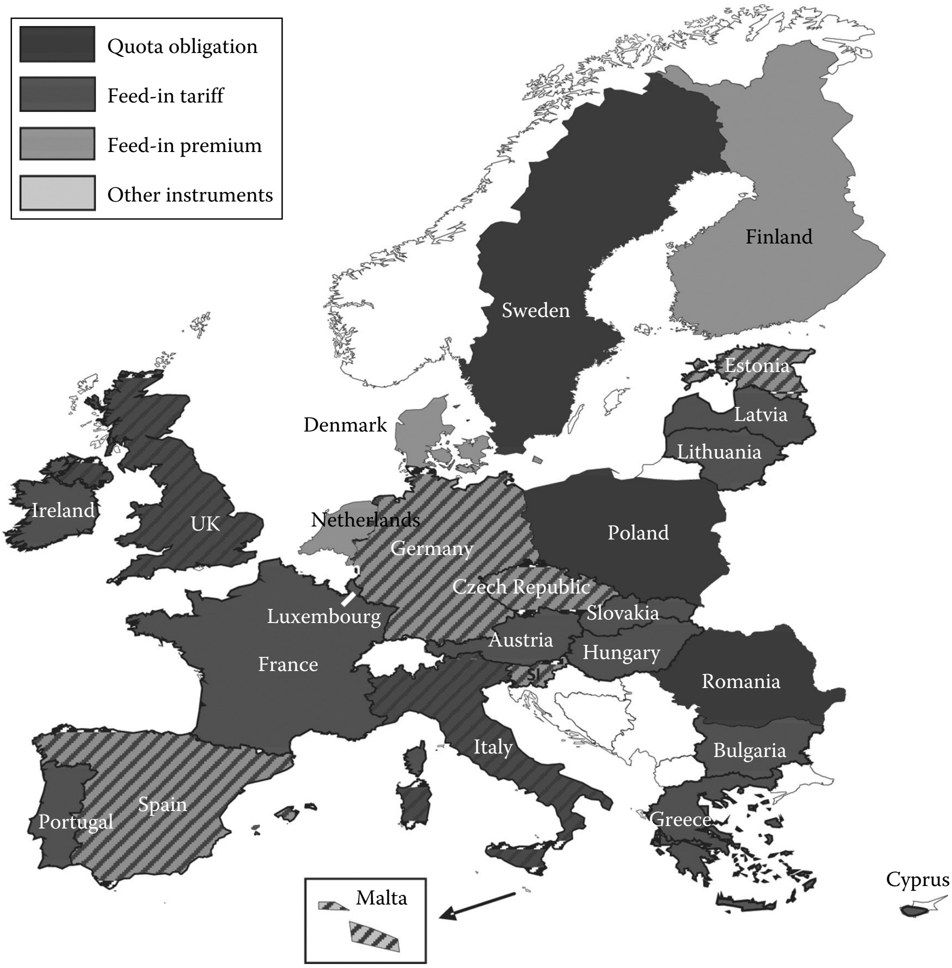

FIGURE 4.1
Overview of RE support instruments primarily applied in EU Member States. *Notes:* (1) The patterned colors represent a combination of instruments; (2) investment grants, tax exemptions, and fiscal incentives are not included in this picture unless they serve as the main support instrument. (From Ragwitz, M. et al., Review report on support schemes for renewable electricity and heating in Europe, report D8 compiled within the E European research project RE-Shaping [work package 3], January 2011, p. 21ff., www.reshaping-res-policy.eu, as of March 6, 2015.)

The *quota system with trading of certificates* requires market actors to provide a certain share of renewable electricity within their portfolio. Alternatively, they can buy certificates for renewable electricity generated by other market actors at variable market prices and might thus fulfill their quota in a more cost-effective way than in the case of own production. The quota system affords good controllability of the development path, provided that nonfulfillment of the required quota is sufficiently sanctioned. Since the revenues from renewable electricity in this scheme are directly dependent upon the electricity prices on the energy exchange, market integration is given. There is little certainty for investors, as not only the electricity prices on the energy exchange but also the prices for the certificates are volatile. RE investors must take high risk premiums into account, which reduces the efficiency of a quota system. On the other hand, the competition orientation has—in the short term—a beneficial effect on efficiency, since RE expansion is channeled to the most cost-effective RE technologies. Quotas could also be set for specific technologies, but this increases the complexity and uncertainty. As can be expected, windfall profits are high, especially if a technology-neutral design is applied.

Tendering alone is not a functional RE support instrument. Tendering can be used for production capacity or produced amount of electricity. In the bidding process, the most competitive bidders are identified and receive investment grants or a payment, for example, spread over the plant depreciation period. This means that support rates are determined by competition, and not set administratively as in the case of fixed feed-in payments and premium model. Tendering offers large scope in designing the instrument while at the same time substantial trade-offs have to be considered in its optimization. Transaction costs tend to be high.

4.2.4 Energy Efficiency

An efficient and economical use of energy can partially offset the rise in energy prices. It can reduce the provision of energy, installations for energy production and conversion, and the necessary infrastructure, for example, energy grids and storage facilities. In addition, energy saving makes the economy more competitive. EE improvement measures for end-users concern local energy provision, conversion, and use in all sectors. The many and varied ways in which energy losses can occur through inefficient use requires correspondingly diverse and small-scale measures. The most important are described in the following paragraphs.

The aim of Directive 2012/27/EU on *energy efficiency* (EE Directive, EED) [16] is to help ensure achievement of the Union's target of improving EE by 20% by 2020 compared to business as usual. The EED contains a multitude of requirements for MS to increase EE. A key element is Article 7, which requires MS to achieve an annual savings quota of 1.5% by 2020. Renovation of public buildings owned by central governments is to be stepped up and energy audits carried out in all larger enterprises. A flexibility clause allows MS to apply derogations, which may be counted toward the saving target in Article 7 at a rate of up to 25% (i.e., application of the derogations may not lead to a reduction of more than 25% of the energy savings resulting from the 1.5% target).

Directive 2009/125/EC, also known as *Energy-related Products* Directive, establishes a framework for the ecodesign of energy-related products [17]. It requires all manufacturers placing products on the market in EU MS to present a declaration of conformity indicating that the product's design complies with the provisions of the Directive and of regulations issued under it for homogenous groups of products. The regulations limit, for example, stand-by and off-mode power consumption of specific groups of devices like household and office equipment. Regulation 1275/2008/EC on electrical office and household equipment [18] alone will reduce unnecessary power losses in the EU by 35 billion kW h/year by 2020. This translates to a saving of 14 million tons of carbon dioxide emissions and nine 800 MW power plants [19]. Another regulation, 2013/801/EU, for data network equipment has entered into force recently. There are also regulations on the EE of televisions, lamps, electric motors, and other groups. Due to the factual ban on basic incandescent lamps, compact fluorescent lamps, also known as energy saving lamps, are being launched on the market in a large variety of forms and designs.

Many of appliances discussed earlier, as well as dishwashers, washing machines, refrigerators and freezers are labeled for their annual energy consumption under Directive 2010/30/EC [20]. Originally, starting in the 1990s, EE was divided into classes A to G for *labeling* purposes. This system had to be changed in response to the EE improvements which labeling brought about for these product groups. Appliances in classes C to G have largely disappeared from the market, and three further classes with one to three plus signs above class A (A+ to A+++) were introduced. The EE of labeled appliances improved 7% in the EU between 2005 and 2010 (ranging from 0% in the United Kingdom and 18% in Spain) [21].

Buildings account for a large proportion of final energy consumption. The European Commission has estimated a share of 40% and addresses existing saving potential in Directive 2010/31/EU on the *energy performance of buildings* [22]. The Directive requires EU MS *inter alia* to set minimum energy performance requirements for new buildings and existing buildings subject to major renovation with a view to achieving cost-optimal levels. By the end of 2020, all new buildings must be nearly zero-energy buildings. Buyers and tenants must be given information on the EE of the building; for example, it is now obligatory for EE parameters to be indicated in housing advertisements.

4.3 Strategies and Instruments in Germany

In Germany, the energy debate started in the 1970s, with the anti-nuclear movement as a part of the New Social Movement and received impetus from the oil-price crises in the 1970s and 1980s, forest dieback in Germany, and the Chernobyl nuclear disaster in 1986. After the UN-Conference in Rio 1992, increasing attention was given to the issues of sustainable development of the energy supply system as an overarching concept as well as climate protection. These discussions promoted various approaches to EE in the buildings sector and to the use of renewable energy (RE) in Germany. By the turn of the millennium, transforming the energy supply system had become an issue acknowledged by the German public as one of the most important tasks of the twenty-first century and which it now broadly supports.

4.3.1 Use of Renewable Energy in Germany

Primary energy consumption in Germany in 2011 amounted to 13,522 PJ. It has remained at similar levels since 1990, between 13,000 and 15,000 PJ. The share of fossil energy sources in primary energy consumption in 2011 was almost 79% (mineral oil 33.5%, natural gas 20.8%, hard coal 12.8%, and lignite 11.6%) and that of nuclear energy was <9%. The contribution of RES, in contrast, rose to a total of 11% [23]. In 2011, Germany had to import over 60% of primary energy consumption placing it in the upper mid-range of EU MS [10].

Provision of electricity, heat, and fuels from RES has almost quadrupled, from about 83 terawatt hours (TW h) in 1998 to around 318 TW h, or 12.3% of total final energy consumption, in 2012. Seventy seven terawatt hours of electricity from RE were provided in 2012. Their proportion in electricity production increased from 4.7% (1998) to 23.5%. Heat supply from RE in 2012 totaled approximately 140 TW h or 10.2% of total final energy consumption for heating (space heating, hot water, and industrial process heat). In the transport sector the contribution of RE was roughly 35 TW h in 2012, or about 5.7% of total fuel consumption by road transport [24] (Figure 4.2).

At the end of 2012, wind turbines with a capacity of about 31,300 megawatts (MW) were installed in Germany, which produced almost 50.7 TW h of electricity in that year.

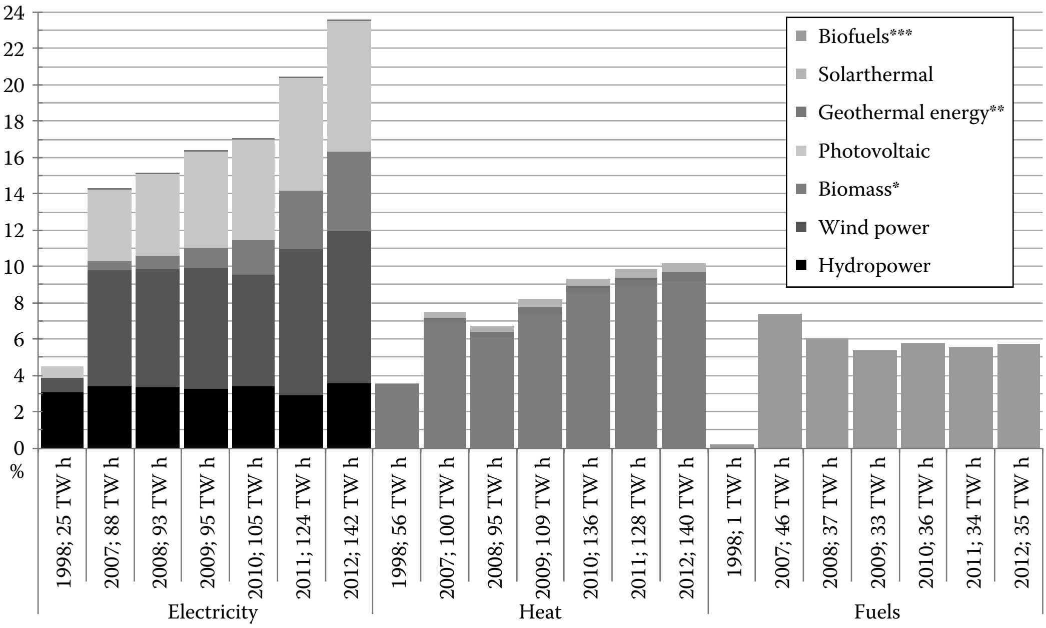

FIGURE 4.2
Contribution of RE to final energy consumption. *Biomass: solid and liquid biomass, biogas, landfill and sewage gas, biogenic share of waste. **Geothermal energy in the heat sector: deep geothermal energy, near-surface geothermal energy, ambient heat. ***Biofuels: biodiesel, bioethanol, vegetable oil, from 2008: biomethane; values rounded; as at August 2013. (From Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (publisher), Renewable Energy Sources in Figures, July 2013; as at March 6, 2015 only the 2014 German update "Erneuerbare Energien in Zahlen", now published by Federal Ministry for Economic Affairs and Industry, is available on http://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/erneuerbare-energien-in-zahlen.html; numbers might differ slightly due to statistical adjustments.)

In addition, photovoltaic systems with a capacity of over 32,600 MW were installed yielding almost 26.4 TW h. Bioenergy outdoes photovoltaics, with over 43.5 TW h from an installed capacity of almost 7600 MW, but is increasingly viewed critically due to harmful environmental and climate effects. Besides these sources, only hydropower plays an appreciable role, with 21.8 TW h from an installed capacity of 5600 MW. Old hydropower facilities in particular can have high impact on the environment; moreover hydropower's potential is largely exhausted in Germany. Electricity production from geothermal systems exhibits large technical potential, but the extent to which it is used is still small due to high costs and other hurdles.

In heat supply from RE, the use of bioenergy dominates, mainly from traditional log burning. This source is viewed critically from the viewpoint of sustainable resource use and because of its environmental impacts, for example, emissions of fine particulate matter. Heat provision from solar thermal and geothermal systems in 2012 only amounted to 6.7 and 7 TW h, respectively despite their large overall potential [24].

4.3.2 Renewable Energy Sources Act—Promotion in the Electricity Market

The Renewable Energy Sources Act (EEG) was enacted in 2000, the last overall amendment became effective in 2014. The purpose of the Act is to facilitate a sustainable development of energy supply by promoting the use of RES in the electricity sector. The objective is the

TABLE 4.1

Current Status and Targets under the *Energiewende* in Germany

	Basis	2011	2020	2030	2040	2050
Greenhouse gas emissions (reduction)						
Greenhouse gas emissions	1990	−26.4%	−40%	−55%	−70%	−80% to −95%
Efficiency (reduction/share of electricity generation)						
Primary energy consumption	2008	−6%	−20%		−50%	
Final energy consumption	2008	−2% per annum		−2.1% per annum (2008–2050)		
Gross electricity consumption	2008	−2.1%	−10%	—	—	−25%
Combined heat and power plants		15.4% (2010)	25%	—	—	—
Building stock (reduction/share in building stock)						
Heat requirement		—	−20%	—	—	—
Primary energy requirement		—	—	—	—	Appr. −80%
Building refurbishment		1% per annum		Increase to 2% per annum		
Transport (reduction/number of vehicles)						
Final energy consumption	2005	Appr. −0.5%	−10%	—	—	−40%
Electric vehicles		Appr. 6600	1 million	6 million	—	—
Renewable energies (share in consumption)						
Gross electricity consumption		20.3%	35% min	50% min	65% min	80% min
Final energy consumption		12.1%	18%	30%	45%	60%

Source: Adapted from Federal Ministry of Economics (BMWi), Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), First monitoring report "Energy of the future", Summary (English), Berlin, Germany, December 2012, p. 4, See full report (in German) for detailed data, p. 21ff., p. 3, download from www.bundesnetzagentur.de/monitoringenergyofthefuture (as at March 6, 2015).

continuous expansion of RE to at least 80% of total electricity supply by 2050 at the latest, with corresponding intermediate targets (see Table 4.1). Due to the investment security for plant operators established by the EEG, the targets so far have always been exceeded. Many countries around the world are therefore adopting feed-in tariffs to promote RES in the electricity sector.

Basic elements in the EEG are the obligation to connect the facilities to the electricity grid and the obligation of grid operators to purchase and convey the electricity. The fixed feed-in tariffs per kilowatt hour paid by the grid operator for 20 years are based on the electricity production costs of the respective type of installation. They are continuously adjusted in line with cost developments.

Due to the growing market shares, *integration of electricity from RES in the energy market and system* is gaining in importance and gradually the EEG is being changed to this end. The amended EEG of 2012 introduces the possibility of direct marketing by the plant operator or a respective service provider on the spot market in conjunction with a market premium, which turned mandatory for plants over 500 kW installed capacity in the 2014 amendment. The plant operator receives a comparable total remuneration as in the fixed feed-in system, which now arises as the sum of revenues in the electricity market and the market premium. Yet facility operation considering the electricity price allows (slightly) higher profits and thus encourages the integration of RE. Corresponding potentials are primarily available in adjustable systems such as biogas facilities.

In addition, the 2014 amendment introduced controversially discussed auction procedures to determine the necessary funding of RE plants. There is great concern regarding the expectations of reduced costs of RE development. Private citizens and cooperatives, who have covered the main part of RE investments so far, might not be able to manage auctioning procedures and economic risks. RE development might be taken over by a few large companies and the current satisfaction with the Energiewende amongst German citizens could suffer.

The electricity that is not direct marketed is sold on the electricity exchange by transmission system operators. The remuneration paid to plant operators is reduced by the sales proceeds. The remaining sum and the paid premiums are allocated to the quantity of electricity sold in Germany and is thus paid by the consumers. This means, the financing of this instrument is independent of annual public budgets, which is a major reason for the stable development of the expansion of RE in the electricity sector [25].

The EEG must be linked with other climate protection instruments. For example, when setting emission caps the European emissions trading system takes into account the GHG emission reduction expected to arise from the EEG development targets and corresponding policies in other EU MS.

4.3.3 Renewable Energies Heat Act and Market Incentive Program

The Renewable Energies Heat Act (EEWärmeG) sets a target of 14% to increase the proportion of RE in final energy consumption for heating and cooling in Germany by 2020 [26]. This percentage is to be achieved by the expansion of RE for heat supply in buildings. For new buildings partial mandatory use applies: a portion of the building supply with heat and cooling must be covered by RES such as geothermal, solar thermal, or biomass. Alternatively, compensating measures for the efficient use of energy may be applied.

For existing buildings in general no mandatory use of RE applies. They are instead incentivized by financial support from the Market Incentive Program (MAP) [27]. Merely public buildings which are thoroughly renovated are for role model reasons obliged to use RE. The restriction of mandatory use to new buildings reduces the scope of the law considerably. Experts therefore advocate obligatory use of RE in the course of extensive refurbishment of all existing buildings. This is rejected by relevant stakeholders such as housing associations citing lack of economic viability. Regardless of this, however, use of RES in combination with EE measures in buildings must be strongly supported.

Additionally to the measures under the EEWärmeG, the MAP fosters the installation of RE facilities for heat supply in general by grants paid by the Federal Office of Economics and Export Control (BAFA). Moreover, the "Premium" Reconstruction Credit Institute (KfW) Renewable Energies Programme finances large commercial RE installations through inexpensive loans. In 2011, a total amount of €350 million were available. To achieve the Energiewende target of 14% by 2020, the MAP must be continuously developed.

4.3.4 Energy Efficiency Measures for Buildings

To achieve German and European targets, the entire building stock must undergo energy-saving renovation in the framework of regulatory elements and a long-term support strategy.

In Germany, the legal basis for this is the *Energy Saving Ordinance* (EnEV). It was formed in 2002 through merging of the Thermal Insulation Ordinance and the Heating Systems Ordinance to facilitate a coordination of technical and heat insulation requirements (i.e., a lower level of thermal insulation can be compensated for by better plant technology, and vice versa). Its central requirement for new buildings and extensively refurbished buildings is the limitation of the specific annual primary energy demand for space heating, ventilation, cooling, and water heating. This facilitates an adequate evaluation of the use of RE, among others. In addition, for new buildings the Ordinance requires compliance with a minimum level of thermal insulation by limiting transmission heat loss of the building shell. For major refurbishment of existing buildings (e.g., rendering refurbishment of external walls), it sets requirements for the heat transmission coefficient of the building components concerned. The energy quality of a building is described in an energy certificate, which must be issued and presented when a building is constructed, sold, or rented out.

The requirements of the EnEV were gradually further increased in 2007 and 2009. Another step will apply from 2016 to achieve the EU target for a nearly zero-energy standard for new buildings by the end of 2020. Refurbishments should be made using passive house components no later than 2018. For the funding of building refurbishment the KfW programme "Energy Efficient Refurbishment" was set up. It should continue to be equipped with a budget of at least €2 billion/year beyond 2020 in order to promote this important task.

4.3.5 Germany's *Energiewende*

In 2010 and 2011, the German government adopted a number of instruments, measures, and long-term goals for a permanent transformation of the energy supply system, subsuming them under the term *Energiewende*. The aim is for Germany to become one of the world's most energy-efficient and environmentally friendly economies which achieves a secure supply of energy with competitive prices and a high level of prosperity [28]. Instruments already in place prior to this, such as the EEG and its goals, were integrated into this concept. The *Energiewende* envisages a significant long-term reduction of energy consumption through much more efficient conversion and use of energy and the extensive replacement of fossil energy sources with RE (see Table 4.1). The complete phase-out of nuclear energy by 2022, which had already been adopted in 2004, was confirmed in the wake of the accident at the Fukushima nuclear power plant.

The implementation of the *Energiewende* is monitored through annual *monitoring reports* and a 3-year *progress report*, which is evaluated by independent experts. The public is closely involved in various developments in order to win the necessary acceptance. Barriers to the planning, funding, realization, and marketing of projects are addressed. On the technical side,

- Fossil-fuel power plants and RE installations are further developed with a view to improving their EE
- Grid expansion—regional, national and offshore—is systematically planned and promoted within the scope of annually revised grid concepts
- Concepts for the integration of heat and electricity use are developed
- Market integration is improved through development and promotion of load management and storage

German government supports, through research programs and other instruments for market development, investigations into cost reduction in the use of RE and EE, and also promotes marketing and the development of new market models to improve supply security.

The *economic effects* of the development that has been set in motion are, in principle, viewed positively. However, their assessment involves methodological problems. For instance, the current development as guided by Germany's energy policy must be compared with the unknown development that would have taken place without this guiding influence. The rise in energy prices brought on by the support must be contrasted with avoided energy imports, avoided external costs such as damage to the environment and climate, or industrial innovations from research and development. For example, in 2011 energy imports valued at €25 billion were avoided due to efficiency measures and RE expansion (energy imports in that year came to €89 billion). The investments triggered by the support, as well as employment and growth effects, also figure on the positive side of the balance sheet, but must be checked against the dampening impact of higher energy prices [30].

Criticism by independent experts and relevant institutions is based on various aspects of the development of individual key indicators. In the area of EE improvement in both the heat and transport sectors, a key prerequisite for GHG reduction, the limited progress is being criticized. In order for the *Energiewende* to succeed, it is essential that EE renovation of the building stock be speeded up. Development and system integration of RE does not happen automatically, not even in the electricity sector, but is progressing only slowly, especially in the heat and transport sectors. The implementation of integrated mobility concepts for passenger and freight transport, which help reduce dependency on fossil energy resources through more efficient traffic management, is essential to achieve this. Environmental protection, as a key requirement for sustainable development, continues to be relevant even when the use of RE (not just of biofuels) is substantially increased. Criticism is also leveled at the economic evaluation of energy supply, which is geared primarily to energy prices rather than macroeconomic indicators including external costs where appropriate. There are also reminders not to forget coordination with European climate policy and to ensure the functioning of the European emissions trading scheme. The drop in allowance prices has largely eliminated incentive for GHG reduction. The experts lament the lack of suitable indicators in several areas (e.g., EE, environmental protection, economic effects), which confounds proper assessment of the development [31].

Energy policy in Germany has embarked on a difficult, highly ambitious course, which is why it is followed closely worldwide. Despite all criticisms, the experts emphasize in their opinion that the process has only just begun and that this prohibits rash or overcritical judgment. It is important, however, that the advancement of the many and varied tasks remains sufficiently dynamic to prevent the possible loss of positive economic and technical development perspectives.

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5

Energy Conservation and Renewable Energy Policies in China

Ming Yi and Yue (Ada) Wu

CONTENTS

5.1 Energy Conservation

As the world's second largest economy, China has remained at an average annual growth rate of about 10% for the last 30 years. With rapid growth of its economy, China's energy sector has also made remarkable progress. China is now the world's largest energy producer and consumer. It has built up a comprehensive energy supply system comprising coal, electricity, petroleum, natural gas, and new and renewable energy resources.[1] However, China has also paid a costly price and faced stiff challenges in the process of transformation from a backward developing country to one of the top economies in the world. During the 11th Five Year Plan period (FYP, 2006–2010), China consumed 40% of the coal, 50% of the cement, 60% of the iron and steel, and 9% of the oil produced in the world, but it only created 5% of the world GDP during the same period.[2] China's energy consumption per unit of GDP is five times the world average.[2] The rapid economic development also brought up serious consequences for the country's air, land, and water.

With limited fossil energy resources at home and huge emission control pressure from the international world, energy conservation and renewable energy have increasingly been a priority of the Chinese government. In 2009, China made a commitment that it would reduce the carbon emission per unit of GDP (carbon intensity) by 40%–45% by 2020, relative to 2005 intensity levels. In 2014, China announced that it will reach carbon emission peak in 2030. To achieve these goals and other related energy efficiency and renewable energy targets, the Chinese government has enacted various laws, rules, and regulations; implemented numerous energy efficiency and renewable energy programs; and also reconstructed its energy-governing agencies to make them function more efficiently.

China's energy sector has been mostly regulated and controlled by government agencies and state-owned enterprises (SOEs). China's National Development and Reform Commission (NDRC) is in charge of coordination of energy planning with the country's overall economic and social development. The National Energy Administration (NEA), which was established in 2008 and restructured in 2013, is under the NDRC and responsible for formulating and implementing energy development strategy, planning, and policies; advising energy system reform; and regulating the overall energy sector in China. Specifically, renewable energy development in China is mainly under the jurisdiction of NEA's New Energy and Renewable Energy Department. In addition to the NDRC, industry energy efficiency is also under the jurisdiction of Ministry of Industry and Information Technology (MIIT), whereas Ministry of Housing and Urban-Rural Development (MOHURD) also covers building energy efficiency. All these government agencies work with each other and other related government agencies such as the Ministry of Finance (MOF), the Ministry of Science and Technology (MOST), and the Standardization Administration in terms of fiscal, tax, and financial incentives; energy-related science and technology; and technical standards and codes for energy conservation and renewable energy development.

5.1.1 General Policy

In 2010, China reduced 19.1% of energy consumption per unit of GDP compared with the level of 2005, close to the 20% reduction target that the Chinese government set for the 11th FYP period that ended 2010. This is largely owing to the robust energy conservation policies and programs that the Chinese government implemented. In 1997, China introduced the country's first energy conservation law, which stipulated general regulations and guidelines for energy conservation in China. The law not only identified four focus areas of energy conservation—industry, building, transportation, and public institutions, but also defined main subjects of energy conservation—enterprises with annual energy consumption more than 10,000 tce (ton coal equivalence).

The law was amended in 2007 and one of the major revisions was the introduction of target responsibility system (TRS) concept. TRS uses a top-down approach to mandate the energy conservation target for the central, provincial, municipal, and county level governments. Local governments are accountable for energy conservation by signing an agreement with higher-level government. The outcomes of local energy conservation activities are directly linked to the performance evaluation of government officials.

The 12th FYP (2006–2010) for National Economy Development and Social Development, passed by the country's legislators in 2011, first proposed that China's energy intensity (energy consumption per unit of GDP) will be reduced by 16% and carbon intensity (carbon emissions per unit of GDP) will be reduced by 17% below 2010 levels by the end of 2015. The 16% reduction will bring the total reduction for the total 10-year period (2006–2015) to 32% below 2005 levels.[3]

Also in 2011, the State Council, China's cabinet, released the Comprehensive Work Plan on Energy Efficiency and Emissions Reduction for the 12th FYP (2011–2015), which details 50 specific measures to be carried out in support of the energy intensity target (as well as absolute reduction targets for criteria pollutants such as chemical oxygen demand, ammonia, sulfur dioxide, and nitric oxides).[4] In the following year, the State Council further issued the 12th FYP for Energy Conservation and Emission Control, which proposed major targets, and prioritized tasks and key projects of energy conservation. According to the plan, priorities will be given to restricting energy-intensive and high emission sectors, retiring outdated production capacity, upgrading traditional sectors, adjustment of energy consumption structure, and promotion of service and other newly emerging industries. Specifically, the plan listed prioritized tasks for energy conservation of industry, building, transportation, and public institutions.

5.1.2 Sector-Specific Energy Conservation Policies

5.1.2.1 Industry

With its energy consumption taking up about 70% of the national total, industry is the largest energy consumer in China. According to the 12th FYP Plan for Industry Energy Conservation issued by MIIT in 2012, China aims to reduce energy consumption per unit of industrial value-added output by 21% from 2011 to 2015 and achieve energy conservation of 670 million tce. The plan also sets specific energy consumption reduction targets for 9 energy-intensive sectors (including steel, nonferrous metals, petrochemical, chemical, building materials, mechanical, light industry, textile, and electronics) and 20 types of products.

To help achieve these targets, the same plan also identified key technologies and approaches to improve energy efficiency for each one of these 9 sectors and 10 types of prioritized energy efficiency projects including energy efficiency of industrial boilers and burners, internal combustion engines, generators, recovery and utilization of waste heat and pressure, combined heat and power, industrial by-product gas, enterprise energy management and control centers, and the combination of industry and information technology in energy conservation. In 2014, MIIT published the National Industry Energy Efficiency Guide (2014), which gives a comprehensive overview of the industry energy efficiency progress made since 2000. Interested readers can refer to the detailed effort China made in industry energy efficiency effort in the past decade.[5]

As a major initiative to help meet the energy conservation target of 670 million tce, the NDRC launched the Top 10,000 Energy-Consuming Enterprises Program, targeting enterprises that use more than 10,000 tce/year. The program, which is an expansion of the

Top 1000 Program that China implemented during the 11th FYP period, aims to achieve an absolute energy saving of 250 million tce. This is almost one-third of the country's total energy saving target in the 12th FYP.[6]

5.1.2.2 Building

Building accounts for nearly one-third of China's total primary energy consumption and carbon emissions. China has 40 billion m^2 of existing buildings, but only 1% is energy efficient. Between 2010 and 2020, China is expected to add 10–15 billion m^2 of residential buildings in urban areas. To improve building energy efficiency of the existing buildings and new buildings, the Chinese government has been actively engaged in the formulation and deployment of a series of legal and policy instruments.

The Renewable Energy Law, the Energy Conservation Law, and the Civil Building Energy Efficiency Code are three major laws and regulations covering building energy efficiency. In addition, more than a dozen of provinces and municipalities have also passed their own general energy efficiency codes and specific regulations. These laws and regulations, together with the 12th FYP on Building Energy Efficiency issued by MOHURD in May 2012 and the Green Building Work Plan issued by the general office of China's State Council released in January 2013, constitute the policy framework of building energy efficiency in China.

According to the 12th FYP on Building Energy Efficiency, China aims to reduce 116 million tce and plans to achieve the target through four prioritized areas: new buildings (45 million), heating supply reform and retrofitting in China's northern areas (27 million tce), government office and public buildings (14 million tce), and renewable energy adoption in buildings (30 million tce).[7]

As early as the 1990s, the Chinese government began to launch a series of policies to promote heat reform and retrofitting in existing buildings, especially in the northern areas where centralized heating is provided in most buildings. The aim of the heat reform is to reduce the amount of energy used through the reform of the heating pricing system and to establish a market mechanism to encourage heat suppliers' effort to improve the energy efficiency of their heat supply networks.[8] Given that the building in China's northern regions accounts for more than 40% of the country's total urban building energy consumption, the residential retrofitting in northern regions also plays a significant role in China's building energy efficiency efforts. From 2006 to 2010, China retrofitted 182 million m^2 of residential space in northern China.[8] It is predicted in the 12th FYP on Building Energy Efficiency that by 2015, China will complete heat supply measurement and retrofitting of 400 m^2 of existing buildings in the northern area.[9]

In addition, the Chinese government takes the initiative to implement various energy efficiency policies and measures for government office buildings, large-scale public buildings, and college and university buildings.[7] This effort is mainly focused on energy consumption monitoring and retrofit of public buildings. By 2015, China aims to retrofiting 120 million m^2 of government office buildings and public buildings.[9]

Application of renewable energy resources in buildings is also one of the government's priorities in building energy efficiency. During the 11th FYP, major initiatives included renewable energy building demo projects and demo cities, and renewable energy application in buildings of rural areas. At provincial and local levels, many supportive policies were introduced and implemented to promote the application of renewable energy technologies in building such as photovoltaic power generation, building integrated photovoltaic (BIPV), solar water heating, and geothermal heat pumps. According to the government's plan, by 2015, the newly added renewable energy building will amount to

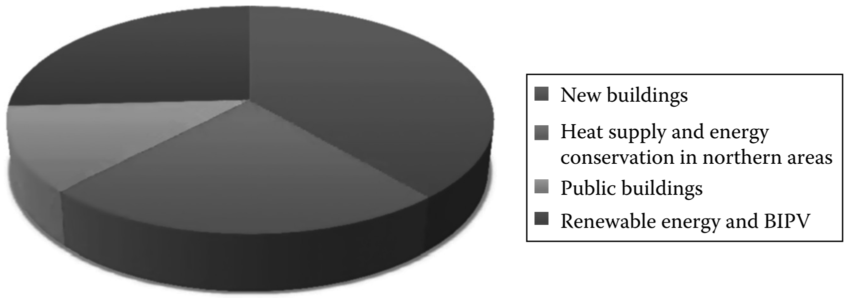

FIGURE 5.1
China's building energy efficiency target by 2015: 116 million tce. (From Ministry of Housing and Rural Urban Development, 12th FYP for Building Energy Efficiency, May 9, 2012.)

2.5 billion m^2, and renewable energy will account for 10% of the total energy consumption of buildings in renewable energy building demo cities (Figure 5.1).[9]

5.1.2.3 Transportation

The transportation sector accounts for one-fifth of China's total energy consumption, making it the nation's third largest greenhouse gas emissions industry. According to the 12th FYP for Transportation Energy Efficiency and Emission Control released by the Ministry of Transportation in 2011, the energy consumption of operational vehicles, ships, and ports will reduce 10%, 15%, and 8%, respectively, compared with the 2005 levels.[10]

According to the plan, energy efficiency in the transportation sector will focus on three aspects—transportation infrastructure, equipment, and network. Similar to the 12th FYPs for other sectors, the plan also identified major tasks and key energy efficiency projects in the transportation sector.

5.1.3 Standards and Labeling Programs

5.1.3.1 National Energy Efficiency Standards

With improvement of living conditions, the appliances and electronics of Chinese households have become a major drive of residential electricity use in China. This spurred the government to implement China's first mandatory equipment standards in 1990, which covered nine electronic products such as refrigerators, air conditioners, clothes washers, irons, rice cookers, televisions, radios, and fans. As of February 2013, China has complied and implemented 109 national energy efficiency standards. The standards have also expanded from those of household electronic appliances to those of energy-intensive industrial products, and energy measurement and management standards.[11] Very recently in 2015, the State Council issued Opinions on Strengthening Energy Conservation Standardization[12], which emphasizes a timely update of energy efficiency standards, the Top Runner program to promote the highest energy efficiency and mandatory Minimum Allowable Value of energy efficiency to outdate the backward 20% capacity and products.

5.1.3.2 China Energy Label (CEL) System

Since 2005, an energy label system has been introduced to illustrate the energy efficiency grade and typical energy consumption (TEC) values. The energy label, which usually appears on the surface or package of applicable products, allows customers to compare the energy efficiency levels of different products and helps them identify products with highest efficiency available. The energy labeling system categorizes appliances and electronics into several grades based on their energy efficiency performance. The first grade indicates the highest energy efficiency and the fifth (or third, depending on product categorization) grade indicates the least energy efficiency, and the least one is defined as Minimum Allowable Value of energy efficiency, a mandatory requirement for the product market access in China. Since 2005, products with an energy efficiency level lower than the fifth grade (or third) cannot be put into the market. In some cases, the first grade is required for government procurement or for an energy efficiency subsidy program. At the end of 2012, ten batches of products have been included in the China Energy Label (CEL) system.[13]

On December 31, 2014, the Energy Efficiency Top Runner Implementation Scheme[14] was jointly announced by seven ministries of Chinese government. This scheme was aimed to promote high energy efficiency product based on previous progress of CEL. The product has to meet the Grade 1 requirement of CEL, also be the highest energy efficiency in the same categorization. The criteria will be upgraded annually. The top runner logo will be added to the current CEL, and the certified year will also be specified. The government promised that further subsidy and promotion measures will be implemented to help R&D and product promotion.

5.1.3.3 Building Energy Efficiency Labeling and Evaluation and Green Building

China began to establish its building energy efficiency labeling and evaluation system in 2006. According to the building energy efficiency labeling regulation issued in 2008, the labeling system mainly covers new and existing government office buildings, large-scale public buildings, national and provincial building, energy efficiency demo projects, and green buildings. Building owners need to apply two types of labels—assets rating label and operational rating label. The former indicates the theoretical value of building energy efficiency evaluated during the acceptance stage, whereas the latter indicates the actual values of building energy efficiency evaluated during the operation of the building.[7] A five star rating system is also introduced in the regulation, with five stars representing the most energy efficiency building. This evaluation and labeling system was updated in 2014 and extended to residential buildings.

Since 2009, the MOHURD has promoted building energy efficiency labeling in newly built government office buildings and large-sized public buildings through pilot projects in selected provinces and cities. Building owners who apply for building energy efficiency labeling must comply with national mandatory standards, including building energy codes (design standards and the acceptance codes), before applying for building energy efficiency labels. As of 2010, 45 building projects had been approved and granted star ratings.[7]

While the U.S. LEED green building rating system is widely used in China, the country also developed its own three star green building rating system in 2004. This rating system is based on the Green Building Evaluation Standards—the first national standards for green buildings and technical guidelines for green building evaluation. Similar to energy efficiency building labeling, there are two types of green building labeling, with one covering building design and the other building operation. By the end of 2010, 113 projects were awarded three star green building label nationwide (Table 5.1).

5.1.3.4 Vehicle Fuel Efficiency Standard System

China's vehicle fuel efficiency standard system consists of fuel consumption test methods, fuel consumption limits, and labeling. China adopted its first nationwide fuel consumption

TABLE 5.1

Energy Efficiency Labeling Rating System Coverage

Energy Efficiency Labeling	Rating System	Coverage
China Energy label	1–5 stars	Ten batches of products ranging from air conditioners to personal computers
Energy Efficiency Building label	1–5 stars	New and existing government office buildings, large-scale public buildings, national and provincial building, energy efficiency demo projects, and green buildings
Green Building label	1–3 stars	Any building at the design, construction, or operation stage
Vehicle Consumption label	N/A	Passenger and commercial vehicles with a gross weight of 3.5 tons or less

limits for passenger vehicles in 2005. They are considered to be the world's third toughest, behind Japan's and Europe's.[7] In 2007 and 2012, fuel consumption limits for light-weight and heavy-weight commercial vehicles were also adopted. According to a new rule issued in March 2013, passenger cars' average fuel consumption is required to reduce to 6.9 L/100 km by 2015 and down further to 5 L by 2020.

Since 2010, vehicle fuel consumption labeling has been implemented for passenger and commercial vehicles with a gross weight of 3.5 ton or less. In addition to some generic information of a vehicle such as brand, make, and rated power, a vehicle fuel consumption label is required to contain information about fuel consumption per100 km and what test methods are used in determining the vehicle fuel consumption values.

5.1.4 Financial Support and Government Procurement

By the end of the 11th FYP period, China reduced 19.1% of its energy consumption per unit of GDP compared with 2005 level and successfully achieved the energy conservation targets set for the period. This is not only owing to the various energy efficiency policies and programs that the government issued and implemented, but also directly related to the massive capital investment that the government made in energy conservation during the period.

Over the 11th FYP period, about RMB 846.6 billion was invested to support energy conservation projects through different measures and channels. Among them, the central government invested RMB 101.7 billion, amounting to 12.1% of total energy efficiency investment in China, and provincial and local governments contributed RMB 48 billion, amounting to 5.7% of the total energy efficiency investment. And nongovernment sectors contributed RMB 696.9 billion, which comes from company investment, loan from banks, and funds raised by the stock market.

Among all the investments in energy efficiency, 95% was used to fund and subsidize energy efficiency–improving projects and the rest of 5% was used in other related fields such as policy and methodology research, institution and capacity building, promotion of energy efficiency products, and so on (Figure 5.2).

5.1.4.1 Financial Rewards for Energy-Saving Technical Retrofits

In 2007, the NDRC identified 10 types of key energy efficiency projects to receive the government rewards, such as coal-fired boiler retrofitting, waste heat and low temperature steam recovery, alternative oil, energy efficient motor systems, and energy system optimization. The program has been continued and expanded during the 12th FYP (2010–2015)

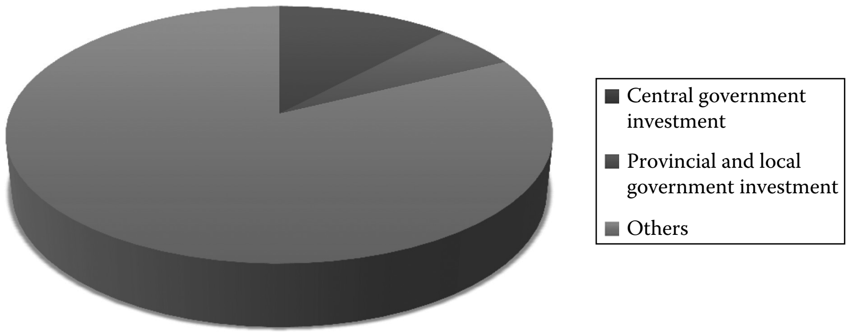

FIGURE 5.2
China's investment in energy efficiency during the 11th FYP (2006–2010). (From Dai, Y. et al., China Energy Efficiency Financing and Investment Report, 2010, China Science and Technology Press, Beijing, China, 2012.)

with raised levels of rewards and revised requirements for eligible projects and enterprises. Previously, eligible projects must have been one of those 10 projects, but the new program now covers more energy conservation technical retrofit projects. Energy-using companies used to be the only recipiens of the rewards, but in the new program, energy service companies (ESCOs) can also apply for the rewards.[15]

5.1.4.2 Energy Efficiency Product Subsidy Program

Promoting energy efficient products is the most direct and efficient way of energy conservation. During the 11th FYP period, the Chinese government provided RMB 16.5 billion to subsidize the public and businesses to purchase and provide energy efficiency products such as lights, air conditioners, and low-emission vehicles and engines.

The government initiated the Energy Efficient Product Subsidy Program in 2005 with household refrigerators and air conditioners among the first batch of products subsidized. By the end of 2012, 10 batches of products have been announced and the subsidized energy-efficient products range from rice cookers to automobiles, from household refrigerators to industry pumps and motors. Basically, the subsidies are either provided to purchasers or manufacturers of energy efficiency products. Also the actual amount of the subsidies ranges from RMB 150 to 3000. The program not only helped improve the energy efficiency level of energy-using products, especially electric appliances, but also raised the awareness of the public and business to use energy efficiency products. On May 12th, 2012, the State Council announced an allocation of RMB 36.3 billion for the subsidy program.

5.1.4.3 Fiscal Incentives for Retiring Outdated Capacity

Retiring the outdated capacity is considered as not only an important way to adjust the economic structure, but also a vital measure to achieve China's industry energy efficiency targets. During the 11th FYP period, the country invested 21.9 billion to wipe out the outdated capacity in 13 sectors. Some remarkable outcomes include the elimination of small thermal power plants with a generation capacity amounting to 80 MkW, and wiping out of outdated production capacities of 121.7 million tons of iron, 69.7 million tons of steel, 100 million tons of cement, and 10.3 tons of pulp.[2]

5.1.4.4 Financial Support for Building Energy Efficiency

During the 11th FYP period, to promote building energy conservation, the central government allocated RMB 15 billion in the following four major areas—new buildings, heat reform and retrofit projects in northern areas, government office buildings, large-scale public buildings, and renewable energy application in buildings.[3]

5.1.4.5 Energy Efficiency and New Energy Vehicles Subsidy

During the same period, RMB 2.22 billion was also allocated by the central government to promote energy efficiency and new energy vehicles in the public sector. Initially, only hybrid, electric, and fuel cell vehicles that are used in public transportation are eligible for government subsidy, but later, the subsidy scheme was expanded to include private cars. Also as an effort to speed up upgrading the auto industry, in 2009, the Chinese government launched a program to provide subsidies for replacing old cars and buses in the public domain with more fuel-efficient vehicles.

5.1.4.6 Energy Performance Contracting and Energy Service Companies

From 2010, the Chinese central government began to issue a series of supportive policies and incentives to foster the energy service industry in China. According to a reward policy for energy performance contact (EPC) projects released in 2010, qualified ESCO companies can receive RMB 240 for every ton of standard coal saved in their EPC projects from the central government and receive at least RMB 60 from the local government.

With government support and investment from financial institutions and private sectors, China's energy service sector has also seen tremendous growth in the past few years. At the end of 2012, there are 4175 companies in China engaging in energy service, among which 2339 are registered with the NDRC and the MOF. The total output of the energy service sector has also reached RMB 165.3 billion in 2012, 32.24% up from a year ago.[16] The Chinese government now considers the EPC model as one of the main market mechanisms for energy efficiency improvement and aims to build an advanced energy efficiency service system by 2015.[17]

5.1.4.7 Demand Side Management Pilot Cities

In July 2012, the MOF and the NDRC announced a new program to support adoption of energy efficiency power plants (EEPPs), demand response technologies and promotion of related scientific research, training and education, verifications, and evaluation work. In October 2012, the MOF and the NDRC announced the first four pilot cities to receive the incentive as the first step of the program.

According to the program, any pilot projects that use EEPP and load shifting technologies to achieve permanent load reductions and peak load shifting will be awarded RMB 400/kW reduced in eastern provinces or RMB 550/kW reduced in central and western provinces. For any pilot projects that lead to temporary reductions in peak load through demand response, there will be a reward of RMB 100/kW.[18]

5.1.4.8 Energy Efficiency Institution and Capacity-Building Subsidy Program

In addition to investment in specific sectors, the central government has also provided funding for institution and capacity building at provincial and local levels. The funding is mainly used to improve the energy efficiency monitoring and management capacity of provincial and municipal energy efficiency management institutions. These bodies, either called energy conservation supervision team or energy conservation center, not only help with the formulation of provincial and municipal energy efficiency planning, policies, and related research, but also facilitate the implementation of government's energy efficiency policies and regulations.

5.1.4.9 Government Procurement Program

Modeled after the U.S. Federal Energy Management Agency (FEMA), a government energy efficiency procurement policy was announced by the NDRC and the MOF in December 2004. Initially, the new policy specified that the products on the energy efficiency procurement list should be given *preferential* consideration in procurement.[19] In August 2007, the procurement policy was made mandatory at all levels of government. The energy efficiency procurement list has been updated several times and expanded from 9 types of products in 2004 to 24 by the end of 2012.

Similarly, the MOF and the State Environmental Protection Administration (now Ministry of Environmental Protection [MEP]) initiated a green purchase policy in December 2006. In July 2008, the MOF and MEP made the use of green purchase list mandatory at all levels of government.[19] There are some overlaps of the energy efficiency government procurement list and the green purchase list with the latter covering a wider range of environmentally friendly products. It is stipulated that the products listed on both lists will be given *preferential* consideration compared to those only listed on one list.

5.2 Renewable Energy

5.2.1 Market Overview

The combination of ambitious renewable energy targets, favorable government policies and entrepreneurial acumen has already made China a global leader in renewable energy. During the 13th FYP period (2015–2020), development of renewable energy and new energy sources will continue to be the government's priority given its importance in environmental protection, combating climate change and sustainable development. According to the 13th FYP for Renewable Energy which is being formulated, renewable energy will play an important role in optimizing China's energy structure and revolutionizing China's energy production and consumption.[20] The status of renewable energy will also shift from what is now called complementary energy sources to alternative energy, displacing a significant portion of fossil fuels.[21]

At the end of 2010, the installed capacities for wind and solar power both exceeded the targets that the Chinese government set in the 11th FYP (2006–2010). 2012 was another pivotal year for renewable energy development in China. The installed renewable energy reached 313 GW, up 11% from the previous year. This includes 248.9 GW of hydropower, 60.8 GW of grid-connected wind, and 3.3 GW of grid-connected solar power.[22] Most significantly, in 2012, wind power replaced nuclear power as the third largest energy source in China, after thermal and hydropower, and accounted for 2% of total energy power generation.[23] By the end of 2014, the installed capacity for renewable energy reached 430 GW, accounting for 32% of the country's total power capacity. The electricity generated by renewable energy reached 1.2 trillion kilowatt-hours, accounting for 22% of the total electricity generated during the same period.[24]

5.2.1.1 Wind Power

China ranks second in terms of wind energy resources, only next to the United States.[25] According to the findings of the wind energy resource survey and evaluation, China has 2380 and 200 GW land-based and offshore wind power potential at a height of 50 m.[26] The combined exploitable capacity is larger than that of hydropower.[1] While China is a latecomer to wind power development and deployment compared with many western countries, the country has witnessed tremendous growth in wind power in the past ten years.

At the end of 2010, China surpassed the US to become the world leader in installed wind power capacity, with 16 GW newly added wind power capacity and a total of 41.8 GW wind capacity.[27] According to the Global Wind Energy Council, the US installed about 5 GW of new wind power capacity in 2010 and its total installed capacity was 40.2 GW.[27] In terms of total grid-connected wind capacity, China also surpassed the US in 2012 with 50 GW on-grid wind capacity installed.[28] By the end of February 2014, the cumulative grid connected installed capacity for wind power reached 100.04 GW, which makes China the first country to top the 100GW wind power capacity milestone.[29] With the rapid and continuous increase of wind power installed capacity, China has already positioned itself as the largest wind power market in the world.

China's wind industry has mainly benefited from the favorable market conditions that government policies and regulations helped to foster. After several years of rapid growth, the wind power industry has been transitioning from frenzied initial stage with the emphasis placed on the maximum installed capacity to a new development phase focused more on quality, safety, reliability and efficiency. Manufacturing overcapacity, together with intense market competition and government policy to hold back funding and approval of wind projects have combined to cut the profit margins of many wind manufacturers in China. The growth rate of newly added wind power installed capacity started to slow down in 2011, from 18.92 GW in 2010 to 12.96 GW in 2012. However the downward trend didn't last very long. Data for 2013 show the wind power industry has regained momentum with 16.08 GW of new wind capacity installed during the year. In 2014, the newly added wind capacity reached an all time high with 19.81 GW new wind capacity installed.[30]

One of the challenges of China's wind power development is grid connection. Due to their weak capacity, many local grids are unable to integrate all the electricity generated by wind power. Large-scale wind power integration also creates serious problems in terms of power grid dispatch, reactive power regulation, grid safety and power quality. Furthermore, since the geographical distribution of wind energy resources does not match the country's power load profile, long distance transmission of electricity becomes necessary. Yet this is again restricted by the limited transmission capacity of power grids.

Largely due to insufficient power grid infrastructure, a great amount of electricity generated by wind power has to be discarded each year. National Energy Administration statistics show that more than 10 billion and 20 billion kWh of electricity generated from wind power was discarded in 2011 and 2012 respectively.[31] The grid connection problem not only needs a technical fix, but also calls for a fundamental change in China's overall power system. After the business of power generation was split from grid companies, which now only focused on power transmission and distribution, grid companies have little motivation to integrate renewable energy into their grids because the integration of renewables will cost them more money due to the extra expenses incurred in the grid connection and electricity purchases.

With the implementation of favorable wind power policies, improvement of grid transmission capacity and reduced amount of wind, the average rate of abandoned electricity fueled by wind power has been decreasing over the past two years from 11% in 2013 to 8% in 2014, which is at the lowest level in recent years.[32] However, the rate climbed again to 18.6% in the first quarter of 2015.[33] The fluctuation of the rate shows wind power grid integration and absorption have been and will continue to be a big challenge for the development of wind power in China.

5.2.1.2 Solar Power

Since 2007, China has also become the largest PV products manufacturer in the world. Among the world's top 10 solar PV module suppliers, six are based in China.[34] About 90% of PV panels manufactured in China were exported to countries with more favorable incentives, such as North American and European countries. From 2002–2008, there were only a few demonstration solar PV projects in China.[35] This is largely due to the high cost of PV systems and the barriers of grid connection, a problem also faced by China's wind power industry.

The cutback of government subsidies and declining PV demand in the European countries had a great impact on China's PV manufacturers, which rely heavily on the foreign market. What weighed further on China's PV industry are the anti-dumping and countervailing duties against Chinese PV products exported to the US, followed by similar trade investigations launched in the European Union, Canada and India. To offset their export losses and absorb manufacturing overcapacity, the Chinese PV manufacturers quickly turned to the domestic market which was largely untapped at the time and emerging markets which witnessed a surge in the growth of renewable energy in the past few years. Overcapacity has also triggered a new round of merging and restructuring among manufacturers in the PV sector. The Chinese government sees this as an opportunity to eliminate the outdated production capacity and upgrade the country's PV industry. It also released a variety of supportive policies to further encourage the expansion of the domestic PV market.

According to research released in the NPD Solarbuzz quarterly report, the demand for PV panels from the Chinese end-market has already risen to 33% of global demand during the final quarter of 2012.[36] In 2013, China has already become the world's largest market for solar power, outstripping Germany, Japan and the US with the installation of 12 GW of new PV capacity. This represents a 232% increase in generation capacity.[37] In 2014, China added 10.6 GW of newly installed PV capacity, which is one fourth of the world newly added installed capacity that year.[38]

China also made remarkable progress in concentrated solar power (CSP) generation in the past few years. According to the 12th Five Year Plan for Solar Power Generation Development, the installed capacity for CSP will reach 1 GW and 3 GW by 2015 and 2020.[39] In 2010, a 50 MW CSP commercial project in Inner Mongolia was launched through a public tending program. However, as of the time of writing, the project hasn't been constructed. It was not until July 2013 that the first CSP plant was connected to the power grid and began to generate electricity in Qinghai province. With a 50 MW installed capacity, the plant is expected to generate 112.5 million kWh electricity, equivalent to reduction of 394,000 tons of standard coal and about 103,000 tons of carbon dioxide.[40] The CSP plant symbolizes the transforming of CSP projects from a small-scale technology demonstration to a large-scale commercial project.

Compared with other forms of solar power utilization, CSP generation has lagged far behind. This is largely due to the lack of clear and robust government support for CSP. First, there's no fixed feed-in tariff (FIT) for CSP generation, and the FIT for a CSP project is decided on a case by case basis. In September 2014, the FIT was set at RMB 1.2/kWh for the 50 MW CSP plant in Qinghai. Secondly, the approval process of a CSP project can be very lengthy and sucks up a large amount of time and money from CSP project investors.[41]

Solar heat utilization has seen rapid development in China with favorable central government policies and incentives from provincial governments. Major forms of solar heat utilization include solar water heaters, centralized solar hot water supply, solar heating and cooling, industrial application of medium and high temperature solar energy, and solar cookers and solar houses, especially in remote and rural areas.[1] Among all, the solar water heater is the most widely used and commercialized form of solar heat utilization. After years of rapid development, China has already become the largest solar water heater manufacturer in the world with a complete value chain of solar water heater production. In 2012, China's solar water heater production has reached 63.9 million m^2 at a growth rate of approximately 10.7%, with total inventory of roughly 258 million m^2.[42] Due to overcapacity and shrinking demand, the solar water heater industry has also suffered a major decline since 2012. In 2014, solar heater production declined 17.6% from a year ago, which is the first negative growth in 17 years.[43]

5.2.1.3 Biomass

China has abundant biomass resources with an estimated annual amount of more than one billion tce. This is more than 1.3 times the country's annual energy consumption.[44] According to a report released by the Chinese Academy of Science on China's renewable energy development strategy, the capacity of biomass energy resources is twice as much as that of hydropower and 3.5 times that of wind power.[45] While biomass is a prioritized renewable energy together with wind and solar, the Chinese government failed to meet some of the targets for biomass energy set in the 11th FYP of Renewable Energy, such as the targets for methane utilization, nonfood fuel ethanol, biomass pellets and briquettes.[46]

There are many hurdles for large-scale utilization of biomass energy, one of which is the nature of biomass energy, such as low energy density and nonuniform consistency. The principal biomass feedstocks in China are wastes and residues from agriculture and forest industries; animal manure from medium- and large-scale livestock farms, and municipal solid waste.[44] So far, there's still no nationwide survey on the quantity, exploitable capacity and distribution of biomass energy resources. The feedstock of biomass energy is mainly collected manually with small-scale machinery. The collection, transportation and storage of feedstock of biomass energy are extremely inefficient. In addition, the technology of biomass utilization and equipment manufacturing remains a bottleneck for developing biomass energy such as the technologies of biomass gasification and second-generation fuel ethanol.

5.2.2 Renewable Energy Policies

5.2.2.1 General Policies

Renewable energy was first incorporated into the legislation list as early as 2003. One of the milestones of renewable energy is the Renewable Energy Law that came into force in 2006. The Law not only identifies the strategic role of renewable energy in energy security, environmental protection and sustainable development, but also serves as a framework for renewable energy related government work including resources investigation, target setting, planning, pricing and cost share, fiscal, financial and tax incentive mechanisms for renewable energy. After the Renewable Energy Law took effect, more than a dozen regulations were enacted to help enforce the law. Some of the provisions of the law were also amended in 2009. The majority of these renewable energy related policies are related to wind power and solar PV generation, whereas only a few are focused on bioenergy, geothermal and ocean energies.

The Renewable Energy Law stipulates that China's NRDC is in charge of overall planning of renewable energy development and energy pricing; the China Standardization

Administration manages technical standards and codes related to renewable energy; the MOF is responsible for fiscal and financial incentive mechanisms, like tax breaks and subsidized loans.[47] Established in 2008, the National Energy Administration is under the jurisdiction of NDRC and responsible for drafting and implementing energy development strategies, plans and policies, advising on energy and regulating sector.[48]

According to the Law and regulations, grid companies are mandated to sign grid integration agreements with eligible renewable energy power generation enterprises and to purchase the electricity that is generated. All the extra costs that grid companies paid to integrate and purchase the electricity generated by renewable energy compared to traditional power (also known as renewable energy surcharge or premium) need to be shared by end users of electricity nationwide. The renewable energy surcharge was first set at RMB 0.002/kWh under the Law and was later raised to RMB 0.004/kWh in 2009.

A renewable energy development fund was established under the Renewable Energy Law to promote renewable energy development and utilization. At first, the source of the fund is solely government allocations, but according to a 2009 amendment to the Law, part of the fund will come from the renewable surcharge paid by all electricity users around the country. With the rapid development of renewable energy installed capacity, the shortfall in funding the renewable energy projects has increasingly become a prominent problem. Statistics show the shortfall of the renewable energy development fund reached RMB 1.3 billion in 2009 and 2 billion in 2010.[49] By the end of 2014, the shortfall has expanded to RMB 14 billion. To make up for the shortfall, the renewable energy surcharge was raised twice to finance the fund from RBM 0.004/kWh to RMB 0.008 /kWh in 2010 and further to RMB 0.015 in 2013.[50]

In September 2007, more than eighteen months after China's Renewable Energy Law called for the establishment of overarching renewable energy targets, the NDRC released the Medium and Long-Term Plan for Renewable Energy Development. It was the first time the Chinese government set explicit quantified targets for renewable energy consumption. The plan established a national renewable energy target (including hydropower) of 15% of total primary energy consumption by 2020.[51] A renewable energy quota system was also introduced in the Plan. In the service range of large-scale power grid, nonhydro renewable energy power generation will surpass 3% by 2020. Power generators with self owned installed capacity over 5 GW are required to have nonhydro renewable energy installed capacity accounting for 8% of total self owned capacity by 2020.[52]

As of April 2015, a new version of the renewable energy quota system has been approved by NDRC and is now under the review of the State Council. According to this version, the renewable energy targets, which are categorized as basic targets and advanced targets, will be first broken down by province and then by city and county within a province.[53] Provincial governments and grid companies are responsible for meeting the targets of renewable energy, whereas local governments will exercise their management responsibility. Instead of setting specific and binding renewable energy targets, the new version allows provincial and local governments more flexibility to achieve their targets.[52] Furthermore, governments that are unable to meet their renewable energy targets will be punished, whereas those that meet the targets ahead of time will be rewarded. In addition to the renewable energy quota system at the national level, a few provinces, such as Hubei and Inner Mongolia, also released their own renewable energy quota systems.

In addition to large-scale renewable energy deployment, China has also been promoting distributed utilization of renewables based on the principle "self-generation, self consumption and feeding the surplus into the grid." This effort includes promoting distributed renewable energy technologies, standards and demonstrations, providing subsidies and tax incentives for distributed renewable energy projects.

To further drive comprehensive renewable energy use in urban and rural development, China plans to build 100 new energy demonstration cities and appoint 200 green energy counties according to the 12th FYP for Renewable Energy Development. One of the requirements for a new energy demonstration city is that by 2020, renewable energy will be no less than 6% of the candidate city's total primary energy consumption. According to the plan, China will also deploy 30 new energy microgrid demonstration projects as a way to explore the economic and technological feasibility of renewable energy-powered microgrids.

5.2.2.2 Wind Power Specific Policies

Wind power is the most commercially available nonhydro renewable energy in China. According to the 12th FYP for Renewable Energy Development released in 2012, China will have a total of 10 GW grid-connected wind installed capacity by 2015, and the annual wind power generation is expected to amount to 190 billion kWh by that time.[54] By the first quarter of 2015, the target for land-based wind installed capacity was achieved with a total installed capacity up to 10.1 GW.[55]

From 2003 to 2009, China mainly implemented a wind power concession program to promote large- scale deployment of wind projects. Under the program, wind power projects with installed capacity smaller than 50 MW is under the jurisdiction of provincial government, and the price of electricity generated from projects was determined through a competitive bidding process. Wind projects larger than 50 MW need to be approved by the central government, NDRC.

Under the Power Purchase Agreement (PPA) signed by a power grid company and a wind power project owner, the former is required to purchase all the electricity generated by the latter. A two-phase electricity rate is applied during the effective period of the PPA. Before the cumulative electricity production of wind power is equivalent to 30,000 full load hours, the electricity rate is the bid price specified in the PPA. Thereafter, the rate is the average price on the power market at the time.[56]

The wind power concession program not only plays an important role in wind power development from demonstration projects to scale up construction, but also helps the government to determine an appropriate FIT for land-based wind power. The price of nonconcession wind projects during the period was either based on the bidding results in the same area or required to be approved by the provincial government on a project by project basis.

In effect since August 2009, a wind power FIT policy for land-based projects was introduced in China. It divided China's territory into four regions with different FITs specified based on wind resources and construction conditions. The tariffs were first set per kilowatt hour at RMB 0.51, RMB 0.54, RMB 0.58 and RMB 0.61.[57] In January 2015, the FIT for the first three categories were lowered to RMB 0.49, 0.52 and 0.56.[58]

As of the end of 2014, China ranks fifth among the world's top offshore wind installation countries. After China's first offshore wind demonstration project was successfully completed and connected to grid in Shanghai, China launched the first concession program for an offshore wind project in China's southeast coastal province of Jiangsu in 2010. A few other provinces have also started working on offshore wind power development plans since then. By the end of 2014, China installed 229.3 MW new offshore wind capacity and the total installed capacity from offshore wind has amounted to 657.9 MW.[59]

According to the 12th FYP for Wind Power Development, the installed capacity of offshore wind power will reach 5 GW by 2015 and 30 GW by 2020.[60] With less than one year left and 657.9 MW total offshore installed capacity so far, China is unlikely to meet its target of 5 GW offshore installed capacity by 2015 (Table 5.2).

TABLE 5.2

Targets of Wind Power Development by 2015 and 2020

Types of Targets	Main Targets	2015	2020
Installed Capacity	Land-based wind power	99 GW	170 GW
	Offshore wind power	5 GW	30 GW
	Total Installed Capacity	100.4 GW	200 GW
Generating Capacity	Electricity Generated by Wind Power	190 Billion kWh	390 billion kWh
	Percentage of Electricity Generated by Wind power	3%	5%

Source: Energy Research Observer Net. (2012) The 12th FYP for Wind Power Development. September 17. Retrieved April 30, 2015 from http://www.chinaero.com.cn/zcfg/xny/09/127069_4.shtml

In June 2014, NDRC also released the FIT scheme for offshore wind projects commissioned before 2017, which is RMB 0.75/kWh for intertidal and RMB 0.85/kWh for offshore wind projects.[61] Later that year, the NEA issued a national offshore wind power project construction plan to boost the development of offshore wind power. According to the plan, 44 offshore wind projects will be constructed from 2014 to 2016 with a total installed capacity of 10.53 GW.[62]

In addition to the FIT for land-based and offshore wind power, wind power generation enterprises can also enjoy a series of tax incentives such as 50% of value-added tax (VAT) return, exemption from corporate income tax during the first three years after the company earns profit from sales; and a 50% reduction of income tax during the 4–6 years after it earns a profit. Wind power equipment manufacturers can also enjoy some tax exemption or cut on import duty of certain key parts and raw materials of wind turbines. Complementing these favorable policies and regulations at the central government level, local governments also released a series of favorable policies on land use and taxation to encourage wind equipment manufacturers and wind project developers to invest in wind projects.

To address the grid integration and safety issues, the Chinese government has tightened the wind power project approval procedure from 2011, requiring all new wind power projects to be approved by the NDRC. Projects only approved by the provincial government will not be allowed to be connected to the power grid or enjoy renewable energy subsidies. In addition, projects in regions where over 20% of electricity generated by wind power is discarded due to limited integration and transmission capacity will no longer be approved. In May 2013, the NEA transferred authority over wind power project approval from NDRC to provincial or local governments.[63] However, a wind project still needs to be listed in the NEA project approval plan in order to receive government renewable energy subsidies.[64]

5.2.2.3 Solar Power Specific Policies

Solar power is the third most commercially viable renewable energy following hydropower and wind. According to the 12th FYP for Solar Power Development issued by the NEA under the NDRC, the target for installed solar power is 21 GW by 2015, among which 10 GW is distributed PV systems, 10 GW is grid connected PV and 1 GW is CSP system.[65] The plan also sets the target of installed solar power generation at 50 GW by 2020. The target of installed solar power by 2015 has been raised several times and the target was raised to 35 GW in 2013. In addition, the 12th FYP also set the total solar heat collection area at 400 m^2 by 2015 (Table 5.3).

Unlike wind power, early policies treated solar power more as one of the supplementary solutions to provide electricity to the remote and rural areas. This mindset was dominant among China's policy makers for quite a long time. It partly explained the reason why China prioritized wind over solar power up to 2008.

TABLE 5.3

China's Targets for Solar Power Installed Capacity by 2015 and 2020

Installed Capacity	2015	2020
Grid-connected PV	10 GW	20 GW
Distributed PV	10 GW	27 GW
Concentrated Solar Power (CSP)	1 GW	3 GW
Total	21 GW[a]	50 GW

Source: National Energy Administration. (2012) The 12th FYP for Solar Power Generation Development. July 7. Retrieved April 30, 2015 from http://zfxxgk.nea.gov.cn/auto87/201209/P020120912536329466033.pdf

[a] This target was raised to 35 GW in 2013.

To promote large-scale PV application and determine an appropriate FIT for solar energy, the Chinese government also adopted a concession program for large-scale grid-connected PV projects. In 2009, China issued its first tender for two 10 MW utility scale solar power plants in Dunhuang, Gansu province. In 2010, the Chinese government initiated a second round of concession bids for 13 large-scale PV projects for a total of 280 MW. The first project was granted RMB 1.09/kWh for the power fed into the grid. In the second round, the winning bids ranged from RBM 0.728/kWh to RMB 0.991/kWh. Largely due to the advocacy of PV manufacturers and local government, the FIT for solar power was established in July 2011. Under the scheme, projects approved for construction prior to July 1, 2011 is eligible for the FIT of RMB 1.15. Projects that finished construction and began the process of commencing generation prior to December 31, 2011 are also eligible for the FIT.[66] Later in 2011, the FIT was lowered to RMB 1/kWh. In addition to these concession projects, there are also other grid-connected PV projects implemented during the same period, and their power price is set by the government on a project by project basis.

In March 2012, a new solar FIT scheme for utility PV ground power plants was released for comments. The new solar power FITs were set at RMB 0.75/kWh, 0.85/kWh, 0.95/kWh and 1/kWh for each of four regions categorized based on different solar radiation level and construction conditions. In August 2013, NRDC announced a new FIT policy for solar power that was set at RMB 0.9/kWh, 0.95/kWh and 1/kWh for each of three types of regions.[67]

To address the overcapacity of solar power production while preventing further grid integration issues, the government has implemented robust subsidy programs for deployment of distributed PV. The Golden Sun program, initiated by the MOF, the Ministry of Science and Technology and the NEA in 2009, provides capital subsidies to electricity end users for solar PV installations. The Golden Sun program subsidies were granted before the construction of a project and there was very limited monitoring of an approved project's power generation. While the government tried hard to improve the implementation of the program, controversies around the program still exist. In March 2013, the government announced that the Golden Sun program would no longer accept applications. Later that year, the Golden Sun program was officially ended. Statistics show four batches of PV generation projects with a total 60 GW installed capacity were approved under the program. However, there is no public information on the status quo of the projects, the amount of electricity generated, and the total amount of subsidies received by these projects.

As a separate program, the Ministries of Finance and Housing and Urban–Rural Development (MOHURD) are providing subsidies to promote application of rooftop PV and building-integrated PV (BIPV) systems. Like Golden Sun program, this program is also one-time subsidy provided before the construction of the project. Differently, the Golden Roof program only focuses on BIPV whereas the Golden Sun program provides subsidies to both rooftop PV and BIPV. The two programs used to be one program jointly issued by the MOF, Ministry of Science and Technology, MOHURD and NEA, but was announced and implemented separately due to different views of MOHURD and NEA on distributed PV policies.[68]

For distributed PV projects, a subsidy of RMB 0.35/kWh was first introduced in 2012. In August 2013, NDRC raised the subsidy to RMB 0.42/kWh and made the eligibility period of the subsidy as long as 20 years.[65] In addition to the subsidy at the national level, provincial and local governments also provide additional subsidies to distributed PV projects in their jurisdictions.

During 2014, the Chinese government further issued a series of favorable policies to accelerate the growth of distributed PV. One of the most noteworthy policies is that rooftop distributed PV project owners can choose to sell either excess electricity or all electricity generated to the grid and that the electricity price will be the same as the local FIT for ground PV power plant. In the past, a distributed PV project owner could only sell excess electricity to a power grid after self consumption.[69] By guaranteeing all electricity purchased by the power grid and a fixed price paid to the project owner, the policy shift guarantees the stable revenue of a distributed PV project and thus is welcomed by the distributed PV project developers around the country.

At present, distributed PV projects mainly consist of PV power plants for residential use, rooftop PV projects of public facilities, and industrial and commercial buildings.[70] Due to reasons like difficulties in project financing, grid integration, and uncertainty in power load, distributed PV development has lagged far behind of that of large-scale ground PV power plants. Since China failed to meet its PV installed capacity targets in 2014 mainly because of distributed PV, NEA no longer sets a specific target for distributed PV for 2015.

Besides, a large scale distributed PV application demonstration area program was launched by the NEA in 2012, requiring provincial government to submit a plan on establishing pilot areas for distributed PV power generation. Following the NEA's efforts, the State Grid Corporation of China, the country's largest state-owned utility, released a series of documents to simplify the procedure of grid integration of residential distributed PV power generation no more than 6 MW. As of 2015 the NEA has announced 30 distributed PV application demonstration areas.[71]

5.2.2.4 Biomass Specific Policies

In China, biomass energy development is an integral part of the government's efforts to develop local economy, improve living conditions in rural areas, and protect the ecology. In the wake of the food crisis, the government issued strict rules to make sure that biofuel development (including fuel ethanol and biodiesel) does not compete with crops intended for human consumption and that the land for developing feedstock should not compete with land for crop production. The government also encourages experimentation with alternative crops such as sweet sorghum and cassava for new ethanol plants.[72]

According to the Chinese government's 12th FYP for Biomass Energy, installed capacity of biomass energy will reach 130 GW by 2015 with annual biomass power generation amounting to 78 billion kWh. The annual production of biogas will reach 22 billion m^3. In terms of various forms of biofuel, China's fuel ethanol utilization capacity will reach 4 million ton and the capacity of biodiesel and aviation biofuel will reach 1 million ton by 2015. In addition, the government aims at achieving full commercialization and large-scale utilization of biomass energy in its power sector, heat supply, and rural life. In the transportation sector, a larger portion of biomass energy is expected to replace fossil fuel by 2015.[73]

The FIT for biomass was first set at RMB 0.25/kWh premium plus the province-specific coal power generation price. The premium was then increased to RMB 0.35/kWh for biomass. The FIT for biomass energy was later raised to RMB 0.75/kWh in 2010 by NDRC. Like solar and wind, biomass energy can also enjoy a series of tax incentives. For instance, the electricity or heat generated from waste is eligible to receive tax rebates at the time the VAT is levied. The income tax for a biomass energy enterprise is calculated using 90% of the enterprise's total sales income as the base. Qualified biomass enterprises can enjoy a corporate income tax exemption during the first three years after it earns profit and enjoy a 50% cut of corporate income tax during the following three years.

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6

Renewable Energy and Energy Efficiency in India

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CONTENTS

6.1 Background

India has traditionally been a low energy and electricity consumption country, notwithstanding its large and fast growing population. This was partly because of the so-called Hindu rate of growth during the several decades after independence. The economic policy changes undertaken since early 1990s with greater participation of private sector and deregulation of infrastructure and industrial sectors resulted in higher growth rates of the Indian economy, which grew in the last decade at an annual rate of about 8%* although it has declined progressively to about 5% in the last 2–3 years because of the

* From the Economic Surveys of the period, published by the Ministry of Finance, Government of India every year.

global recession. But the chances are that growth may continue to be between 7% and 9% in the long term. This process is being accompanied by large-scale urbanization, growth of the middle class, and changing life styles, leading to a huge growth in buildings and cars and sale of electrical appliances topped by air conditioners, fridges, geysers, and microwaves. Necessarily therefore, there has been, and will continue to be, significant increases in India's energy and electricity demand. In 2011, India was the fourth largest energy consumer in the world after the United States, China, and Russia.* India has been ranked by the IMF as the world's tenth largest economy and the third largest in terms of purchasing power parity. India will continue to climb up this ladder. An Indian Planning Commission study in 2006 estimated that based on 8%–9% growth, primary energy demand may go up 4–5 times by 2031–2032, while electricity generation requirements may go up by 6–7 times. It estimated that electricity-generating capacity may have to go up to 7–800 GW.†

Energy services have always remained in focus of successive Indian governments that has resulted in the expansion of the energy infrastructure within the country and steady expansion in total energy use. Commercial energy use increased 21 times and the power generation capacity went up by 100 times during the past 60 years. In 2012, the total commercial energy supply was 537 million tons of oil equivalent (mtoe) and involved coal, oil, gas, and electricity generated from nuclear, hydroelectric, and renewable sources.‡ These figures do not include the energy that is consumed from traditional sources by 56% of Indian households.§ Estimates of energy use from traditional sources tend to be approximate, but figures indicate that in 2012, 174 mtoe of energy came from such sources as fuel wood, dung, crop residue, biogas, and waste.¶ India's energy intensity has been declining over the years. From 1.09 kgoe per U.S. dollar, it has reduced to 0.62 kgoe per U.S. dollar in 2011.**

Nevertheless, the growth of energy sector could not and has not been able to match the growth in economy in spite of impressive progress in the last decade. The energy sector continues to be viewed as an important bottleneck to India's industrial growth that in turn is seen as critical to stimulating the country's economic and social development. While supporting around 17.8% of the world population, India's share in world energy use and electricity consumption is only 5.7% and 4.0%, respectively.†† The per-capita energy use at around 0.60 toe is far below that of industrialized countries, and, more importantly, is almost only a third of the world average. The situation in per-capita electricity consumption is even worse with a per-capita annual consumption of only 710 kWh, which is around a fourth of the world average.‡‡ In fact, in the event of achieving the capacities of 7–800 GW, the per-capita primary energy consumption will rise only to almost 1.25 toe, which would still be much lower than the current world average of about 1.88 toe/capita/annum.§§ Electricity deficit levels have remained consistently high

* US Energy Information Administration 2013.
† Planning Commission of India (2006). Integrated energy policy report; Available online: http://planningcommission.nic.in/reports/genrep/rep_intengy.pdf' last accessed on 22 March 2015.
‡ Planning Commission of India (2013): 12th Five Year Plan document (Vol 2) page 133. available online: http://planningcommission.gov.in/plans/planrel/12thplan/pdf/12fyp_vol2.pdf, last accessed on 22 March 2015.
§ Census of India 2011.
¶ Planning Commission of India (2013): 12th Five Year Plan document (Vol 2 p. 133).
** Planning Commission of India (2013): 12th Five Year Plan document (Vol 2 p. 130).
†† IEA Key World Energy Statistics 2013.
‡‡ IEA Key World Energy Statistics 2013.
§§ IEA Key World Energy Statistics 2013.

in recent years with supply trailing requirement by an estimated 8%–10%.* And this may not even be reflecting the total demand. Another major challenge continues to be providing access to modern energy sources to a large proportion of the country's population. Around 45% of rural households still rely on kerosene for meeting their lighting requirements.† Further, around 86% of rural households and more than 20% of the urban households still rely primarily on traditional fuels such as firewood, wood chips, or dung cakes to meet their cooking needs.

6.2 Growth of Electricity Capacity

The Indian power sector has grown significantly since 1947. The power-generating capacity has increased from 1.3 GW in 1947 to over 261 GW by January 2015.‡ However, despite significant growth in electricity generation over the years, shortage of power continues to exist primarily on account of growth in demand for power outstripping the growth in generation and capacity additions in power generation. The average energy deficit was 9.1% and the average peak power deficit was 12.8% between 2003 and 2012.§

The Electricity Act 1910 was the first act that was introduced to govern the Indian power sector. The Electricity (Supply) Act 1948 was introduced after independence, but it did not achieve the desired results. Following the liberalization and reform of the economy in 1991–1992, the electricity sector too witnessed major policy and regulatory initiatives. A regulatory framework was set up with independent regulators in the center and states recognizing that electricity and other infrastructure sectors required substantial investments in the face of resource constraints, investment by the private sector (including foreign capital) was allowed in electricity generation. Now 100% foreign direct investment (FDI) is allowed in generation, transmission, and distribution segments. The most important among all the policies announced by the government was the enactment of the Electricity Act 2003. It opened up the power generation sector and encouraged greater private participation. It unbundled the State Electricity Boards; separated generation, transmission, and distribution; and introduced open access. Over the past few years, the government of India undertook several further measures like the National Tariff Policy, National Electricity Plan, Competitive Bidding Guidelines, and Ultra Mega Power Projects. Incentives were also given to the sector through waiver of duties on capital equipment under the mega power policy. These all resulted in a surge in creation of capacity. A capacity of about 46 GW of thermal power was created between 2006 and 2012. However, this growth in capacity should be seen in the context of what has happened in China. The total capacity of China went up from 725 GW to about 1200 GW from 2007 to 2012, respectively.¶ The growth in power capacity over the years is given in Table 6.1.

Notwithstanding this recent growth, many problems are being faced, which may make it difficult to achieve the capacity that has been estimated to be required by 2032. The problems are caused by forest and environmental and logistical issues for coal. Problems related to the liability law and increasing people's opposition after the Fukushima incident

* Central Electricity Authority, All India Electricity Statistics, General Review 2012.

† Census of India 2011.

‡ Ministry of Power, Government of India.

§ Central Electricity Authority, All India Electricity Statistics 2012.

¶ U.S. Energy Information Administration.

TABLE 6.1
Growth in Electric Installed Capacity (in MW)

	Thermal	Large Hydro	Nuclear	Gas	Renewables	Total
1950	1,153	560	0	0	0	1,713
1990	41,421	18,307	1,565	2,343	0	63,636
2002	63,266	26,269	2,720	11,163	1,628	105,046
2007	72,323	34,654	3,900	13,692	7,760	132,329
2012	113,564	38,990	4,780	18,039	24,504	199,877
2017 (estimate)	183,364	49,887	10,080	20,579	54,503	318,414

Source: Central Electricity Authority, Bangalore, India (2002–2017 are 5-year plan periods).

in Japan suggest that nuclear may increase slowly perhaps reaching about 25–30 GW by 2032, instead of the targeted 60 MW. Gas reserves are not much, exploitation of new fields has been delayed, and production from existing fields has declined, leaving much of newly created gas power capacity stranded. Oil is facing similar problems. Large hydro was forecast to reach 150 GW, but there have been environmental and logistical problems to develop this potential in the Himalayas. Even reaching 100 GW, for which we must make our utmost efforts, may be a problem. With this scenario, meeting increasing demand will require other solutions apart from efforts to maximize use of all above sources.

The Power sector in India is also facing other problems and challenges apart from those of creating generating capacity in the future. First, irrespective of the capacity created, the supply availability of fuels is becoming a problem especially with respect to coal and gas. Second, these problems are necessitating higher imports of all fuels—gas, coal, and oil. Estimates including those made in the Integrated Energy Policy Report suggest that import dependence for energy in 2031–2032 could be as high as around 60%. There is great worry about the likely import dependency on oil of over 80%–90% and coal around 45%. Third, costs of all fuels are increasing. There is perhaps rise of 10%–15% in prices of coal because of imports, and the worry is that this trend may continue. Domestic prices for gas have also increased and imported prices will be more. The price per unit of electricity generated from gas is likely to become even higher than the current solar price. Rising capital costs of nuclear plants also suggest much higher generation costs in the future. Fourth, electricity tariffs have traditionally been lower than costs and have only been revised in the last couple of years in several states, though partially. Yet there is considerable political opposition to this and pressure to reduce. Rural tariffs have been lower still, and the rural irrigation power sector has been the lowest. This has resulted in most of the utilities being in very poor financial health. This restricts both investments in improving infrastructure as also in limiting purchases of power to meet normal demand. Fifth, the rising costs of imported fuels, caused by the increase in quantities has adversely impacted India's current account deficit. Huge subsidies for various oil products have caused serious problems for the revenue and fiscal deficits apart from creating other aberrations. The annual subsidy on kerosene alone is around U.S. $5 billion (though this is declining because of recent fall in oil prices). Domestic cooking gas has about 30%–40% subsidy.

It is clear from the aforementioned data that India's need for secure, affordable, and environmentally sustainable energy has become one of the principal economic and development challenges for the country. It is also clear that while energy conservation and demand management and energy efficiency will have important roles to play in the national energy strategy, renewable energy will become a key part of the solutions and is likely to play an increasingly important role for augmentation of grid power, providing energy access, reducing consumption of fossil fuels, and helping India pursue its low carbon developmental pathway.

6.3 New and Renewable Energy

After the oil shock of the seventies, there was a global recognition of the need to develop alternative energy technologies. Government of India created the Department of Non-Conventional Energy Sources (DNES) in 1982. The thrust areas identified included research, development, demonstration, and dissemination of renewable energy technologies for providing energy services in the rural areas and also for meeting energy needs of the country through renewable sources. Later in 1992, DNES was upgraded into an independent Ministry of Non-Conventional Energy Sources (MNES), which was further renamed as Ministry of New and Renewable Energy (MNRE) on October 20, 2006. Perhaps this is the only such ministry in the world.

In 1987, a separate financing institution called the Indian Renewable Energy Development Agency (IREDA) was set up as a public sector undertaking for providing institutional finance exclusively in the field of renewables and energy efficiency. IREDA entered the market when lending to the renewables sector was considered a high-risk and low-profit business. Over the years, IREDA has paved the way for broadening and deepening the market for renewables. In the initial years, it received bilateral and multilateral credits. Over the years, other financing institutions also started providing financial assistance for renewable energy projects and consequently, the market share of IREDA-financed projects has at present come to around 15%.

The programs started slowly with mostly concentration on small applications and rural areas—solar lanterns, solar cookers, solar water heating, water mills, etc. Two national programs were started on rural cooking energy viz National Programme on Biogas Development and National Programme on Improved Cook stoves and were initiated in 1981–1982 and 1984–1985, respectively. Alongside programs for deployment of solar energy devices were initiated. Small hydro (below 25 MW) was started in 1988. In the 1990s, path-breaking development started in wind power development, which gathered steam in the last decade and became the main driver of grid renewable energy in India. There were also developments in the cogeneration area with particular success in bagasse being utilized for power generation in sugar mills, particularly in those in the private sector. Biomass-based power plants also started being set up primarily based on rice husk.

The solar cooker program slowly withered away, not being able to establish a regular market. Solar dishes have since come in small sizes as well as large systems. They have also, however, not taken off in a big way, although there is a solar thermal system in the religious place of Shirdi where 20,000 meals are cooked every day. The biogas program continues at slow pace, installing about a lakh of plants annually, partly because of budgetary constraints and partly because of poor progress in northern states of UP, Bihar, and Haryana. The cook stove program was disbanded in the central sector and transferred to the states in 2002 after about 32 million improved stoves had been installed. After that it also quickly withered away. Improved cook stoves are continuing through efforts of some NGOs, etc., in small ways in different parts of the country. The solar water heating program has been expanded, but inroads into the industrial and commercial sector have been difficult and limited. There are some pilots of solar air conditioning, but this has to go a long way before it can be said to be mature or competitive. Solar lanterns have increased significantly, largely in the private market or locally funded initiatives though the central government and some states also distribute some. Urban waste to energy plants were set up in some towns, but they did not function properly because of difficulties of segregation of waste. This problem continues. There have been some medium and small plants using industrial waste and urban kitchen waste, but this has yet to really spread. One to two megawatt plants have been piloted based on fuel wood or other agri residues using the gasifier technology that has shown promise, though tariff continues to be a problem. There is a huge potential but not much progress. In the last few years, there was a large program to cover 10,000 remote villages where the grid was not likely to go. This was primarily covered by solar home lighting systems. Rural banks have also supported several thousand solar home lights through loans. The record, therefore, is mixed and patchy.

6.3.1 Solar Grid Developments

In 2008, India came out with a National Action Plan on Climate Change with 8 missions covering various areas of sustainable development.* As the Indian prime minister said: at the centerpiece was the proposed National Solar Mission, which would launch an ambitious plan for all-round development of solar energy. This mission was launched in January 2010, with an ambitious target of achieving 20 GW of grid power by 2022, 2 GW of off-grid solar power, covering 20 million households with solar lighting and installing 20 million m^2 of solar thermal collector area.† However, in the Budget 2015–2016, the Government of India has announced much more ambitious renewable energy targets of 175 GW by 2022. This includes scale-up Grid Connected (including roof top) Solar Power Projects from 20 GW to 100 GW. This program is well underway. From virtually zero, a capacity of 3000 MW grid power has already been installed. Both the center and the states have launched different policies and it is expected that the targets of the mission would be substantially met. The most significant development has been the reduction in costs globally for solar PV, and the reduction consequently in India achieved through competitive bidding rather than the prevalent feed-in-tariff (FIT) system. India has perhaps become the lowest cost solar power producer in the world, as acknowledged in a recent World Bank Report.[5] There will be challenges, particularly in relation to transmission infrastructure and land.

6.3.2 Capacity Creation

The following table provides details of the progress in renewable energy deployment up to January 31, 2015 (Table 6.2).

In between 2002 and 2013, share of renewable grid capacity has increased more than 6 times, from 2% to around 13% in only 13 years, and is contributing 6% to the electricity

* The National Action plan on Climate Change (NAPCC) was released on 30 June, 2008 to state India's contribution toward combating climate change. The plan outlines Eight National Missions. The NAPCC consists of several targets on climate change issues and addresses the urgent and critical concerns of the country through a directional shift in the development pathway. It outlines measures on climate change related adaptation and mitigation while simultaneously advancing development. The Missions form the core of the Plan, representing multi-pronged, long termed and integrated strategies for achieving goals in the context of climate change.

† The ultimate objective is to make solar energy competitive with fossil-based energy options. By increasing the share of solar energy in the total energy mix, it aims to empower people at the grass roots level. Another aspect of this Mission is to launch an R&D program facilitating international co-operation to enable the creation of affordable, more convenient solar energy systems and to promote innovations for sustained, long-term storage and use of solar power.

TABLE 6.2

Cumulative Progress of Renewable Energy Deployment as of December 31, 2013

S. No	Renewable Energy Programmes/ Systems	Cumulative Achievements
I. Power From Renewables		
Grid-Interactive Renewable Power (in MW)		
1.	Wind power	22,597.68
2.	Small hydro power	4,017.05
3.	Biomass power/cogeneration	4,183.55
4.	Waste to power	107.58
5.	Solar power	3,099.68
	Total	34,005.68
Off-Grid/Distributed Renewable Power (in $MW_{eq.}$)		
6.	Biomass (non-bagasse) cogeneration	569.75
7.	Biomass gasifiers	171.63
8.	Waste-to-energy	142.27
9.	Aero-generators/hybrid systems	2.43
10.	SPV systems	229.35
11.	Water mills/micro hydel	15.21
12.	Bio-gas based energy system	4.07
	Total	1,134.71
II. Remote Village Electrification		
	Villages/hamlets provided with electricity/lighting systems	11,308
III. Decentralized Energy Systems		
10.	Family type biogas plants (in lakh.)	47.95
11.	SPV street lighting system (in lakh.)	3.42
12.	SPV home lighting system (in lakh.)	11.94
13.	SPV lanterns (in lakh.)	9.85
14.	SPV pumps (nos.)	19,501
15.	Solar water heating (collection area in million m^2)	8.73

Sourse: Ministry of New and Renewable Energy, New Delhi, India.

generation mix. The grid renewable power has been dominated by wind, though now solar is making its presence felt. The important thing to notice in this progress is that the % age of renewables capacity has increased substantially at a time when there was maximum development of conventional power capacity. The high level of penetration of renewable power, after large hydro is added, in India compares favorably with that of the EU and far exceeds that of the United States.

6.3.3 Policy Support

The government has been promoting private investment in setting up of projects for power generation from renewable energy sources through an attractive mix of fiscal and financial incentives, in addition to the preferential tariffs being provided at the states' level. These include capital/interest subsidy, accelerated depreciation (AD) and nil/concessional excise, and customs duties. The level of capital subsidy being provided for off-grid depends on the renewable resource and region, and varies from about 10% to 90% of project cost, the higher level being given for projects in North-Eastern Region/special category states.

Electricity Act 2003 provided the necessary regulatory framework for growth of renewable power in India. The act required State Regulatory Commissions to specify renewable purchase obligations (RPOs) and also fix renewable resource–specific FIT. In addition solar-specific RPOs, starting with 0.25% in the first phase of the Solar Mission and leading to 3% by 2022, have also been introduced. The National Electricity Policy 2005 has further provided for progressive increase in these levels and purchases by distribution companies through competitive bidding process. The Tariff Policy 2006 requires fixation by State Electricity Regulatory Commissions (SERCs) of a minimum % age for purchase of energy from such sources taking into account availability of such resources in the region and its impact on retail tariffs and procurement by distribution companies at preferential tariffs determined by the SERCs. As of date, most of the SERCs have specified % ages for purchase of electricity from renewable sources of energy. Preferential tariff for grid interactive renewable power is being given in most potential states. Uniform guidelines by Central Electricity Regulatory Commission (CERC) for fixation of such preferential tariffs have been issued.

Other instruments include AD up to 80% to investors/developers in the first year. This was a tax benefit for profit-making companies and individuals, something akin to the production tax credit in the United States. This model led to substantial development of the wind sector. In 2010, generation-based incentive was also provided as an alternative for such power producers, which could not avail the benefit of AD in order to provide a level playing field. This resulted in more than 3 GW being installed in 2010–2011, the highest ever. However, the AD benefit for wind has since been discontinued, though the generation-based incentive (GBI) has recently been restored.

Renewable energy sources are not evenly spread across the country. On the one hand, there are states where the potential of renewable energy sources is not that significant; on the other, there are states where there is very high potential. Five southern states produce most of today's wind power and solar power's potential is similarly concentrated. This poses economic and operational challenges for these states. In 2010, tradable renewable energy certificates (RECs) have been introduced to address this gap and assist states in meeting RPOs. Renewable energy generators offer REC on the exchange, and the utilities, also of areas where with less renewable energy potential could buy and fulfill their RPO. However, in the absence for any focus on RPO compliance, the REC market is not taking off.

On December 19, 2014, the Government of India introduced the Electricity (Amendment) Bill, 2014 in the Lok Sabha (the National Parliament). It has many provisions for accelerating renewable power deployment in the country including provision for more robust RPO compliance and preparation, review, and notification of the National Renewable Energy Policy.

6.3.4 Solar Power Policy

Solar power was promoted with some additional measures. Under the Central initiative of the Solar Mission, a central agency was specified to buy the solar power produced by the developers. It then bundled it with cheaper thermal power available to its parent producer NTPC in the ratio 1:4 and sold to utilities with whom it entered into power purchase agreement (PPA). This bundling reduced the cost of power to the utilities tremendously bringing it near to the normal price of purchase. In addition, a separate solar purchase obligation was mandated for the utilities. At the start in 2010, solar PV tariff as calculated by the CERC was almost Rs. 18 per unit,* levelized over 25 years. But a bidding

* At present 1 U.S. $ is equivalent to around Rs. 60.

route was also adopted, asking developers to offer discounts to the CERC price. The two rounds of bidding brought down the lowest bids, first to about an average of Rs. 12 per unit (U.S. $20 cents) and later an average to about Rs. 7 perhaps more per unit (U.S. $12 cents). This was the policy for the first phase of 1.1 GW.

However, for the second phase of around 750 MW, the tariff has been fixed at Rs. 5.30 per unit. Developers were asked to bid for a minimum viability gap funding (VGF) to achieve this tariff. The bid results suggest that on an average VGF of Rs. 1 crore/MW installed capacity have been asked by the developers. In case of domestic solar cells, the VGF sought is in the order of Rs. 2.50 crore/MW. Power will be purchased and sold as earlier by a newly formed Solar Energy Corporation of India. Both phases had limited quantities and procedures for domestic content to support the hard-hit domestic industry because of low cost manufacture in China, which also damaged their export capability to Europe as also low cost financial support by the U.S. Exim bank for their local thin film manufacturers. This provision of domestic content was only for the National Solar Mission and not for state initiatives. However, the United States has gone out of its way to complain against Indian policies. It is felt that it has not only been overly aggressive and unfair but has also not realized the implications that would favor the Chinese industry rather than their own.

6.3.5 Future Projections and Trends

Renewable energy outlook for the country seeks to graduate from the present role of supplementing the fossil fuel based conventional energy sources, to becoming a mainstream source and eventually reaching a stage of substantially replacing them. There are different prognoses about the time frame when such sources could completely overtake conventional fossil fuel–based sources. The 12th Five Year Plan document of the Planning Commission, Government of India (for the period 2012–2017) has already depicted a 2030 outlook which suggests around 33% electricity installed capacity from renewable energy sources. Planning Commission, 12th Five Year Plan: online http://planningcommission.nic.in/plans/planrel/12thplan/pdf/12fyp_vol2.pdf

The Planning Commissions “Report of the Expert Group on Low Carbon Strategies for Inclusive Growth 2014” has estimated that under low carbon for inclusive growth scenario solar and wind power capacity by 2030 will be around 225 GW out of the total installed capacity of around 700 GW, and in energy terms these will contribute to around 14% in the electricity mix. Planning Commission “Report of the Expert Group on Low Carbon Strategies for Inclusive Growth 2014” online http://planningcommission.nic.in/reports/genrep/rep_carbon2005.pdf. Given the right mix of technology, finance, and necessary improvement in grid infrastructure these estimates could be achievable.

6.3.6 Renewable Energy in Off-Grid Mode

The problems with the grid in India, and the unique ability of solar to provide power from the smallest unit onward, offer almost unlimited potential for off-grid solar. There are four prime areas in India. First, simple roof top with the difference that this will be largely for self-consumption rather than being fed into the grid as is the usual practice so far in developed countries. This will both reduce demand for day-time electricity and partly meet the needs of small diesel generators, which are in use in plenty because of power shortages. Second, village electrification is a big problem in India, which we shall briefly discuss shortly. Kerosene supplied at highly subsidized rates meets the lighting through small ill-lanterns giving very poor light. Solar, whether through mini grids, or solar home lighting systems and lanterns, could provide a much better alternative. It will certainly save billions of liters of kerosene and huge amounts for the government in subsidies, possibly over Rs. 20,000 crores annually at present prices and subsidy rates if large-scale solarization happens. Third, there are a couple of hundred thousand telecom towers in rural areas. Because of unreliable supply of power in many areas, billions of liters of subsidized diesel is used. A lot of it can be saved by solar meeting power needs in the daytime when power cuts are the maximum. Fourth, India has more than 20 million irrigation pumps in the rural areas, with a large number running on diesel. Most of these pumps over time can be replaced by solar-powered pumps. And maybe there will be additional markets. There can be many more pumps, which are currently not installed, because either electricity is not there or diesel is too expensive. As we move toward eastern India from Delhi, the water table is high enough and electricity is scarce. This is a perfect combination and needs to be pursued as a separate mission. Altogether these can create a market of 50 GW, with no land and transmission requirements, no involvement of the grid, and no losses as generation will be at consumption points. But solar companies need to become oriented to provide such small and dispersed services. In fact, this will allow many professional small companies and generate employment and incomes in rural areas. It will simultaneously help India's energy security by saving very large amounts of nonessential use of kerosene and diesel. Besides, huge amounts of undeserved subsidy would also be saved. And the utilities will save a lot of their losses arising out of rural supplies supplied at low tariffs, both for households, and particularly for irrigation. Therefore, in the Indian situation, which may find similarities in many other developing countries, solar off-grid is a completely win–win situation. The best part is that all the beneficiaries will actually be spending less on their fuels than currently, leave alone doing so in the future.

6.3.7 Energy Access

Energy access includes both electricity and cooking energy. The position in India in respect of both is quite dismal. This is also primarily a rural problem. Though it may be difficult to put exact numbers, it is generally expected that 300 million people in India do not have electricity access and 700 million people use biomass in traditional stoves for cooking. India has made rapid progress in rural electrification through the Rajiv Gandhi Grameen Vidyutikaran Yojna in the last several years and we claim that over 90% of the villages have been electrified. However, over 40% of the above poverty line (APL) rural households do not have electricity connections (a large number of below PL households were given connections under the official program). The problem has been the definition, which allows a village to be deemed electrified if 10% of the households have connections. There are additional problems of the number of hours of supply, which sometimes are not many and mostly not in the evening hours when needed most. There are worries that these problems may continue with power supply being short and the utility finances continuing to be affected adversely by low tariffs. It is, therefore, believed by many that solar minigrids or solar home lighting systems may be the answer to India's electricity access problems.[6] Many pilots have been conducted, and there is subsidy support. However, a regular business model is yet to be found as also who could be the possible entrepreneurs. This is going to be an important area for policy development in the next few years. This is also a good area for international funding.

6.3.8 Cooking Energy

As far as cooking is concerned this is a serious problem although there has not been enough recognition of it by the policy makers, and indeed even in public discussion. In 2014, the Global Disease burden study showed that indoor air pollution from combustion of biomass in inefficient cook stoves was the biggest health hazard for India. In general, there has been a belief that the real solution is the supply of cooking gas. However, studies have noted the difficulties of shifting to cleaner fuels, even if subsidized, in a situation where biomass is largely free. Besides, the country simply cannot afford the subsidy either of cooking gas or kerosene for this solution to work. Therefore, biomass will remain the principal fuel. And it is imperative that we move to ultraclean stoves, which will burn all types of biomass and also last for at least 5 years. Some efforts in this direction are ongoing. Efforts are also on to finalize proper standards. Cost of such stoves could be an issue, and they may require subsidies. Had the carbon market been working properly, distribution of improved cook stoves could probably be fully financed. In its absence, the government would have to provide some subsidy as we develop slowly a proper market. The market size could be 100 million, and if the life is about 4 years, there will be a huge replacement market. Unfortunately, the international system has done precious little to deal with this problem, except express concern. More, and decisive, action is needed.

6.3.9 Carbon Emissions—Issue of Energy Intensity

It may be useful in the context of this scenario to briefly examine the issue of India's contribution to carbon emissions. In the climate change negotiations, often India has been painted as a villain. It is true that India has argued for the developed nations to accept their historical responsibility for filling up the carbon space and therefore reduce their emissions substantially even as there needs to be space for her to grow to address the problems of development and removal of poverty. The developed countries initially accepted this argument and promised differentiated responsibilities. However, they have hardly delivered on any of their promises. And, they have now started arguing that the developing countries will become the larger emitters in the future and, therefore, they must restrict or also reduce their emissions. Nothing could be more insidious and ethically unacceptable. But the real problem is that the fingers are pointed at China and India and both of them are put in the same boat. But consider the differences. China emits about 26% of the global emissions now and India about 5%–6%, roughly same as Japan and the Middle East, which is also growing rapidly. The United States is about 16% and the EU about 12%. Moreover, in per-capita emission terms, India is well below the per-capita global average of 4.5 tons, while the United States is well above. Therefore, India is not the problem. The problems of power supply mentioned earlier also suggest that we will not be in the future. Ideally, it would only be equitable if the first ceiling for emissions for countries should be the current global per-capita average multiplied by the current population. This would give India enough space to grow in a reasonably carbon-constrained manner, which would require strong reliance on renewable energy, energy efficiency, and a new transport model. If we did this, we should also be able to meet our commitment of 20%–25% reduction in emission intensity of GDP by 2020. Needless to say, it will also be a much more sustainable model designed to meet more economic and social equity principles also.

6.4 Energy Efficiency

National interest in energy conservation in India was triggered by the oil crisis of 1973 but was largely concerned initially with petroleum products. The Petroleum Conservation Research Institute (PCRA) was set up in 1978. Much later, in 1989, the Energy Management Centre (EMC) was set up to promote conservation in power. After the opening up of the economy in 1991, and as electricity became important, the need was felt for proper legislative and institutional backing to promote electricity efficiency. In 2001, the Energy Conservation Act was passed. In 2002, the EMC was reconstituted as the Bureau of Energy Efficiency (BEE), which became a statutory body. The Electricity Act 2003 mandated efficiency in generation, transmission, and distribution. The National Electricity Policy 2004 gave demand side management (DSM) a high priority. Periodic energy audits were made compulsory for power intensive industries; emphasis was placed on labeling of appliances and high efficiency pumps in agriculture. The Integrated Energy Policy Report 2006 emphasized that investments in energy efficiency were as important as investments in generation as energy saving was more advantageous in many ways than energy generated. One could say that a view emerged that energy efficiency should be India's primary fuel. Under the National Action Plan for Climate Change in 2008, a new National Mission on Enhanced Energy Efficiency (NMEEE) was proposed that was approved in 2010 and is under implementation.

Industrial and domestic sectors are the two largest consumers of utility generated power, with the latter growing rapidly because of economic growth, rapid urbanization, and changing lifestyles, which is leading to huge growth in personalized transport, residential buildings, and electric appliances. It is estimated that while India's energy consumption may go up by 6 times, its per-capita emissions may only have space for a little over doubling. Therefore, it has become imperative to identify areas where huge reductions are possible, as also where power supply from conventional sources can be replaced by renewable energy sources. Some of the important areas are briefly discussed in the following text.

6.4.1 Buildings

Almost 40% of the total energy is utilized in the building sector. As urbanization is growing rapidly, this sector will create great demand for energy in the future. In 2009, the buildings sector consumed one-third of the total electricity, with the residential sector being 25% (BEE). Eighty percent of the electricity is for cooling and lighting, with ACs accounting for 40%–50% having more than doubled in the last few years. This will only increase as it is estimated that 60%–70% of the building stock is yet to be built by 2030. Forty percent savings could accrue if we have energy-efficient buildings.

There are many policy drivers to ensure this. There is a National Building Code. There is the Energy Conservation Building Code that specifies some norms for certain types and size of buildings. This needs to become more stringent and mandatory for more sizes of buildings. Larger complexes require prior environmental clearances, but this is somewhat loosely administered in terms of ensuring final compliances. There are two voluntary rating systems for green buildings. The U.S. LEED-inspired IGBC-LEED system, which is more western oriented and the TERI—MNRE GRIHA system, which is based on traditional Indian architectural and solar passive principles. The latter is more suited to Indian conditions and seeks to reduce also AC and lighting needs. The former focuses on efficient systems and encourages glass facades. The Government of India took a decision that all their new buildings should be at least GRIHA 3*. This norm has also been accepted by the

Central Public Works Department, which leads the issues regarding specifications and building codes. None of these instruments, however, have created the type of huge impact that is needed, and builders and developers are clearly ignoring these needs; there is neither sufficient knowledge nor interest for consumers to demand such buildings as people do not follow life cycle cost principles. There is an urgent need for municipal regulations and to move tax concession on house building loans toward energy-efficient housing. A few municipalities have taken some steps.

6.4.1.1 Electrical Appliances

This is going to be a high growth area. Mckinsey (2009) has said that household energy demand will spike up to 1300 TWh by 2030. There has been a voluntary labeling program in India for some years. Currently, it is incrementally increasing the norms for each level of star rating. However, even though moderately successful, star label penetration is still low. In 2008, star AC's penetration was 1.5% and fridges 7.5%. This must have gone up since then. Since this will be a huge growth area, and 30%–40% savings are possible, and the use of appliances will spread to washing machines, microwaves, dish washers, etc., it is imperative that norms become stricter and are mandated. Other products should simply not be allowed in the market.

6.4.2 Lighting

Lighting is a huge electricity load, particularly at evening peak time. The CFL market in India has been growing at about 20% annually. LED is just beginning, including their assembly/manufacturing in India. A lighting/LED revolution must happen in India—both for domestic or institutional lighting and for street lights. There was a very unique CDM project for the period 2009–2011 targeting replacement of 400 million light points converting bulbs to CFLs with a potential saving of 20,000 MW. Twenty million lights were changed, but then the carbon market collapsed. We believe that a program such as this, probably now shifting to LED, and a project for 100 million cook stoves would have been the best possible carbon projects, and should be funded from the voluntary market. Such lighting would make even solar more attractive as lesser modules would be required to provide the same amount of light. A huge program for change in municipal street lighting to LEDs is also required funded by a special tax if need be. Twenty-five to thirty percent of the lighting load of municipalities is from street lights. Steps in this direction are underway.

6.4.3 Industry

As per Central Electricity Authority, 23% of total electricity is used by industry in the country, of which >60% is by few large and heavy industrial consumers. India's energy intensity in manufacturing sector has fallen consistently over the last 20 years, but there is still a saving potential of up to 25% even as the total energy consumption naturally increases. Under the NMEEE, a Perform, Achieve and Trade (PAT) scheme has been launched that covers the 9 most energy-consuming industries—thermal power plants, iron and steel, cement, fertilizer, aluminum, textiles, pulp and paper, and chlor alkali. Energy consumption reduction of 5%–10% is targeted between 2011 and 2014. All this would lead to 5623 MW of avoided capacity. Clearly, we have to do more and include more industries while also doing everything possible in the medium and small sector also. Motors, pumps, and boilers are the key.

The activities under the PAT scheme provide opportunities for new markets as it devises cost-effective energy efficient strategies for end-use demand-side management leading to ecological sustainability.

6.4.4 Agriculture

This sector uses almost one-third of the electricity while contributing to only about 8%–10% of the revenue. This is predicted to grow at 2%–5% annually till 2020. Seventy percent of irrigated area is from ground water. Since the tariff is extremely low and it is really not metered, the marginal cost of pumping water is zero and farmers have no incentive to restrict or reduce their usage of electricity (and water) or invest in energy efficient pump sets. Rationalization of tariff and mandating production of energy efficient pumps is required. Even in municipalities, energy efficient pumping is important, because 15%–30% of their electricity load comes from this area.

We have suggested that solar irrigation pumps could be a good alternative in the long run.

6.4.5 Future Directions

There are several barriers that are preventing large-scale adoption of energy efficient measures. Some of the most important are as follows:

1. Price distortions including subsidized prices of petroleum products and electricity. Proper energy pricing and reductions of subsidies, though politically difficult, will be very important.
2. High costs of upfront investments. This may be applicable for government agencies or organizations. Absence of development of the RESCO model, where roof top solar or energy efficiency measures can be investments of others paid back in rental mode. Also lack of successful examples and knowledge of interventions.
3. Policies are not fully in place. Mandating is not easy. The mindset, whether of individuals or organizations, is still not sensitized to both the urgent need for saving energy and its conservation, as well as the benefits, both financial and otherwise, which would accrue. This also underlines the need for both behavioral and attitudinal change at all levels.
4. And, as part of the chicken or egg coming story, there is a lack of successful examples and knowledge of interventions that create confidence as well as mitigate an environment of risk.

As far as financing is concerned, there are a number of options to accelerate pace of energy efficiency program. Establishment of state level Clean Energy Funds using the Public Benefit Charge concept could be an area of action. Such funds may be established as special purpose funds by national or state governments and regulators for financing clean energy projects. Internationally also the most common, reliable, and sustainable source of funding is a tariff surcharge, cess, or levy established by the regulator and collected by the utility via the customer's electricity bill. Such a surcharge or levy is known as a Public Benefit Charge. The funds could be utilized for leveraging commercial financing, interest *buy-down* on commercial loans, loan guarantees, grants for public sector projects, and rebate. Other options could be development of regulatory schemes to acquire energy efficiency resources using a Standard Offer Programme, promoting utility financing of energy efficiency projects by establishing energy efficiency obligations, encouraging Indian banks and financial institutions to mainstream energy efficiency in corporate loans, creation of a facility to provide energy savings insurance, establishment of a *clean Energy Financing Facility* for debt financing of energy efficiency projects, and designation of energy efficiency financing as Priority Sector Lending.

Simultaneously, there is a need to have a much more comprehensive program of awareness building and education.

6.5 Conclusion

Historically, India has initiated systematic programs for renewables including for research and development and also for energy efficiency. The challenge for India is gigantic and exciting. Considerable progress has been made but actions are required on many fronts. Policy issues related to all sectors of conventional electricity generation are urgently needed. Renewable energy has already caught the imagination and with proper policy framework and planning, India could be in a position to meet significant portion of its energy needs through these sources. There must also be a large-scale off-grid program. The successful implementation of the National Mission on Enhanced Energy Efficiency could also yield similar results, but simultaneously, its coverage needs to be substantially increased. Curtailment of consumption of oil products by various methods in the transport sector and some suggested here in the electricity sector have to be prioritized. All these would also lead to substantial reduction of, or less increase in, carbon dioxide emission. While budgetary support for renewable energy and energy efficiency have progressively increased over the years, particularly for large-scale grid connected power, these need to be further enhanced for both grid and off-grid to achieve the large upscaling that is required. Subsidy reform would automatically provide substantial funds. But some critical policy and structural gaps remain, particularly for decentralized distribution in the areas of access to capital, technology development and adaptation, innovation induction, and strategies to upscale deployment. However, new opportunities and compulsions will lead to think beyond the government-centric programs and to create new instruments, strategies, and pathways.

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7

Renewable Energy Policies in Brazil: Bioenergy, Photovoltaic Generation, and Transportation

Ricardo Rüther

CONTENTS

Bioenergy is regarded as one of the key options to mitigate greenhouse gas (GHG) emissions and to substitute fossil fuels [1,2]. While there are many renewable energy technologies available for large-scale electricity production with low or no direct GHG emissions, the transport sector, which is responsible for 23% of GHG emissions [3–5], is almost entirely based on fossil fuels, and has fewer alternatives.

Transportation represents some 27% of the world's secondary energy consumption (21% of primary), grows 1% per year on average, and is almost exclusively fuelled by petroleum [4,5]. Biofuels can play an important role in addressing both the GHG emissions of transport and the dependency on petroleum. However, currently marketed, first-generation biofuels represent only around 3% of global road transport fuels, and can be regarded as a transition technology. This limited penetration of first-generation biofuels is due in part to the potential competition with food crops and market prices (sugar × ethanol prices in international markets). Concerns that these technologies are falling short of expectations have led to the development of second-generation (cellulosic ethanol, biomass-to-liquids, pyrolysis oil, dimethyl ether) and third-generation (algal-biodiesel, biofuels from third-generation processes) biofuel technologies [4], which still need to be scaled up in order to become cost-competitive.

With the exception of sugarcane ethanol, the traditional biofuels have a number of severe disadvantages that are related to the feedstock. The current costs of rapeseed biodiesel and ethanol from cereals or beets are much higher than the costs of gasoline and diesel, and substantial subsidies are needed to make them competitive. These high costs are a result of the low net energy yield of most annual crops (100–200 GJ/ha year in the long term [6]), the high-quality agricultural land required, and the intensive management. The lower productivity per hectare and high fertilizer requirement also limit the well-to-wheel reduction of fossil energy use, which limit the environmental benefits [7,8]. The net energy of perennial crops (220–550 GJ/ha year), grasses (220–260 GJ/ha year), and sugar cane (500–650 GJ/ha year) is considerably higher, and Brazil has been a world leader in promoting biofuels for over 30 years under its *Proálcool* program.

7.1 *Proálcool* Program in Brazil

Since 1975, Brazil has mandated that ethanol be blended with all gasoline sold in the country. Although the required blend level is adjusted frequently, it has been in the range of 20%–25%, and all filling stations are required to sell gasohol (E25) and pure ethanol (E100). Tax incentives have been given to vehicles that run on pure ethanol in the early days of the *Proálcool* program, and more recently, the introduction of the so-called *flex fuel* vehicles by most of the local automakers allows for any proportion between ethanol and gasoline (E25–E100) to be used any time. This has led to the growing share that *flex fuel* cars hold in the Brazilian market [9,10], which should reach over 96% by the end of 2014 [11,12]. In 10 years, U.S. $16 billion were invested in genetic research for sugar cane improvement, alcohol subsidies, and agrobusiness, and policies have included blending mandates, retail distribution requirements, production subsidies, and other measures [13].

After a rocky period in the 1980s and 1990s, when high demand resulted in a seller's market, which led to high alcohol prices and delivery shortages [13], the escalating oil prices and the event of the *flex fuel* car have brought attention back to ethanol. Advances in electronic fuel injection technology solved many of the technological problems associated with ethanol engines (in cool mornings, drivers had to wait precious minutes for their car engines to warm up before they could drive). In 1985, with falling oil prices, the Brazilian government was not able to keep up with the required subsidies, and in 1989, ethanol shortages and high prices resulted in very disappointed drivers and the near collapse of this promising technology. In 1990, the sector was deregulated, and the *Alcohol and Sugar Institute* (IAA—Instituto do Açúcar e do Álcool), which regulated export quotas and subsidies, was closed down. In a free, deregulated market, ethanol producers chose to turn back to sugar when the international price of that commodity recovered, and the automakers reduced alcohol-driven car production to negligible levels. More recently, with the boom in *flex fuel* car sales, ethanol prices soared once again. This time however, with *flex fuel* cars came the choice for consumers to avoid abusive price increases from alcohol producers, and whenever ethanol prices go over the mark of 70% of gasoline price, *flex fuel* car drivers fill up with the traditional fossil fuel. While at present 9 out of 10 cars produced in Brazil run on both fuels, ethanol has not been the choice of most drivers. This is mostly because the price difference between ethanol and gasoline has been below 20% in the last few years, due to the more profitable sugar market. Furthermore, because *flex fuel* cars running on pure ethanol have a ~30% lower mileage than when running on gasohol, there is no real advantage in filling up with the so-called green fuel.

7.2 Bio-Oil

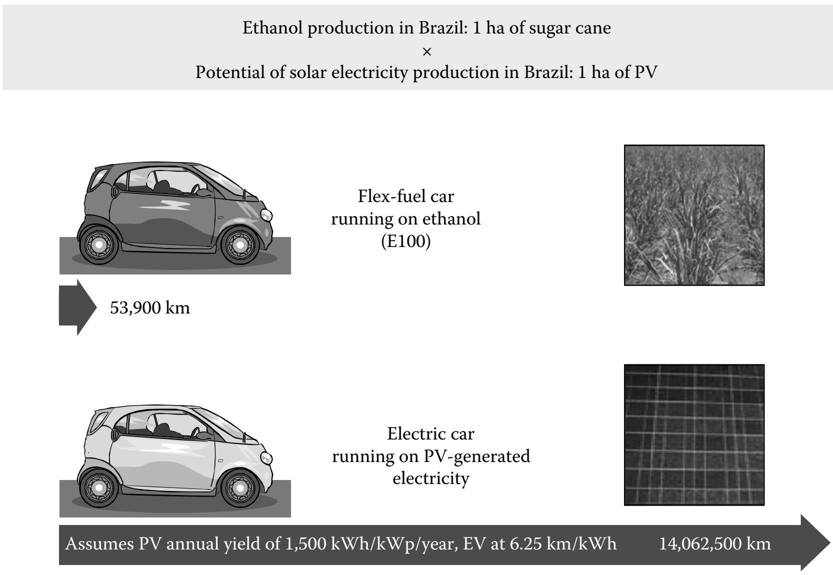
Brazil has more recently begun to target increased use of biodiesel fuels, derived primarily from domestically produced soybean oil, with recent legislation mandating blends of 5% biodiesel in diesel fuels (B5). Brazil has the potential to be a world leader in biodiesel production, as it will be able to produce bio oil from many different sources. The issue fuel × food, however, will always persist, and might be even more pronounced in the case of biodiesel than it has been so far in the case of bioethanol.

7.3 Photovoltaic Generation and the Net Metering Law in Brazil

In early 2012, Brazil has enacted new legislation allowing for solar photovoltaic (PV) generators of up to 1 MWp to be connected to the public distribution grid and to feed excess electricity to the grid under a net metering scheme [14]. The excellent solar radiation resource availability in the country, ranging from over 1,500 to nearly 2,200 kWh/m^2/year [15], and the extensive rooftop availability in the residential, industrial, commercial, and public sectors, complemented by considerably high electricity tariffs in most parts of the country, should make building-integrated, grid-connected, and net metered PV generation an attractive option for a large number of consumers in the near future.

7.4 Prospects

In addition to Brazil, mandates for blending biofuels into vehicle fuels have been appearing in several other countries in recent years, mostly driven by GHG reduction targets. In the long term, however, it can be argued that biofuels will play a transitional role toward electric vehicles and solar PV generation. In terms of energy conversion efficiency, biofuels for transportation can be largely regarded as a transition technology. A direct comparison between sugar cane ethanol + *flex fuel* cars, and sunlight-to-electricity (PV) conversion + electric cars is illustrated in the following figure: a 1 ha (100 m × 100 m) sugar cane plantation will yield from 6,800 to 8,000 L of ethanol per year, allowing a medium-size *flex fuel* car to drive up to 53,900 km/year in a best-case scenario. If the same area is covered with commercially available solar PV modules at 15% conversion efficiency and a 1,500 kWh/kWp/year energy yield, the electricity produced over 1 year on the same 1 ha will allow the electric version of the same medium-size car to drive over 14,000,000 km/year (over 260 times more!). The reasons for this overwhelming difference are related to both the orders of magnitude larger efficiency of PV conversion over photosynthesis, and the considerably larger efficiency of electric motors over internal combustion engines. While fully electric, plug-in vehicles are still in the early stages of large-scale production, battery technologies are continuously being improved, and volume production should lead to the necessary cost reductions for this benign technology to be adopted worldwide. In a sunny and large country like Brazil, building-integrated PV in the urban environment can not only cover the additional electricity needs represented by a new fleet of electric vehicles, but can also supply on site a considerable fraction of the urban electricity needs, without any further area requirements and without competing with arable land.



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8

Energy in Israel: A Case for Renewables

Gershon Grossman

CONTENTS

8.1 Introduction

Israel is a country of 8.0 million inhabitants in an area about 20,000 km^2 located on the eastern Mediterranean coast. Israel's electric grid and overall energy economy are isolated from those of its neighboring countries. The precarious political situation has led in the past to the country being subjected to energy and other economic boycotts. Until recently, Israel's economy has depended almost entirely on imported coal and petroleum. Despite the political difficulties, Israel's economy is the fastest growing in the Middle East, leading to an ever-increasing demand for energy. Israel's total energy consumption has almost doubled in the last 20 years, and electric power production and consumption have increased by a factor of 2.75 in that period of time [1].

Israel has learned to use the one abundant and inexhaustible energy resource it has—solar energy. Israel has been a pioneer in developing solar technology, leading the world (together with Greece and Cyprus), and until recently is number one in the world in per capita utilization of solar energy. According to the Ministry of Energy and Water Resources (MEW) Division of Energy Conservation [2], about 85% of households (i.e., about 2,100,000 households) use domestic solar water heating, accounting for 3% of the country's primary energy consumption. Government encouragement and regulations, along with over 50 years of proven experience, have made this application widespread. Other forms of solar energy utilization are considered, with the potential of supplying a much larger portion of the country's energy demand.

Israel faces a number of choices in securing reliable, clean, and efficient sources of energy over the next 25 years. Recent discoveries of offshore natural gas have generated interest in developing this resource for domestic consumption to reduce dependence on imported coal and petroleum, which involves both economic and environmental risks. According to a MEW-commissioned forecasting study on Israel's energy demand [3], the overall merits of developing these gas reserves entail a number of trade-offs involving energy security, the environment, and cost. Development of renewable sources is free of these concerns and holds a great promise to supply the country with long-term clean and secure energy.

8.2 Israel's Energy Economy

The Israeli economy is largely fueled by imported coal and petroleum. Prior to 1982, only a small amount of coal was consumed and the country's primary energy source was oil and its derivatives. At present, coal accounts for about 35% of Israel's primary energy. It is almost entirely used in electric power generation. Recent discoveries of offshore natural gas fields have added this important resource, which at present is used mainly for electric power production.

Central Bureau of Statistics (CBS) data [1] show that the total primary energy supply to the country for the year 2009 was about 17.4 million tons oil equivalent (MTOE). Total end use was about 13 MTOE, consisting roughly of 8 MTOE of petroleum products and 5 MTOE of electric power. Among petroleum products, gas oil and diesel oil comprise the largest category. Electric consumption is about 1/3 for residential and 2/3 for industrial use (goods and services), the latter comprising a significant portion for agriculture and water pumping. Fuel consumption other than for electric power generation is split at 60%, 36%, and 4% among the transportation, industrial, and residential sectors, respectively. The same consumption pattern has been in effect for the last 10 years. According to forecast [3], it is likely to change in the coming years, with the introduction of natural gas, which will replace heavy oil in the electric power and industrial sectors.

Another component of the energy economy—relatively small in quantity but important in significance—is solar energy, utilized mainly for domestic water heating. As mentioned earlier, it accounts for about 3% of the country's energy demand and saves about 5% of the electric power. Israel is currently one of the three largest per capita users of solar energy in the world, challenging the notion that solar energy is not yet economical.

The government MEW's stated goals and objectives with regard to energy are the following [2]:

- Expansion of the supply and diversification of energy sources for the national economy and consumers
- Advancement of the well-being of the national energy and mining economy, while improving product quality and prices and the service provided
- Minimization of environmental effects created by energy facilities in the national economy
- Aiming to satisfy demands reliably and stably while conducting activity to reduce demand through economizing in the use of energy resources
- Analysis of opportunities in natural resource inventories in Israel and securing their availability while conducting licensing processes and encouraging exploration and excavation activity
- Activity for securing Israel's social, economic, and physical strength, which will allow for coping with the inevitable occurrence of strong earthquakes, while minimizing possible loss of life, reduction of the extent of damage to property and infrastructures, and rapid transition to an ordinary life routine
- Promotion and support of studies for expanding knowledge in soil and sea scientific fields

A number of measures have been initiated to promote renewable energies in electric power generation. A government resolution dated January 2009 set an objective to produce at least

10% of the total electric power from renewables by the year 2020. An intermediate goal is to produce 5% of the total electric power from renewables by the year 2014. Accordingly, the Public Utilities Authority has instituted a set of premiums for licensed electricity producers employing renewables, proportional to the achieved reduction in pollution. Another government resolution dated August 2008 endeavors to develop technologies for electric power generation from renewables, with dedicated funding under a 5-year plan. A further government resolution dated September 2008 promotes energy conservation and reduction in national electricity consumption. Energy conservation by the public is encouraged by market transformation—increasing public awareness of energy efficiency in appliances and the like.

A number of laws, regulations, directives, and legal instruments have been introduced to implement energy policy. Most of them regulate the use of petroleum and petroleum products, natural gas, and electric power and deal with licensing and safety issues. Some deal with energy efficiency, minimum standards, and labeling. Recent regulations encourage cogeneration and distributed generation. Noteworthy is Article 9 of the Law for Planning and Building (1970), mandating the installation of solar water heating systems in all new constructions [4]. This article has contributed a great deal to the advancement of solar energy utilization and will be discussed further in the next section.

8.3 Solar Energy Utilization in Israel—The (Incomplete) Success

A visitor to Israel will unavoidably notice the urban landscape bursting with solar collectors and hot water storage tanks covering the roofs of buildings. Almost all residences in Israel are equipped with solar water heaters. The most common is the thermosyphonic system, a completely passive, stand-alone unit consisting of one or two flat plate solar collectors and an insulated storage tank. Large multistory apartment buildings often use a central system with a collector array on the roof and a storage tank in the basement, employing a pump controlled by a differential thermostat. Other arrangements are also available. In most of the country, the solar system will supply the full demand for hot water during 9–10 months per year, with an electric resistance backup employed the rest of the time. Freeze protection is never required, except in some isolated locations. The economics: the installed cost of a typical single-family system comprising a 150 L storage tank and 2–3 m^2 of flat plate collectors is about \$700; an equivalent electric-powered system costs about \$300. The difference of \$400 is recovered by the owner in about 4 years (on a simple-payback basis); these systems carry a manufacturer's warranty for 6–8 years, and if properly maintained can last over 12 years. Several decades of nationwide experience have generated consumer confidence and acceptance to the point that a domestic solar water heater is perceived as a common, reliable household appliance.

There is no single legislation concerning solar energy utilization in Israel. The aforementioned Article 9 of the Law for Planning and Building (1970) [4] is probably the most important solar legislation, and has been the government's predominant contribution to Israel's success in the solar area. The law requires the builder (not the homeowner), since 1980, to install a solar water heating system in every new building up to nine stories tall. The MEW is currently leading a move designed to extend the requirement to multistory buildings. This is driven by the clear tendency in recent years to build high-rise buildings. Other laws and regulations describe in detail the size of the installation required for the various types of buildings, set minimum standards for the quality of the solar equipment and installation, and provide the regulations for retrofit installation of solar water heaters in existing multiapartment buildings. Based on government data [5], an average single-family domestic solar water heater saves 1250 kWh of electric power per year; the total contribution to the country is about 1.6 billion kWh/year, 21% of the electricity for the domestic sector or 5.2% of the national electricity consumption, providing for 3% savings on primary energy consumption. This amounts to about 270 kWh/year/capita—one of the highest in the world.

Israel's example in domestic solar water heating provides an impressive demonstration of what can be achieved (in countries with similar or even more favorable climates), if the government makes a commitment to clean and environment-friendly technologies [5]. However, while solar for residential use has become an everyday reality in Israel, the much larger industrial/commercial sector uses very little solar energy, despite the fact that the industrial user is much better suited to do so than a homeowner. Some key considerations are: industry works mostly during the day, requiring little storage relative to a residence; the economy of scale provides a significant capital advantage to large industrial installations; industry generally has plenty of roof area in one-story buildings located in areas where architectural considerations do not hinder the installation of solar collectors; the industrial user is equipped to perform small maintenance jobs, thus eliminating the need for a full-proof system and reducing first cost. While some industries require high-temperature process heat, there are many who need the same temperature range as the domestic user; these include textile, food, pharmaceutical, chemical, and many more. The same applies, of course, to the commercial sector. It is estimated that widespread solar energy utilization in industry for process heat and the like, and in commercial applications, could increase the country's utilization by a factor of five, if not more.

Unfortunately, current tax considerations create a negative incentive for businesses to use solar energy. An industry burning polluting fuel can write off the cost as a business expense, thus reducing its tax liability, whereas an investment in a solar heating system can only be amortized over 8–12 years, making it considerably less attractive economically. Moreover, the law currently exempts industrial plants, shops, hospitals, and high-rise buildings (height over 27 m) from the requirement to install a solar water heating system in new buildings [5]. The government could play an important role in changing this situation, by introducing appropriate measures, closing tax loopholes, and creating positive incentives for renewable energy. This can be achieved within a short time—there is no need for long-term investments and development of new technologies. Solar energy is a reality here and now, as already demonstrated by the country's residential sector.

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9

Renewable Energy in Australia

Monica Oliphant

CONTENTS

9.1 Energy Sector in Australia

Australia is resource rich in both minerals and energy. It is a net energy exporter with 68% of total energy production being exported and with a value of AUD$71.5B in 2012/2013. It is the eighth largest energy producer in the world but is a net importer of crude oil and refined petroleum products. Coal is Australia's largest energy export earner, with a value of around AUD$40B in 2012–2013, down AUD$8B from 2011 to 2012. China is the largest importer of Australia's coal. Australia is also one of the world's largest exporters of uranium, though it does not have any installed nuclear power plants of its own.

Over the past 10 years, Australia's real export earnings have increased, on average 10% a year. However, they fell 12% in 2012–2013 largely as a result of lower coal prices but then rose by 6% in 2013–2014 supported by higher LNG prices [1].

In 2012–2013, fossil fuels, coal, oil, and natural gas made up about 94.4% of energy consumption. However, there has been a gradual shift away from coal to natural gas. The penetration of renewable energy is still small on a primary energy level at 5.6%—bioenergy and hydro making up 4.7% of this. See Table 9.1 and Figure 9.1 [1].

The high fossil fuel penetration in the energy mix has led to Australia to become one of the world's highest greenhouse gas emitters per capita. However, the contribution from

TABLE 9.1

Australian Energy Consumption by Fuel Type

	2012–2013		Average Annual Growth	
	PJ	**Share (%)**	**2012–2013 (%)**	**10 Years (%)**
Coal	1946	33.1	−5.9	1.4
Oil	2221	37.7	1.3	2.4
Gas	1387	23.6	2.2	3.3
Renewables	330	5.6	11.5	1.9
Total	**5884**	**100**	**−0.5**	**1.1**

Source: BREE 2014, Australian Energy Statistics, Table C.

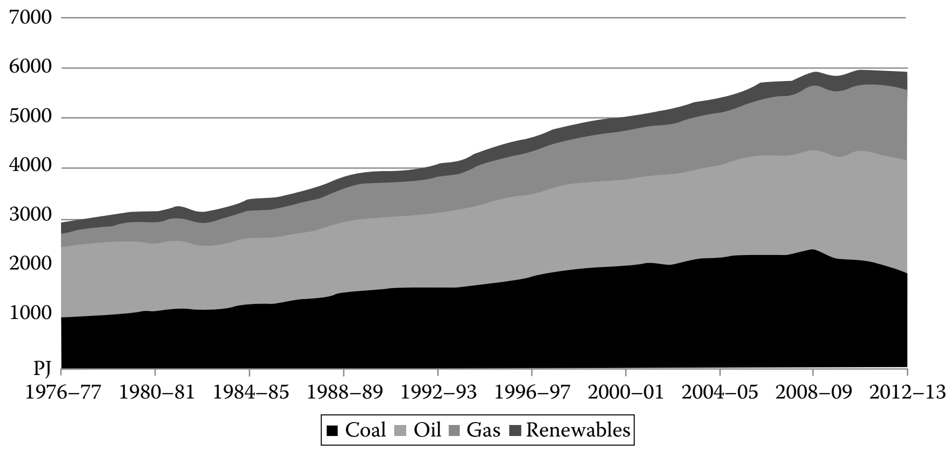


FIGURE 9.1
Australian energy consumption by fuel type. (From BREE 2014, Australian Energy Statistics, Table C.)

wind and solar is starting to increase particularly in the electricity sector (see the following). It is well endowed with a range of possible renewable resources—solar, wind, geothermal, wave, and tidal power. Currently, hydro is the largest source of renewable electricity, but its growth is limited and confined mainly to the State of Tasmania and some parts of the eastern seaboard, and the biomass at present is mainly bagasse from sugarcane in Queensland and landfill gas from around the country.

The electricity sector is also dominated by fossil fuels (86.9% in 2012–2013)—see Table 9.2 and Figure 9.2 that was derived from Table 9.2 [1]—but renewable energy is on the increase, in particular large-scale wind and rooftop solar. A number of successful policy initiatives were put in place between 2000 and 2013 that enabled the growth of renewables in Australia. However, between 2013 and 2015, growth and investment in renewables has stalled due to government policy uncertainties—see later.

The electricity network in Australia is divided into two main sections—the national grid in the East, extending over 5,000 km with 40,000 km of transmission line and cable—and the western Australian (WA) grid. The two grids are not connected because population between the two grids is extremely small (Figure 9.3).

TABLE 9.2
Australia's Electricity Generation, by Energy Source, 2012–2013

	2012–2013		Average Annual Growth	
	GWh	**Share (%)**	**2012–2013 (%)**	**10 Years (%)**
Fossil Fuels	**216509**	**86.91**	**−3.4**	**0.3**
Black coal	111491	44.8	−4.4	−0.9
Brown coal	47555	19.1	−13.6	−1.7
Gas	51053	20.5	5.1	5.7
Oil	4464	1.9	65.2	13.9
Other[a]	1945	0.8	78.8	0.8
Renewable Energy	**32566**	**13.1**	**26.2**	**6.2**
Bioenergy	3151	1.3	26.2	6.2
Wind	7328	2.9	19.9	29.7
Hydro	18270	7.3	29.7	1.3
Solar PV	3817	1.5	49.2	56.4
Geothermal	1.0	0.0	0.0	0.0
Total	**249075**	**100**	**−0.3**	**0.9**

Source: BREE 2014, Australian Energy Statistics, Table O.
[a] Includes multifuel fired power plants.

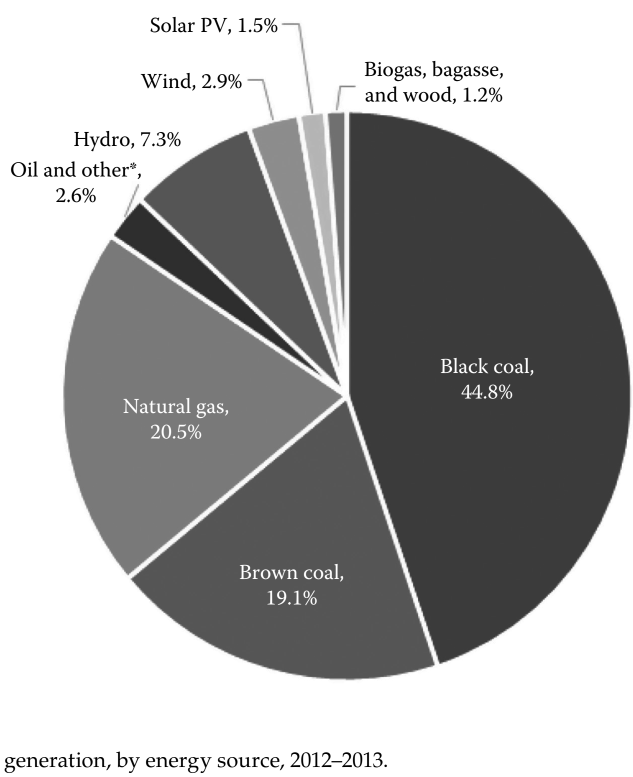


FIGURE 9.2
Australia's electricity generation, by energy source, 2012–2013.

FIGURE 9.3
Australian electricity transmission network. (From Briefing Note: Parsons Brinkerhoff to ENA, March 2009, Energy network infrastructure and the climate change challenge, http://www.aph.gov.au/~/media/wopapub/senate/committee/climate_ctte/submissions/su b307a_pdf.ashx, accessed April 1–16, 2015.)

9.2 History of Renewable Energy Policy in Australia

9.2.1 National Renewable Energy Policies

The main support for renewables on a national level has been the Renewable Energy Target (RET) scheme. Brought into effect in 2001 as the Mandatory Renewable Energy Target (MRET), it was a certificate-based scheme designed to increase the contribution of renewable energy to Australia's electricity demand from 10.5% in 1997 to 12.5% in 2010. During the development of the legislation, the target was fixed at 9500 GWh. Fixing the target was aimed at providing certainty to the energy industry. The MRET created a market for Renewable Energy Certificates by placing an obligation on electricity retailers and other wholesale electricity purchasers to source a proportional share of the target from eligible renewable energy sources (1 Renewable Energy Certificate or REC = 1 MWh).

In 2009, the national RET was expanded by nearly five times to become a target of 45,000 GWh in 2020 to support the Commonwealth Government's policy commitment that "at least 20 per cent of Australia's electricity should come from renewable sources by 2020." At this time, a Solar Credit "multiplier" was applied to the number of certificates received from certain small-scale generation technologies. The creation of Small-scale Technology Certificates (STCs) is a tradable commodity attached to eligible installations of renewable energy systems (including solar panels, solar water heaters, and heat pumps), with the number of STCs based on the amount of electricity in MWh that is

- Generated by a small-scale solar panel, wind, or hydro system over the course of its lifetime of up to 15 years or
- Displaced by a solar water heater or heat pump over the course of its lifetime of up to 10 years

The number of certificates that can be claimed may vary, depending on geographic location.

At the beginning of the program, the PV solar multiplier was 4× and delivered quite a significant capital cost reduction together with the 15-year deeming. In July 2013, the multiplier was reduced to 1 STC per MWh.

The STC multiplier program resulted in a large number of "virtual" certificates being generated, especially when the added state and territories feed in tariffs (FiTs) were introduced around 2009 thereby escalating growth in residential PV. The overall effect was to depress REC prices and discourage investment in large-scale projects, wind and solar farms, etc. So in June 2010, two separate markets were established—the Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES). These new markets began operating on January 1, 2011 with the LRET being capped at 41,000 MWh.

The SRES is uncapped, but with an implicit target of 4000 MWh. All PV systems up to 100 kWp are, currently, able to claim STCs up-front for up to 15 years of deemed generation, based on location. This means that the STCs for such systems act as an initial capital cost reduction.

From 2011, the two schemes no longer competed with one another.

On July 1, 2012, a price on carbon was introduced in Australia as part of a broad energy reform package called the Clean Energy Plan, which aimed to reduce greenhouse gas emissions by 5% below 2000 levels by 2020 and 80% below 2000 levels by 2050 plus provide funding to achieve the 20% of electricity from renewables by 2020. The price on carbon aimed to accomplish these targets by encouraging Australia's largest emitters to increase energy efficiency and invest in sustainable energy. The price started at $23.50 in 2012/2013 and was to reach $24.40 in 2014/2015 and then transition to an emissions trading scheme. However, in 2013 there was a change in Federal Government, from Labor to Liberal. One of the first things the Liberals did on achieving power was to fulfil their election promise of "axing the carbon tax," and a "Direct Action" program was introduced instead—see later. They also introduced in 2014 a scheduled RET review headed by a well-known climate skeptic who recommended that the RET be considerably cut back. One rationale for this was that the growth in the electricity sector had slowed down, and it was anticipated that the target of 41,000 GWh in 2020 would be greater than 20% of sales. At the time of writing, April 2015, there were intense political negotiations as to what the new target should be. The new government does not want to go above 32,000 MWh, which would have quite a significant impact on the RE industry. Opponents want a higher target but have suggested a compromise of 33,500 GWh—which has not been accepted.

Historically, the Large-Scale Generation Certificates (LGCs) commanded prices between $40 and $50/MWh but dropped to almost $20/MWh with the uncertainty of the RET, but the price has been steadily increasing in the hope of an imminent resolution of the target. The STCs have remained around $40/MWh since mid-2014 when the number of certificates reduced due to the phasing out of the multiplier and FiT in most states.

The RET uncertainty has had a significant impact on RE investment in Australia, and though globally renewable energy sales increased 16% in 2014 [3] in Australia, Kane Thornton, CEO of the Clean Energy Council, announced in January 2015 that "Investment in large-scale renewable energy projects such as wind and solar farms last year was down 88 per cent to just $240 million (it was $2.1 billion in 2013)—the worst levels we have seen for more than a decade. Australia's renewable energy investment is now lagging behind countries such as Panama, Honduras and Myanmar" [4].

9.2.2 Australian State-Based Renewable Energy Policies

Each state and territory in Australia has its own renewable energy policy, incentives, and energy efficiency programs.

By far, the most effective program has been the FiT—mainly confined to small-scale PV programs. The FiT was first legislated in South Australia in 2008 and came into being in 2009. Most other states then followed. There was no federal FiT program and no consistency in programs around the country. As what happened in many places globally, high incentives were initially introduced, but then as expected targets were rapidly exceeded, the FiT was either reduced or phased out—having a damaging effect on PV installation businesses.

A review of FiT incentives for mid-2013 can be found at http://www.ecosmartelectricians.com.au/index.php?page=what-is-the-feed-in-tariff.

The FiT has been criticized as being the source of increased electricity tariffs and being a mechanism whereby the low-income population subsidize the rich. However, in reality, the FiT contribution to the average retail electricity price in Australia has been estimated to be about 2.3% and the combined RET scheme and FiT about 5%, compared to a network cost contribution of 45.7% [5]. In addition, the majority of the purchasers of PV systems are the middle- to low-income demographic rather than those with high-income demographic; nevertheless, programs are underway to try and reduce cost impacts on disadvantaged sectors of the community.

Though Australia has, as a whole, a target of 20% of its electricity from renewable sources by 2020, two regions of the country have higher targets. The Australian Capital Territory—90% by 2020 and South Australia—50% by 2025 [8] and http://www.environment.act.gov.au/__data/assets/pdf_file/0004/581701/Renewable-energy-brochure_ACCESS.pdf.

9.3 Renewable Energy Penetration in Australia: Detail

The penetration of renewable energy in the primary energy mix of Australia has been reasonably constant at around 4%–6% for about two decades (see Table 9.1). However, the composition has changed from predominantly hydro and biomass around 2000 to currently hydro and wind electricity generation from large-wind farms. The latter having been installed as a result of RET program support—wind being more cost effective than solar technologies to date. So far, no large-scale solar thermal electricity generation projects have been installed in Australia but many projects have been proposed. Though most of the growth in renewable electricity generation has been from wind, its penetration as a percent of total electricity generation in Australia is small, ~3% of total. However, in the state of South Australia (SA), wind averaged 31% of electricity generation during 2013/2014 [6] and 33% by the end of 2014—http://www.renewablessa.sa.gov.au/—up from zero 10 years ago. Additionally, the contribution of rooftop solar to electricity generation has been 6% from 25% of SA households over 2013/2014 giving a total of 39% of intermittent generation on the SA grid. Per capita, this is one of the highest penetrations of intermittent generation globally and has come about not only due to the exploitation of a good wind resource but because of good State Government policy support and legislation in the early years.

The growth of wind in Australia is shown in Figure 9.4 and now is approaching 3500 GW, with about 40% of installed capacity being in South Australia [7].

(For those interested, daily performance data of wind generators on the National Grid can be seen at http://windfarmperformance.info/.)

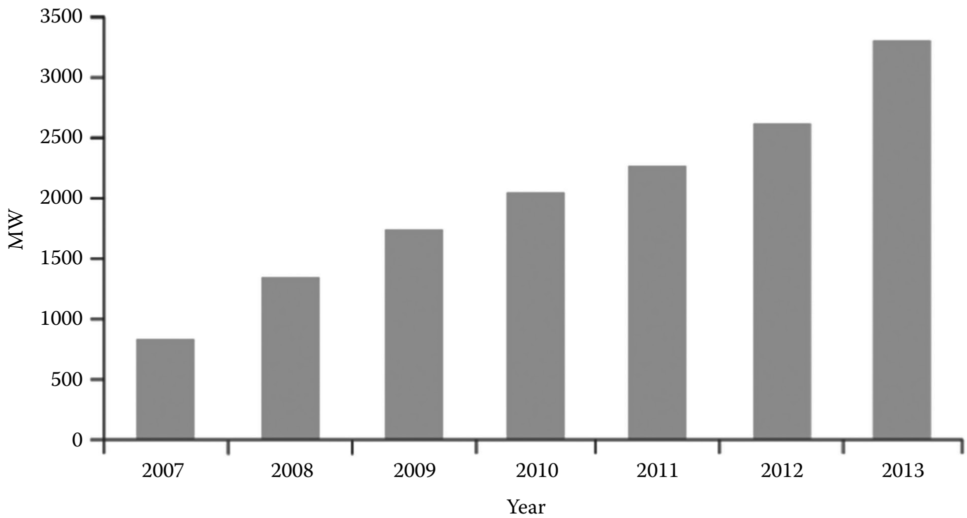


FIGURE 9.4
Cumulative installed wind capacity in Australia.

The installed renewable electricity generating capacity from hydro, wind, and PV (mainly rooftop solar) on the National Energy Market (NEM) grid is shown in Figure 9.5 [7] and totals, excluding large hydro, 12,875 and 28,476 MW, including hydro (August 2014). Adding in Western Australia and the Northern Territory to get an Australia wide total, increases installed renewable capacity by about another 1000 MW. See [8].

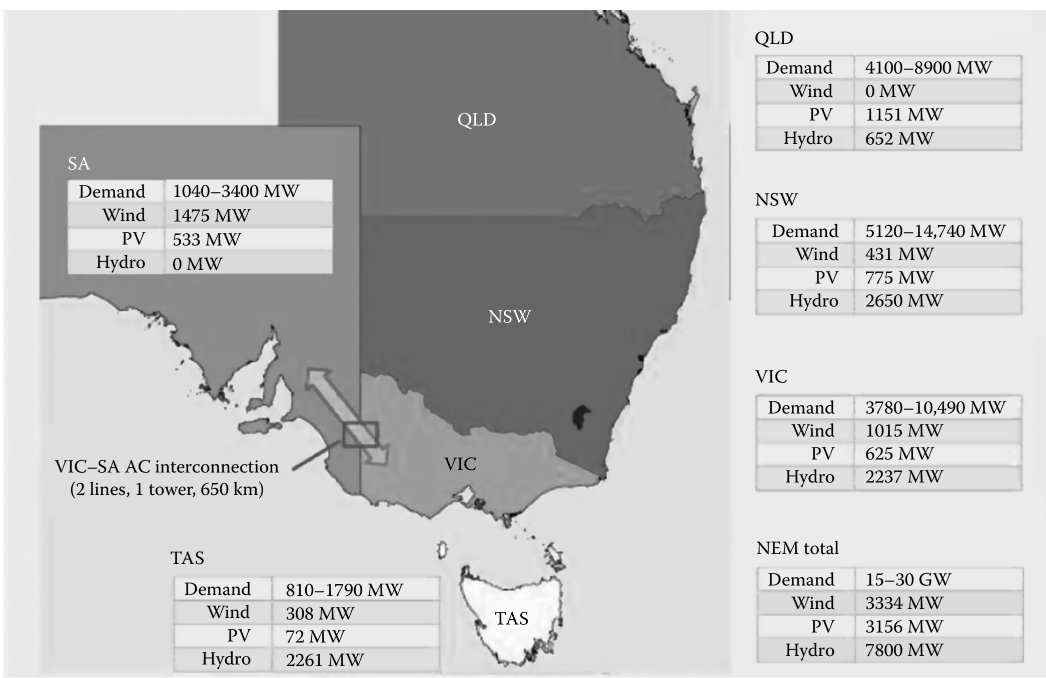


FIGURE 9.5
Renewable generation on the NEM (National Energy Market grid).

9.4 The Solar Energy Resource in Australia

Australia has a very good solar resource—better in central regions where the population is very sparse and there is no electricity grid. In these locations, the average annual DNI can be as high as 30 $MJ/m^2/day$, compared with the populated coastal regions where the DNI averages, annually, 18–20 $MJ/m^2/day$.

Geoscience Australia in collaboration with the Australian Bureau of Meteorology and funded by the Australian Renewable Energy Agency has developed the "Australian Solar Energy Information System (ASEIS) Online" http://www.ga.gov.au/solarmapping. Figure 9.6 shows a representative picture of the mean DNI solar resource in January. Maps can display distance to transmission line, topographic information, etc. Metadata are also available. More detailed 1 min solar data can be obtained from the Bureau of Meteorology website at http://www.bom.gov.au/climate/data/oneminsolar/about-IDCJAC0022.shtml.

Despite the good solar resource, only about 0.2% of Australia's primary energy use is from solar energy—about 90% of this being used in the residential sector for solar water heating and rooftop PV. Over the 10-year period to 2012–2013, electricity generation from solar PV grew at an average annual rate of 56.4%, from a very low base to 1.5 TWh in 2012–2013—see Table 9.2 [1].

Figure 9.7 shows very clearly how the introduction of the FiT in Australia in 2009 increased the number of residential grid-connected PV installations. In 2013, typical PV module prices were \$0.50–\$0.75/W AUD and installed costs \$1.8–\$2.5/W AUD [9].

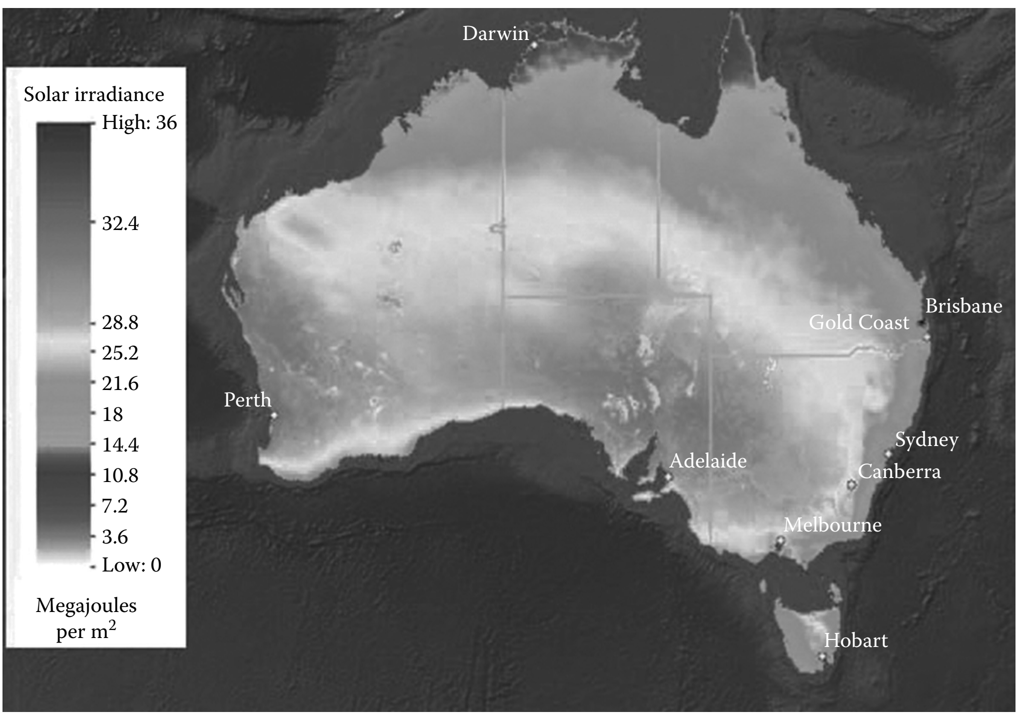


FIGURE 9.6
January mean DNI—Direct Normal Irradiance on a horizontal plane.

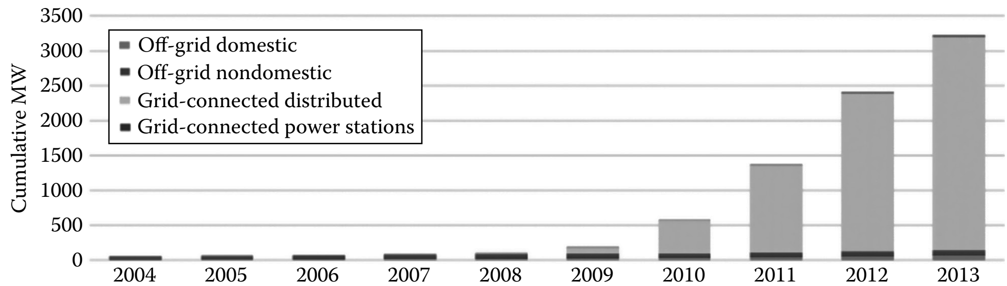
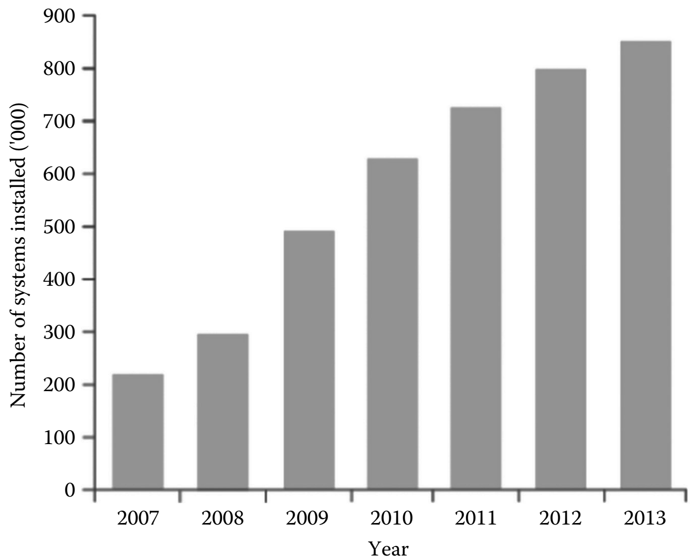


FIGURE 9.7
Cumulative installation of PV in Australia 2004–2013. (From Muriel Watt et al., June 2014, APVI Report: National Survey Report of PV Power Applications in Australia, 2013, http://apvi.org.au/wp-content/uploads/2014/07/PV-in-Australia-Report-2013.pdf, accessed April 1–16, 2015.)



Year	Cumulative number of installations
2007	212,422
2008	297,806
2009	492,497
2010	619,589
2011	724,639
2012	794,105
2013	847,700

FIGURE 9.8
Cumulative installed solar water heaters in Australia.

Australia has no local commercial manufacturer of PV cells and one module assembler—Tindo Solar (South Australia).

There has also been a rapid growth in recent years of solar water heaters—see Figure 9.8. This growth has been helped by the phasing out of high emission storage electric and low-efficiency gas water heaters [10].

9.5 Large-Scale Solar Installations

In October 2012, the 10 MW Greenough River PV Solar Farm near Geraldton, Western Australia was completed using First Solar modules. At that time, it was the largest PV installation and the only one with greater capacity than 1 MW in Australia. In July 2013, it was announced by electricity Retailer and Generator AGL that two solar farms would be installed in New South Wales, 100 MW at Nyngan, and 50 MW at Broken Hill both using First Solar PV modules, with supporting funding being provided by the Australian Renewable Energy Agency, ARENA, and others. By May 2015, 25 MW of the Solar Farm had been installed and started generating at Nyngan, and the Broken Hill plant was under construction.

The largest grid-connected concentrated PV (CPV) installation in Australia is the 1.5 MW demonstration system in Mildura Victoria, commissioned in April 2013 by Silex, previously Solar Systems. It was hoped to upgrade this to a 100 MW system; however, uncertainty in the Federal Government's RET has meant that this upgrade has been abandoned. Project used ultra-high-efficiency (43%) "multi-junction" PV cells, technology originally developed by Boeing to power satellites.

At present, there are no Solar Thermal Electric Power Stations in Australia. However, at the 2000 MW Liddell coal-fired power station 260 km north of Sydney, a 9.3 MW thermal solar-concentrating system based on Fresnel solar collector technology has been installed. (Total mirror surface of 18,500 m^2.) The solar boiler acts as a fuel saver by feeding steam into the existing coal-fired power station and reducing the coal required to operate the facility. The Fresnel collector system was a development out of Sydney University and the University of NSW. The original company formed was "Solar Heat and Power"; it is now owned by Novatech.

A good review of the current status of concentrating solar thermal power technologies, their potential costs, benefits, grid impacts, and market development in Australia is the May 2012 report prepared for the Australian Solar Institute by IT Power (Australia), "Realising the potential of Concentrating Solar Power in Australia." The cover photo on the report, Figure 9.9, shows the solar gas research facility at the CSIRO Solar Thermal Research Hub of the CSIRO National Research Centre at Newcastle NSW.

FIGURE 9.9
Solar gas research facility at the CSIRO solar thermal research hub of the CSIRO National Research Centre at Newcastle NSW.

9.6 Renewable Energy Research in Australia

Australia has a long history of renewable energy research particularly in Solar Energy with groundbreaking work having been conducted on the following:

- High-efficiency PV research—University of New South Wales
- Evacuated tubular collectors—Sydney University
- Solar Thermal "Big Dish"—Australian National University
- Solar Gas Research —CSIRO
- Cooperative Research Centre for Low Carbon Living

to name but a few.

In July 2012, the Australian Renewable Energy Agency (ARENA) was established with a budget of AUD$3 billion extending to 2022 for

- Research, development, demonstration, deployment, and commercialization of renewable energy and related technologies
- Storage and sharing of knowledge and information about renewable energy technologies

The website http://www.arena.gov.au outlines the projects, initiatives, and reports funded by ARENA.

In mid-April 2015, the Australian Federal Government released its Energy White Paper [11] in which less than one page of the 74-page document was devoted to Renewable Energy. An extract from the page is given in the following:

> The Australian Government is providing over $1 billion toward the research, development and demonstration of renewable energy projects. The Australian Renewable Energy Agency (ARENA) was established as a statutory entity to make renewable energy solutions more affordable and increase the amount of renewable energy used in Australia. It has currently committed over $1 billion to more than 200 projects. The Clean Energy Finance Corporation invests in projects that use a commercial approach to overcoming market barriers and mobilising investment in renewable energy, energy efficiency and low emissions technologies. The Australian Government has announced that it will abolish these agencies, but maintain a commitment to existing projects.

The Energy White Paper does not address climate change; this is left to the "Direct Action" program in the Federal Department of the Environment.

9.7 Direct Action

The Australian Government intends to reach its emissions reduction target through its Direct Action Plan "to efficiently and effectively source low cost emissions reductions and improve Australia's environment. This will be done primarily through the Emissions Reduction Fund." See http://www.environment.gov.au/clean-air.

The Emissions Reduction Fund (ERF) is the centerpiece of the Government's climate action policy. It will work with other incentives under the Direct Action Plan to help meet Australia's target of reducing emissions by 5% below 2000 levels by 2020. Design options for the Safeguard Mechanism for the ERF fund are currently in the consultation phase.

A large part of the ERF will be soil carbon and carbon offsets through revegetation programs.

9.8 Conclusion

Australia's energy sector is dominated by fossil fuels, in particular coal. Although the contribution by renewables to primary energy in Australia is small, about 5.6% in 2013, they represented 13.1% of electricity generation. There is a very large renewable energy potential that could be exploited in Australia, with significant natural resources for solar, wind, geothermal, and marine energy and with more limited resources in hydro and bioenergy.

Electricity consumption in Australia has been declining over the past few years due to the increased implementation of energy efficiency programs, installation of rooftop solar and solar water heater systems, and a downturn in the industry sector. In addition, this has led to the shutdown or reduced usage of some coal-fired power stations around the country. It is also behind the reasoning of the Federal Government desire to reduce the RET.

Up to 2013, the RET had already attracted about $18.5 billion of investment in RE into Australia and created about 21,000 jobs. However, after over a year with no target having been decided on and with uncertainty in Government support for renewable energy programs and R & D, investors and investment in large-scale renewable energy programs have significantly declined and there have been many job losses. There has, however, been an increasing interest in community-driven programs, and it is likely that change will be driven by the people. Additionally, it has been found that the electricity grid can support high penetrations of intermittent renewables—up to almost 40% in South Australia already exists. Though problems have been created they can be solved and a paradigm shift in how electricity distributors and retailers will operate in future is likely to come sooner rather than later.

Many are following with interest how renewable energy in Australia will develop in the next few years. There is potential that some areas of Australia could be a model of how to integrate successfully and reliably a range of renewable energy sources into the energy mix if old business models are not followed.

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10

Japan's Post-Fukushima Energy Policy

Keibun Mori

CONTENTS

10.1 Introduction

Japan's approach to greenhouse gas (GHG) mitigation long advocated not only for energy efficiency and renewable energy, but also for nuclear energy. This three-pronged approach, along with the contributions from Kyoto mechanisms and economic stagnation, had been effective in meeting the Kyoto Protocol obligation. However, in response to the massive earthquake and associated nuclear accident in March 2011, the Japanese government issued a moratorium on the restart of nuclear reactors and new construction, and the share of nuclear power in electricity generation declined sharply from 29% in FY 2010 to 11% in FY 2011, and to only 1.0% in FY 2013.[1] A nationwide electricity-saving campaign slashed demand by 5%, and Japan was able to avert an electricity shortage due largely to successful nationwide energy saving campaign. Still, the sustained moratorium on nuclear energy caused the increased mobilization of thermal plants fueled by natural gas and petroleum, resulting in adverse impact on electricity costs and GHG emissions[2] (Figure 10.1).

Under these circumstances, the Noda administration of the Democratic Party of Japan (DPJ) in 2012 drafted a new energy plan called *the Innovative Strategy for Energy and the Environment*, which aspires to phase out all nuclear power plants during the 2030s through accelerated renewable energy deployment (17.7% in total electricity generation by 2020 (Table 10.1)) and rigorous energy conservation measures (total energy consumption 19% below 2010 levels by 2030).[3] Nonetheless, its forecast however shows that without nuclear power, the emissions in 2020 will be below 1990 levels only by 5% at most, far short of the reduction goal of 25% below 1990 levels by 2020, set in 2009. Furthermore, electric utilities and energy intensive industries raised the concerns over the grid stability and economic costs of such a drastic change in the electricity generation fuel mix.

For these reasons, the subsequent Abe administration of the Liberal Democratic Party (LDP) shelved this ambitious phase-out plan and instead revised *the Basic Energy Plan*,

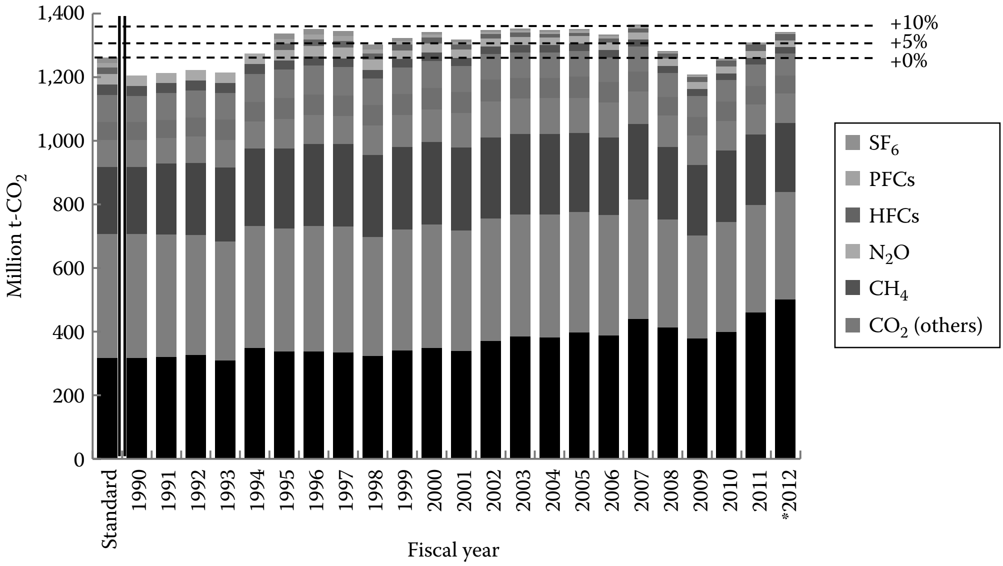


FIGURE 10.1
GHG emission contributions and trend. * The figure for 2012 is. (From Greenhouse Gas Inventory Office of Japan, National greenhouse gas inventory report of Japan, 2013, http://www-gio.nies.go.jp/aboutghg/nir/nir-j.html.)

TABLE 10.1
Renewable Energy Target in the Innovative Strategy for Energy and the Environment

	2010		2020		2030	
Source	**TWh**	**%**	**TWh**	**%**	**TWh**	**%**
Renewable	114.5	10.5	192.4	17.7	308.0	28.7
Hydropower	89.4	8.2	109.1	10.0	117.5	11.0
Photovoltaic	3.8	0.3	35.1	3.2	66.6	6.2
Wind	4.3	0.4	16.9	1.6	66.3	6.2
Geothermal	2.6	0.2	7.5	0.7	21.9	2.0
Biomass	14.4	1.3	23.6	2.2	32.8	3.1
Marine	0.0	0.0	0.0	0.0	3.0	0.3
Others	976.3	89.5	897.5	82.3	764.3	71.3
Total	1,090.8	—	1,089.9	—	1,072.3	—

Source: Cabinet Office of Japan, Innovative strategy for energy and the environment, 2012, http://www.cas.go.jp/jp/seisaku/npu/policy09/sentakushi/database/index.html.
Note: No nuclear in 2020 and 2030, robust growth, and before additional measures.

a long-term vision previously drafted in 2010. The revised *Basic Energy Plan* repositions nuclear power as *an important baseload electricity source* and describes the prospect of renewable energy to be *further above* the past forecasts, footnoting 13.5% by 2020 and 20% by 2030 as a reference, in lieu of the explicit numerical target set by the Noda administration. In 2015 the Abe administration plans to establish new targets of electricity generation fuel mix as well as GHG emissions for 2030, and the new mix is likely to have a significant share of nuclear energy while showing less ambitious role of renewable energy.

In practice, in spite of the first approval of the restart of a reactor under the new safety regulation by the politically-independent Nuclear Regulation Authority in 2014, a more risk-averse public makes it unrealistic to count on the restart of high-risk reactors or new construction for the foreseeable future. Moreover, the authority established the so-called 40-year rule which requires *special safety checks* on the restart of reactors after 40 years of operation that in principle makes the restart impossible without costly retrofits; in fact, several utilities are leaning toward decommissioning outdated reactors after experiencing the complex and lengthy approval process for relatively new reactors. When combined with the continuing needs to reduce GHG emissions, these tight limits on Japan's nuclear future prompted the country to roll out a number of policy actions accelerating renewable energy development and energy efficiency investment.

10.2 Feed-In Tariff

A feed-in tariff (FIT) program for renewable energy, introduced in July 2012, is perhaps the most drastic policy change after the accident, replacing a facile renewable portfolio standard (RPS). The FIT aims at stimulating renewable energy development through government-guaranteed 20-year power purchase contracts* with a predetermined purchase price (tariff). An independent expert panel determines the tariff rates for each technology type and facility scale to expedite investment in a diverse array of renewable energy projects, and it revises the rates every year to reflect various changes such as a fall in solar panel costs (Figure 10.2).

Due to the urgent need for new power generation amid the moratorium on the restart of nuclear power plants, the expert panel granted premium rates in the first year to enable investors to secure financing promptly. The rates were then trimmed each year for PV, after the premium rates and the legally-binding purchase system resulted in extraordinary growth of utility-scale PV, whereas new categories were created in FY 2014 and FY 2015 for several costly but promising technologies such as offshore wind and small-scale biomass.

The outcome of the FIT has been mixed thus far. According the Agency for Natural Resources and Energy (ANRE), the cumulative installed capacity of renewable energy jumped from 20.3 GW at the program start to 35.2 GW in November 2014, plus 58.6 GW worth of authorized projects in the pipeline. PV was responsible for most of this growth, showing that other energy sources have yet to gain traction (Figure 10.3). The likely causes of the apparent favoritism for PV are (1) favorable tariff structure, (2) an environmental assessment waiver, and (3) siting advantages. The basis of the tariff rates was the national study of life cycle costs of electricity generation in 2011,[4] but the costs of solar panels have fallen sharply since then, enabling the investors to exploit the price differentials between the actual and assumed costs. The second factor favors utility-scale PV by waiving the lengthy environmental assessment process, which normally takes at least 3 years for most renewable energy development, for PV projects covering an area of 50 ha or less and having no adverse impact on land use. Utility-scale PV also has siting advantage as it can be built on most vacant property, whereas wind, geothermal, and biomass power plants typically have to be located in remote areas with little transmission infrastructure to major energy consumption centers. These factors gave PV competitive advantage over other renewable sources, causing the concentration of investment in a single generation technology, at least for now.

The heavy growth in PV is causing several complications. First of all, the capacity factor, a ratio of its actual output over a period of time (e.g., kWh) to its potential output (e.g., kW), is

* For small-scale photovoltaic and geothermal, the contract duration is 10 and 15 years, respectively.

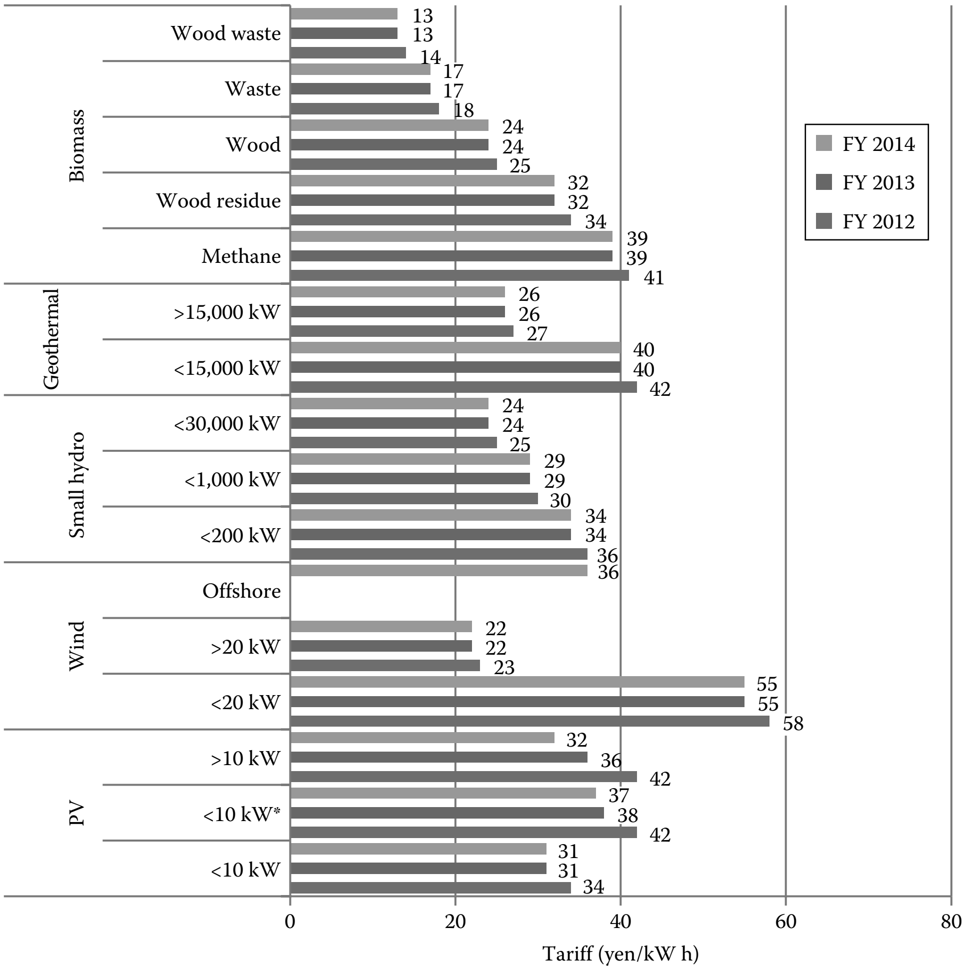
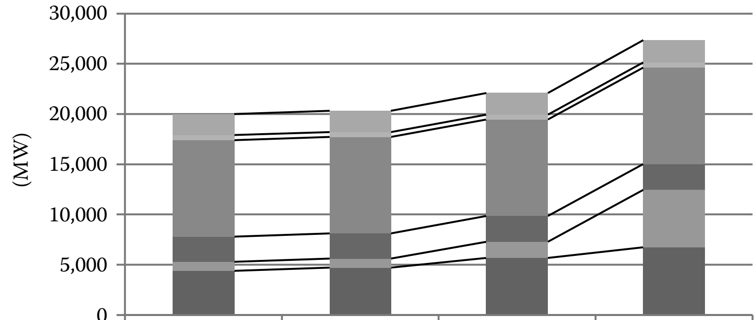


FIGURE 10.2
Tariff rate of the FIT program. (From Agency for Natural Resources and Energy, Avoidable cost calculation method and facility certification system reform, 2014, http://www.meti.go.jp/committee/sougouenergy/shoene_shinene/shin_ene/kaitoriseido_wg/pdf/003_s01_00.pdf.)

so low for PV that the development figure in capacity basis tends to mislead the public about the impact on national fuel mix. In fact, despite the massive introduction of renewable energy in capacity basis, the share of renewable energy (excluding large-scale hydropower) in electricity generation increased only by 0.8% between FY 2011 and FY 2013, from 1.4% to 2.2%.[1]

Lastly and most importantly, the impact on grid stability is also a concern for electric utilities, as the current intraregional grid system is designed to balance the load and generation within a single region and thus can integrate only a limited amount of variable energy sources. In fact, in late 2014, several major electric utilities declared the moratorium for granting grid-access for new renewable energy developments despite the legal obligation, citing the limitation of the grid ability to handle variable energy sources. In response, ANRE established new rules in January 2015, allowing electric utilities to curtail grid-access for PV and wind energy producers for up to 360 hours per year without compensation, along with possible unlimited curtailment without compensation for future project developers if the



	March 2012	June 2012 (FIT start)	March 2013	December 2013
Biomass	2,100	2,106	2,136	2,225
Geothermal	500	500	501	501
Small hydro	9,600	9,602	9,605	9,608
Wind	2,500	2,500	2,563	2,574
PV (Utility-scale)	900	902	1,606	5,731
PV (rooftop)	4,400	4,700	5,669	6,716

FIGURE 10.3
Cumulative renewable energy capacity development. (From Agency for Natural Resources and Energy, Avoidable cost calculation method and facility certification system reform, 2014, http://www.meti.go.jp/committee/sougouenergy/shoene_shinene/shin_ene/kaitoriseido_wg/pdf/003_s01_00.pdf.)

utility determines that its grid is saturated with existing generation capacity. While major curtailment is unlikely to occur in near future due to the slow approval process for restart of nuclear reactors, this new rule crowds the long-term financial certainty for variable energy developers and thus is expected to stagnate new developments, especially utility-scale PV.

These circumstances suggest that there needs to a fine-tuning to provide more incentives for other renewable energy sources and new mechanisms to promote load and generation shaping measures that enable grid integration of more variable resources, such as expanded use of demand management strategies, flexible backup energy sources, interregional power interchange, and energy storage facilities. Secondly, the high costs of PV could possibly compromise Japan's global economic competitiveness through increased electricity prices, particularly in energy-intensive sectors such as the steel industry. ANRE reports the national costs of the FIT program amount to 130 billion yen (approx. U.S. $1.3 billion) for FY 2012, which is anticipated to grow to 313 billion yen (approx. U.S. $3.1 billion) in FY 2013,[5] and the increasing economic burden could adversely impact low-income households and energy-intensive industries in the coming years.

10.3 Energy Conservation Law

Since the 1970s oil crisis, Japan has made massive investments in energy conservation technologies and practices, leading Japan to achieve one of the lowest energy intensities (per GDP) in the world[6] despite the presence of energy-intensive manufacturing industries

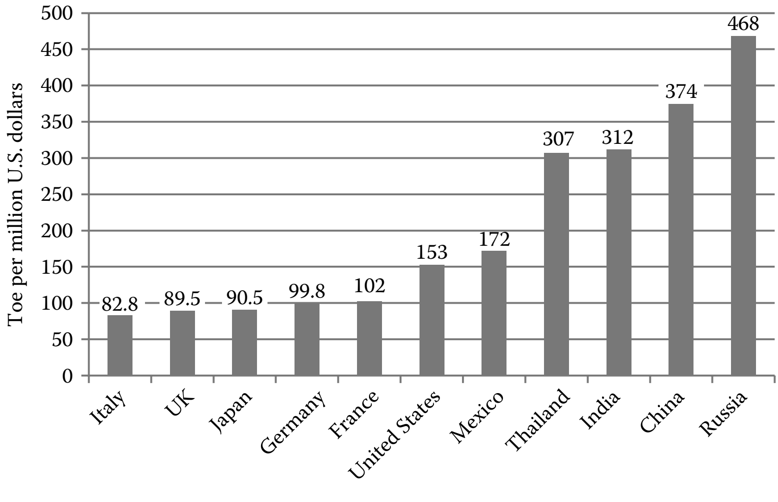


FIGURE 10.4
Energy use per nominal GDP in 2010. (From Energy Data and Modeling Center, *Handbook of Energy and Economic Statistics in Japan*, 2013.)

(Figure 10.4). The energy conservation law has been the primary policy instrument propelling energy efficiency investment; it was first enacted in 1979 and amended in 1998, 2002, 2005, 2008, and 2013 to expand the target and enhance the enforcement mechanism. The law not only targets specific emitting equipment such as trucks and refrigerators, but also requires businesses to draft and implement energy conservation plans for their factories, buildings, and fleets. For example, businesses reporting total energy use of 1,500 tons of oil equivalent (toe) per year must draft and implement a long-term plan to improve efficiency by 1% or more annually, and the latest amendment in 2013 encourages a *peak cut*—curbing electricity demand during peak hours through measures such as demand shift, cogeneration, and storage battery installation.

For equipment, the law establishes *the Top Runner Program*, which sets energy efficiency standards based on the performance of the best available technologies (*top runners*) for each item.[7] The program began in 1999 with standards for 11 items, and expanded the coverage over time to 27 items (Table 10.2). The focus of the program has been on automobiles and office and home appliances, but the latest amendment in 2013 added building materials as an enabling item to save energy used in other equipment. The impact of the program has been outstanding: for instance, the energy use of a standard air conditioner decreased by 43.3% between 1995 and 2012,[6] and the average fuel efficiency of a passenger car rose by 58.5% between 1993 and 2012.[8]

The regulatory approaches under the energy conservation law have been successful in Japan due largely to the unique cooperative relationship between businesses and regulators, and the law gained popularity among the general public as a plain and transparent regulation.[9] Nonetheless, some businesses claim the uniform reduction mandate on commercial energy use is unfair, as the difficulty in achieving the target depends on the baseline energy use, where those who acted early to reduce their energy use now have to work harder to meet the requirement. The *Top Runner Program* now applies to roughly half of the energy use in the residential and commercial sectors, but misses some energy-intensive equipment such as washers, dryers, commercial refrigerators, and commercial freezers. The program sets separate standards for size-based subcategories,

TABLE 10.2

Target Items in Top Runner Program

Start Year	Item		
FY 1999	Passenger vehicle	Freight truck	Air conditioner
	Television	Fluorescent lamp	Copying machine
	Magnetic disk unit	Video cassette recorder	Computer
	Freezer	Refrigerator	
FY 2002	Space heater	Gas stove	Electric toilet seat
	Petroleum water heater	Gas water heater	Vending machine
	Transformer		
FY 2006	Rice cooker	Microwave oven	DVD recorder
FY 2008	Router	Switching unit	
FY 2012	Printer	Multifunction printer	Electric water heater
FY 2013	Thermal insulator		

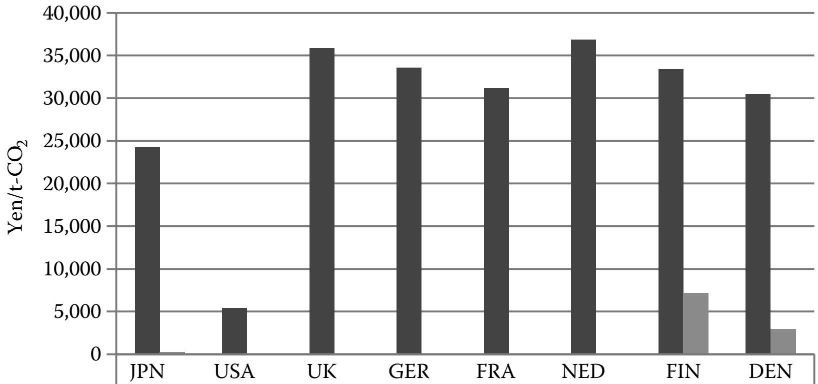
Source: Agency for Natural Resources and Energy, Comprehensive energy and environmental strategy research report, 2013, http://www.meti.go.jp/meti_lib/report/2013fy/E003456.pdf.

and some analysts have argued that it may be discouraging downsizing of passenger cars, televisions, or other items. These criticisms suggest that, though the 36-year-old law has made important contributions to energy conservation in Japan, it still has room for improvement.

10.4 Carbon Tax

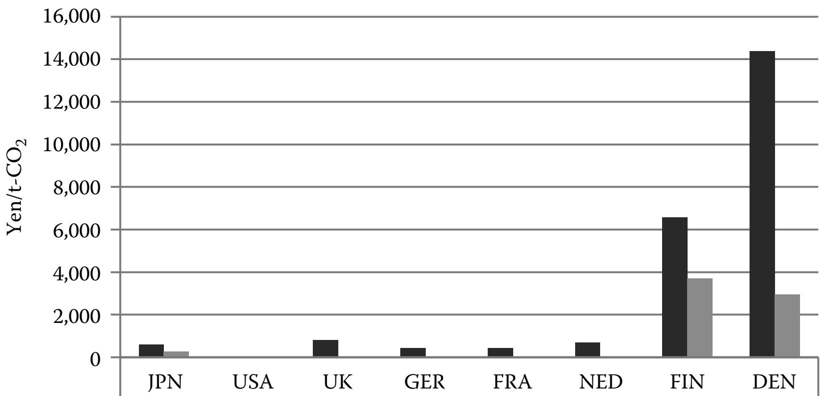
In response to the oil crisis, Japan imposed heavy taxes on petroleum, but not on other fossil fuel sources. In October 2012, however, Japan introduced a carbon tax (*tax for global warming countermeasures*), whose rate is based on carbon content, and thus giving largest impact on coal prices due to its high carbon intensity. The tax rate began at 95 yen (approx. U.S. $1) per t-$CO_2$ and is slated to reach a cap of 289 yen (approx. U.S. $3) in 2015. While it is still relatively small compared to CAN $30 per t-$CO_2$ in British Columbia, Canada, Japan's carbon tax covers all fuel uses, including aviation and industrial use, which are often exempted or taxed differently in other areas, and is in addition to a variety of other high energy taxes (Figures 10.5 and 10.6). It is expected to raise 262 billion yen (approx. U.S. $2.62 billion) in FY 2015 and thereafter, and its revenues are dedicated for energy efficiency and renewable energy programs, unlike British Columbia's revenue-neutral approach where the revenues are offset by reductions in other taxes.

The major intent of the tax is to incentivize energy efficiency and renewable energy investment by sending price signals to favor energy-saving technologies and behaviors. In addition, the elevated costs of fossil fuels are expected to impact electricity generation fuel mix in favor of other sources, and the revenues allocated to various R&D and rebate programs are expected to accelerate the development and deployment of new, low-carbon technologies. The Ministry of the Environment (MOE) estimates that the tax will lower 2020 emissions by 0.5%–2.2% relative to a no-action baseline,[10] but this estimate does not account for impacts on fuel mix and behavioral change, so the impact could be substantially larger if accounting for these factors.[11]



	JPN	USA	UK	GER	FRA	NED	FIN	DEN
Total tax	24,241	5,424	35,892	33,614	31,167	36,887	33,403	30,452
Carbon tax	289	0	0	0	0	0	7,189	2,950

FIGURE 10.5
Energy taxes on gasoline (2014). (From Ministry of the Environment, Interim report from the environmental tax commission, 2013, https://www.env.go.jp/policy/tax/conf01.html.)



	JPN	USA	UK	GER	FRA	NED	FIN	DEN
Total tax	590	0	816	434	434	692	6561	14,384
Carbon tax	289	0	0	0	0	0	3708	2,947

FIGURE 10.6
Energy taxes on coal (2014). (From Ministry of the Environment, Interim report from the environmental tax commission, 2013, https://www.env.go.jp/policy/tax/conf01.html.)

A carbon tax is an economy-wide policy tool to curb GHG emissions, and the resulting price signal can incentivize low-carbon technologies and behaviors without the significant implementation cost and economic inefficiency of regulatory approaches. While MOE's expert panel recommends more extended use of a carbon tax,[12] energy-intensive industries argue that a higher tax could lead to a leakage problem in which economic activities, and their GHG emissions, are shipped overseas. For this reason, worldwide implementation or some form of a border tax may be needed for more extended use of a carbon tax.[13]

TABLE 10.3

Target Items in Green Investment Tax Break

Area	Item	
Renewable energy	Photovoltaic	Wind, hydrothermal
	Snowpack storage	Biomass
Transportation	Hybrid electric truck	Plug-in hybrid vehicle, electric vehicle
	EV charging system	Hybrid electric construction machinery
Commercial Building	Insulated window	Efficient ventilation system, solid state lighting (LED)
	Efficient air conditioner	Building energy management system (BEMS)
Industrial and power sector	Cogeneration system	Combined-cycle gas turbine, efficient industrial furnace
	Efficient processing tool	High-voltage transmission system

10.5 Tax Incentives and Subsidies

The government has long adopted various tax incentive and subsidy programs for individual items such as the Eco-car Tax Break and the Residential PV Installation Support Subsidy. The Green Investment Tax Break* is perhaps the most comprehensive tax incentive program for corporations, targeting a variety of items in renewable energy, transportation, building, and industrial efficiency (Table 10.3). The government launched the program in 2011 to reduce the tax burden through bonus depreciation—30% of purchase and installation costs—or 7% tax credit for corporate income tax. This tax scheme is similar to the Business Energy Investment Tax Credit in the United States but covers a broader set of low-carbon technologies.

The total tax break from the program amounted to 97.6 billion yen (approx. U.S. $976 million) in the first year, and a survey estimates it induced 7%– 45% of additional investment, depending on the item.[14] The same study forecasts the annual GHG reduction to total 3.1 million t-CO_2 in 2015, equivalent to 0.2% of the national emissions, from the FY 2011 tax break alone. Although the impact of the program will become larger as it continues to induce more investment, the major concern is that the beneficiaries are limited to profit-making firms paying corporate income tax. The worldwide recession and the 2011 earthquake collaborated to put over 70% of Japanese enterprises reporting losses or accumulated losses in FY 2011,[15] so the vast majority of businesses were simply not eligible for the program. The economic recovery is broadening the coverage, but a fundamental problem remains that many small and startup businesses tend to report losses. For this reason, a tax break on other taxes such as property tax may be a better policy instrument to attract investment from all businesses.

10.6 R&D

Japan has been one of the R&D leaders in low-carbon technologies, successfully commercializing various low-carbon technologies such as hybrid and electric vehicles, heat pump water heaters, PV cells, carbon fiber, power electronics, hydrogen fuel cells, and

* Translated from the original name, *Green Toshi Genzei*.

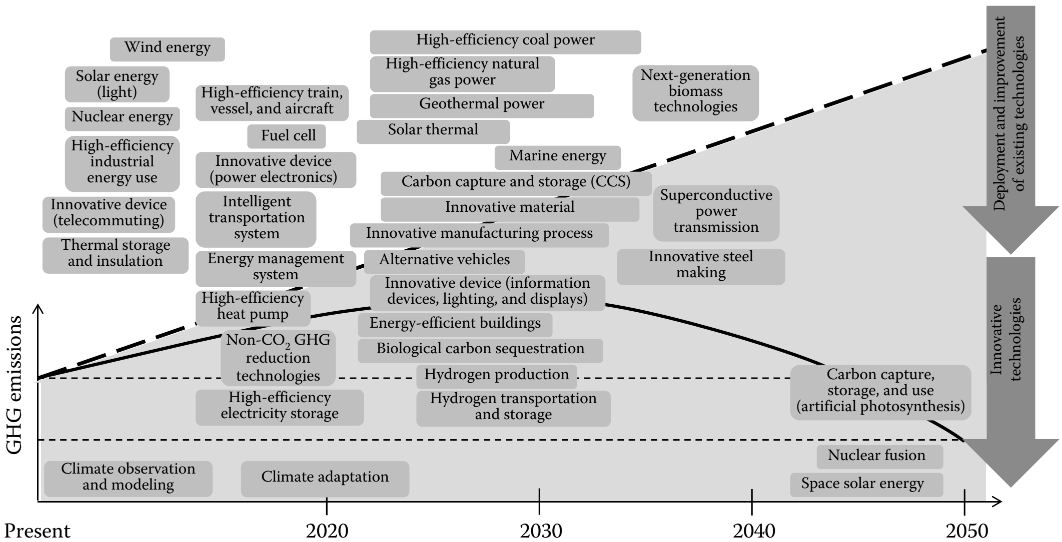


FIGURE 10.7
Focus areas in *the Environmental Energy Technology Innovation Plan*. (From Council for Science and Technology Policy, The Environmental Energy Technology Innovation Plan, 2013, http://www8.cao.go.jp/cstp/gaiyo/kankyo/20130809.html.)

LED light bulbs. To build on these successes, in 2013, the Abe administration revised a comprehensive R&D roadmap for low-carbon technologies called the *Environmental Energy Technology Innovation Plan*.* The plan is a basis for government R&D funding allocation, and lists 37 technology areas to cut today's world GHG emissions in half by 2050 (Figure 10.7),[16] of which five are new for 2013: (1) innovative materials such as carbon-fiber-reinforced plastic (CFRP) and high tensile strength steel (HTSS), (2) artificial photosynthesis to produce various chemicals such as hydrogen and olefin, (3) geothermal energy including enhanced geothermal system (EGS) and advanced exploration and drilling techniques, (4) solar thermal energy such as concentrated solar power (CSP) and direct use of thermal energy in heating and cooling, and (5) ocean energy such as tidal and current power.

Shifting attention to ongoing R&D activities, the government is boosting funding for the following prospective technologies: (1) offshore wind, particularly massive floating wind farms tested off the shore of Fukushima and Nagasaki, (2) hydrogen and fuel cells for residential application branded as Ene-Farm and for automobile use, rolled-out for the mass in 2014, (3) advanced thermal power such as advanced ultrasupercritical (A-USC) and integrated coal gasification combined cycle (IGCC) demonstration, (4) advanced electronics such as normally off computing, organic light-emitting diodes (OLED), and ultralow voltage devices, and (5) cost reduction and capacity enhancement of various types of battery such as Li-ion, sodium-sulfur, and redox flow batteries. The government envisions these technologies to play a pivotal role in curbing the emissions not only in Japan but also elsewhere in the world through export and technology transfer.

* Translated from the original name, *Kankyo Energy Gizyutsu Kakushin Keikaku*.

10.7 Conclusion

The earthquake and associated nuclear incident in 2011 triggered a variety of policy changes to propel energy efficiency and renewable energy investment. The policy instruments covered in this section will be crucial in curbing GHG emissions in Japan, but it is difficult to assess if the nation as a whole will be able to achieve significant reduction amid the uncertain future of nuclear energy. To maximize Japan's contribution to the world's efforts to reduce the emissions, Japan needs to actively share its technologies through export, licensing, and mostly notably a technology transfer instrument called Joint Crediting Mechanism (JCM). Moreover, the lessons learned from policy implementation in Japan, including the benefits, drawbacks, and areas for improvement, could be valuable for other nations to craft optimal strategies to encourage energy efficiency and renewable energy investment.

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11

Policies for Distributed Energy Generation

David M. Sweet

CONTENTS

11.1 Introduction

Decentralized energy* (DE) is showing ever-increasing promise as a cost-effective method of electricity supply, resulting in significant environmental benefits. Though every sector of the DE industry is showing impressive growth, the total share of DE in overall global electricity capacity remains at only about 7.2%.[1] Lack of clear policy in the energy sector is one of the main barriers preventing greater investment in DE. It is clear that adopting policies that ensure an independent regulator combined with open

* DE technologies consist of the following forms of power generation systems that produce electricity at or close to the point of consumption:

- High efficiency cogeneration/CHP
- Onsite renewable energy systems
- Energy recycling systems, including the use of waste gases, waste heat, and pressure drops to generate electricity onsite

WADE classifies such systems as DE regardless of project size, fuel or technology, or whether the system is on-grid or off-grid.

markets that reward investors for noneconomic benefits of DE will be key in driving future growth in the sector.[2]

In June 2004, the largest renewables energy event to date was held in Bonn, Germany. Over 3000 attendees from 154 nations were present. Though the conference dealt only with renewables, to a large extent, the recommendations would also hold true for all forms of DE, including cogeneration. Arising from that event were some guidelines for policy makers as to what must be put in place in order for DE policy to be effective. For DE to become an integral part of the energy mix, policymakers must*

1. Integrate DE into overall energy policy
2. Establish clear goals
3. Establish transparent market conditions
4. Reduce or eliminate subsidies for conventional centralized energy
5. Address cost issues
6. Create incentives that are eventually phased out
7. Ensure that energy issues form part of the basis of decisions in *nonenergy* sectors such as urban planning and infrastructure, etc.
8. Educate the public on the benefits and costs of DE
9. Promote DE jobs and training
10. Develop public organizations to promote DE
11. Strengthen regional and international cooperation on DE matters
12. Secure grid access for DE
13. Do not omit thermal energy in decision making
14. Support research and development in DE
15. Involve a range of actors in promoting DE including local governments, financiers, international bodies, and multilateral and bilateral banks and institutions
16. Harness the power of public procurement

However, in general, it is important that a policy be stable enough in the long term to foster confidence to everyone that the rules will not change after they have committed to one plan of action. Involving locals in the establishment of DE policies is the other key to both garnering public support and establishing a basis of shared experience on which future policy revisions can be made.

The aforementioned list illustrates some of the goals of policies to promote DE. There are a multitude of approaches that can be used to achieve these goals and the following section provides many examples from all over the world. For each of the nations covered in this chapter, there will be a short summary paragraph followed by a table with three major headings: Technical, Financial, and Others.

The Technical heading will discuss policies that address technical issues such as mandated technologies, interconnection procedures, manufacturing and interconnection

* http://www.renewables2004.de/pdf/policy_recommendations_final.pdf.

standards, and safety rules. Technical policies if designed carefully can be important drivers for DE investment just as poorly designed policies or lack of policies can stifle investment in DE.

The Financial heading will cover policies that exist in the area that are based on economic incentives such as rebates for investing in certain technologies, tax breaks for eligible investments, and pricing arrangements for power produced by on-site generators. Although project economics is affected by a multitude of factors (including fuel prices, capital expenditures, opportunity costs, etc.) financial policies can often make the difference between a project that is feasible and one that is not.

The Others section will discuss all remaining issues relating to DE policy including more general policy guidance and legislation mandating DE use or energy efficiency/renewables.

The general organization of each section will take the form of the following table.

In some cases, no examples for the specific category of policy/technology were found for a given jurisdiction in which case the given cell was left blank.

General Organizational Structure for Country Policy Summaries

Technical	DE in general
	Large-scale cogeneration
	Domestic cogeneration
	PV
	Wind
	Hydro
Financial	DE in general
	Large-scale cogeneration
	Domestic cogeneration
	On-site PV
	On-site Wind
	Hydro
Others	DE in general
	Large-scale cogeneration
	Domestic cogeneration
	PV
	Wind
	Hydro

It is very difficult to separate policies that aim to promote renewables and efficiency in general from those aimed at promoting DE. For example, many policies aim to promote renewables in general including large-scale wind farms, which should not necessarily be considered as DE. Likewise some policies are aimed at only cogeneration and do not affect renewables. In other cases, for example, in the case of rooftop PV, renewable policy and DE policy is one in the same. In most cases, however, policies that affect DE will be framed in the context of policies to promote renewables or general efficiency (in the case of cogeneration). Currently, there remains a shortage of concrete policy examples that target on-site power or DE. In order for DE to truly reach its potential, laws and policies will have to be increasingly aimed at DE specifically.

11.2 Canada

With a low population density and wide climatic variations, Canada has one of the world's highest energy use per capita. The Canadian government has taken some steps to promote DE using financial mechanisms, but coordinated policy cooperation between the various provincial governments and the federal government may prove most effective for promoting DE.

Canadian Distributed Generation Policy by Technology and Type

Technical	DE in general	The federal government in Canada has control over interprovincial gas pipelines and transmission lines crossing international borders. Because the Canadian constitution enshrines energy as a provincial jurisdiction in all other cases, each utility tends to have its own interconnection policy. Interconnection policies tend not to be technology specific. The government funds the *micropower* connect initiative, which aims to harmonize interconnection rules in the provinces.
	Large-scale cogeneration	Interconnection rules vary by province.
	Domestic cogeneration	Interconnection rules vary by province
	PV	Interconnection rules vary by province.
	Wind	Interconnection rules vary by province.
	Hydro	Interconnection rules vary by province.
Financial	DE in general	There is no federal law, which guarantees retail electricity prices. In most cases, on-site generators feeding excess power to the grid obtain wholesale electricity price or less, and in some cases, retail price is earned. Various funding schemes exist to promote energy innovation including: the technology Early Action Measure program, the Climate Change Technology and Innovation Program, the Federation of Canadian Municipalities Green Fund, and a program to promote on-site generation at government facilities. In many cases, the utility companies of a province have much influence over provincial electricity policy so that policy is often determined by the private sector.
	Large-scale cogeneration	Under Canadian renewable and conservation expenses (CRCE), regime development of a cogeneration equipment may have tax benefits. CRCE generally includes intangible expenses incurred by a *principal-business corporation* (as defined in the act) and payable to an arm's length party in connection with the development of an energy project wherein at least 50% of the capital cost of the depreciable property in the renewal energy project is property described in Class 43.1 (a *Class 43.1 Asset*) or Class 43.2 (a *Class 43.2 Asset*), under the Canadian taxation system for capital cost allowance (*CCA*) under Schedule II to the Regulations. Recent amendments have expanded Class 43.2 with respect to waste-fuelled thermal energy equipment and equipment of a district energy system that uses thermal energy provided primarily by eligible waste-fuelled thermal energy equipment. These amendments have also expanded Class 43.2 to include equipment that uses the residue of plants, generally produced by the agricultural sector, to generate electricity and heat (biowaste). These measures should encourage investment in technologies that can contribute to a reduction in emissions of greenhouse gasses and air pollutants in support of Canada's targets as set forth in the Federal Sustainable Development Strategy. These measures may also contribute to the diversification of Canada's energy supply.

(*Continued*)

Canadian Distributed Generation Policy by Technology and Type		
		The 2013 Canadian Federal Budget proposes to expand Class 43.2 by making biogas production equipment that uses more types of organic waste eligible for inclusion in Class 43.2, including pulp and paper waste and wastewater, beverage industry waste and wastewater and separated organics from municipal waste, and the range of cleaning and upgrading equipment used to treat eligible gases from waste that is eligible for inclusion in Class 43.2, to all such cleaning and upgrading equipment. These proposed measures will apply to property acquired on or after March 21, 2013, that was not used or acquired for use before March 21, 2013.[a]
	Domestic cogeneration	Cogeneration equipment is listed as Class 43.1 assets: they are eligible for accelerated depreciation rates for capital costs (30%).
	On-site PV	Various feed-in tariffs (FiTs) exist depending on the type (rooftop, free field) and the capacity of the panels.
	On-site wind	Financial incentives vary province by province, some offer net metering (which allows small wind turbine owners to offset their electricity consumption, or earn credit from their local utility if they produce excess power through their turbine), others have special loans, or FiTs. The Canadian federal government also supports the research, development, marketing, and deployment of small wind turbines in Canada through R&D initiatives.
	Hydro	In 2009, Ontario enacted FiT for hydropower. Under the new FiT rules, hydropower producers are paid 13.1 cents/kW h for up to 10 MW over a 40-year term. The rate is 12.2 cents for 10–50 MW over the same period. According to the order of the Minister of Energy in fall 2013, changes to the FiT program are expected.
Others	DE in general	The Government of Canada has set a goal of generating 90% of Canada's electricity from zero-emitting sources by 2020, while various provinces have their own goals to improve their zero emission sources. (e.g., Ontario plans to end coal generation by 2014, and is expecting to reach 2650 MW of solar PV by 2015.) In 2011, Canada announced its withdrawal from the Kyoto Accords, but participated in Durban talks, which were leading to a new binding treaty with targets for all countries to take effect in 2020.
	Large-scale cogeneration	
	Domestic cogeneration	
	PV	Between 2014 and 2018, installed solar capacity in Canada is expected to reach 3.48 GW, which presumes an annual growth of 450 MW.
	Wind	Current installed wind capacity in Canada is 6500 MW, which is only 1.3% of the total energy demand.
	Hydro	Canada is the world's largest producer of hydroelectricity in the world (before China and Brazil), and one of a few countries to generate the majority of its electricity from hydroelectricity. Some provinces and territories, such as British Columbia, Manitoba, Newfoundland and Labrador, Quebec, and Yukon, produce over 90% of their electricity in this manner.

[a] http://www.millerthomson.com/en/publications/newsletters/tax-notes/april-2013/canadian-renewable-conservation-expense.

11.3 Mexico

Mexico is resource rich for many DE sources including natural gas, sunshine, wind, and biomass, but little of that potential has been realized. To date there has been limited success in developing a strong policy foundation for DE. The recently announced intention of the Mexican government on energy reform, to open the market for foreign investors, may result in fundamental changes on power generation as well.

Mexican Distributed Generation Policy by Technology and Type

Technical	DE in general	In 1992, a law was established which permitted nonutility generation and on-site generation for the first time. The *Ley del Servicio Público de Energía Eléctrica* (LSPEE) forbids bilateral trading of electricity between individuals but allows companies to generate for their own demand and cogeneration with a permit from the Comisión Reguladora de Energía (CRE) provided they meet the conditions as defined by Art. 36 of LSPEE. However, in 2012, certain amendments were made to this law, and in 2008, the *Ley para el aprovechamiento de energías renovables y el financiamiento de la transicion energetica* has been approved, there are still serious barriers that exist for DE.
	Large-scale cogeneration	The Mexican government defined cogeneration in the 1992 law permitting private sector involvement in the electricity sector[a] but stated that the power must be used on-site. Interconnection, wheeling, and backup services are allowed but require permits from the CFE and the energy secretariat (SENER). Interconnection standards for cogeneration plants are based on the U.S. IEEE 1547.
	Domestic cogeneration	
	PV	
	Wind	
	Hydro	
Financial	DE in general	Mexico's income tax law (ITL) provides a 100% deduction incentive for taxpayers who carry out investments in renewable energy equipment. Qualifying sources like sun, wind, water, and geothermal energies, as well as biomass fuel equipment, are eligible for this incentive. To finance sustainability projects, the Fund for Energy Transition and Sustainable Exploit of Energy was created in 2009. Companies or individuals may request incentives from the fund by submitting proposals for projects that involve renewable energies and energy transition. Every fiscal year, the Ministry of Energy (SE) and the National Council of Science and Technology (CONACYT) establish a special fund for energy sustainability projects in which universities and research centers are the potential participants and beneficiaries. The resources for the fund are provided by the Mexican oil company PEMEX.[3]
	Large-scale cogeneration	The Mexican government incentivizes cogeneration by treating it as a renewable energy source. Pollution control equipment or equipment for research and technological development in renewable energy are exempt from general import and export taxes. Mexican policy outlines accelerated depreciation for investments in renewable energy, allowing 100% depreciation on investment for machinery and equipment for generating energy from renewable sources.

(*Continued*)

Mexican Distributed Generation Policy by Technology and Type		
		Incentives and funding programs for cogeneration projects can also be found through the Mexican Secretariat of the Environment and Natural Resources, SEMARNAT.[b]
	Domestic cogeneration	
	On-site PV	The country offers tax incentives for solar projects and a so-called net metering system, as well as the possibility of long-term power purchase deals with CFE.
	On-site wind	
	Small hydro	
Others	DE in general	Investors have to secure a wide array of permits, which can be very costly. In some cases, more than 100 permits are required (an existing plan is to reduce to 31) including local/municipal planning permission, environmental permitting, gas supply and connection permits, power generation authorization and network interconnection permits, etc. According to a recently published analysis by Frost and Sullivan, insufficient centralized electricity, which has compelled several consumers to generate their own power, along with incomplete grid facilities in large isolated areas, offers huge scope for the distributed power generation (DPG) market in Mexico; however, DE providers' reliance on electricity subsidies coupled with grid integration issues in isolated areas makes market development uncertain. Energy subsidies have added to the challenge, as artificially low electricity prices for most consumers in the country reduce opportunities for DE technologies, which have become a costly alternative to grids. In fact, although DE technologies reduce transmission costs and provide the benefit of local energy management and economies of scale, their start-up costs are higher than that of centralized electricity production, further affecting adoption.[c] A 2012 law requires 35% of electricity from renewable resources by 2024. At the Solar Power Mexico conference in 2012, it was said that PV electricity and solar will comprise up to 5% of Mexico's energy by 2030 and up to 10% by 2050. By the announcement of the Mexican government at the beginning of August 2013, Mexico is ready to change its constitution to let foreign private companies to find and produce oil and gas in the country. The initiative also seeks to liberalize Mexico's electricity sector by allowing private firms to produce and sell electricity to consumers. These changes might open up more opportunities for cogeneration to flourish in the country.
	Large-scale cogeneration	In March 2013, SENER, Spain, published an *Initiative for the development of the cogeneration potential in Mexico*, which accepted an action plan with main actions such as: energy surplus remuneration methodology, interconnection process standardization, private sector participation in PEMEX projects, and development of transportation network and natural gas distribution, and secondary actions such as measures for financial support for combined Heat and Power (CHP) projects in the short term and communication plan and pilot projects to eliminate current cultural and information limitations.[d]
	Domestic cogeneration	
	PV	By the end of 2012, installed PV capacity was 38 MW, which is expected to increase up to 60 MW or even more in 2013.
	Wind	By the end of 2012, installed wind capacity was 1370 MW.

(*Continued*)

Mexican Distributed Generation Policy by Technology and Type	
Hydro	Recently Mexico's congress has changed its renewable energy and energy transition law to include larger hydroelectric projects in the country's definition of *renewable*, provided they satisfy a certain criteria. According to the modifications, hydropower plants with capacities about 30 MW are to be classified as *renewable*, but only if they meet a generation density standard. Mexico's current total installed hydropower capacity accounts for about 11.5 GW, which is expected to increase by as much as 4 GW with regard to its small hydroelectric capacity and 40 GW with regard to its large capacity.

[a] WADE Market Analysis 2005.

[b] http://www.semarnat.gob.mx/informacionambiental/publicaciones/Publicaciones/Guia%20de%20Programas%20de%20Fomento%20de%20Energ%C3%ADas%20Renovables.pdf.

[c] http://www.frost.com/prod/servlet/press-release.pag?docid=278940767.

[d] http://www.sener.gob.mx/webSener/res/0/Cogeneration_01.pdf.

11.4 United States

The United States remains highly influential in international energy policy development. As the single largest energy-using nation, policy to promote DE is clearly needed to develop capacity to meet the United States' rising demand. Many innovative policy developments have been introduced at the state level that have effectively buoyed DE markets, and the United States remains one of the world leaders in renewable energy development. Recent results of shale gas and oil research, impacts of climate change, and express government intention to increase the ratio of unconventional energy may elevate DE to a more important position. However, steps to harmonize state level policy with policy at the federal level still will be the main factor for successfully advancing DE.

USA Distributed Generation Policy by Technology and Type		
Technical	DE in general	Section 1254 of the Energy Policy Act of 2005 requires that electric utilities offer grid interconnection based on a nationwide standard. Currently to connect DE units must be IEEE P1547 compliant, which requires *automatic and rapid disconnection in the event of a fault*.
	Large-scale cogeneration	
	Domestic cogeneration	
	PV	
	Wind	
	Hydro	
Financial	DE in general	At a state level, the United States has many promising policies in support of renewables and distributed generation. Grant programs, financing, R&D funds, net metering, FiTs, and tax breaks are some of the financial measures that have proven successful for promoting DE technologies at a state level. The Energy Act of 2005 grants tax credits for developers who build energy efficient buildings that could have ramifications for DE especially microcogeneration.

(*Continued*)

USA Distributed Generation Policy by Technology and Type	
	In details, the following support schemes are available: **PTC** is applicable for wind, geothermal, landfill gas, trash combustion, open-loop biomass, closed-loop biomass, hydropower, and wave tide. The PTC provides a tax credit for the production of electricity from renewable sources and the sale of that electricity to an unrelated party. Credit amount is 2.2 cents/kW h for wind, closed-loop biomass, and geothermal, and is 1.1 cents/kW h for other renewable energy resources. PTC is available for facilities placed in service before January 1, 2014 (2013 for wind), and available for a 10-year period beginning with the year the facility is placed in service. **Investment tax credit (ITC)** is applicable for solar, geothermal, qualified fuel cell or microturbine property, CHP systems, small wind, geothermal heat pumps, and PTC-eligible facilities placed in service after 2008 and before 2014 (2013 for wind). The ITC provides a credit for qualifying energy property. For any taxable year, the ITC is the energy percentage of the basis of each energy property placed in service during the taxable year. Credit amount is 30% of eligible costs for fuel cell, solar, and small wind property, 10% of eligible costs for CHP, microturbine property, and geothermal heat pumps. The ITC is generally available for eligible property placed in service on or before December 13, 2016. **Grant in lieu of PTC and ITC** is applicable for tangible personal property or other property that is an integral part of a qualified facility (as defined by the PTC and ITC rules). The American Recovery and Reinvestment Act (ARRA) enacted a new grant program, which provides a cash grant in lieu of the PTC or ITC. ARRA permits PTC or ITC projects to elect a grant of up to 30% of costs of construction of PTC or ITC energy property in lieu of tax credits. Projects must begin construction before 2012 and submit a grant application no later than October 1, 2012. Projects must be placed in service before their PTC or ITC credit expires, PTC before 2014 (2013 for wind), ITC before 2017. **Renewable portfolio standards (RPSs**) generally place an obligation on electric supply companies to produce a specified fraction of their electricity from renewable energy sources and enumerates mechanisms that are permitted to achieve compliance, such as renewable energy credits (RECs). Currently, no federal RPS legislation has been enacted. A total of 29 states and the District of Columbia have an RPS.[3]
Large-scale cogeneration	Microturbines and CHPs are eligible to corporate tax incentive with the following conditions: Credit for microturbines equals 10% of expenditures, with no maximum credit limit stated (explicitly). The credit for microturbines is capped at $200/kW of capacity. Eligible property includes microturbines up to 2 MW in capacity that have an electricity-only generation efficiency of 26% or higher.

(*Continued*)