Potential of Non-conventional Source of Energy and Associated Environmental Issue: An Indian Scenario

Arabinda Sharma
Civil Engineering Department
BRCM College of Engg and Technology
Bahal-127 028, Bhiwani, Haryana

Chadetrik Rout
Civil Engineering Department
M.M. University,
Mullana-, Ambala, Haryana

ABSTRACT

Recently demand for energy has been increased many fold in India due to rapid urbanization and industrial growth which is difficult meet through conventional way. Moreover, the global crisis on petroleum product forced every nation worldwide to think of some alternative non-conventional sources of energy. India was also not able to keep herself away from this situation. Today, India is one of the few nations which are having an independent ministry of non-conventional source of energy. Moreover India is one of the fastest growing economies in the world. In order to keep continuing with this growth rate, India needs to improve its energy and power sector. Unfortunately, limited reserve of coal, petroleum and other fossil fuel India cannot achieve the desired goal. Hence, the Indian government has floated numerous schemes, formulated several policy decision to promote the development and generation of non-conventional energy in the country. Since then India has observed a record growth in the development and generation of non-conventional energy. However, like any other developmental project the non-conventional source of energy (wind, solar) is also associated with some unforeseen environmental impacts including climate change.The present communication presented a detail and up to date potential of various non-conventional source of energy in India and also their possible effects environmental effects. The paper do not meant to criticize the use of non-conventional energy resource but to bring awareness to all the stakeholder on the environmental issue related to uses of these resources so that a more environmental friendly technology can be invented through research.

Keywords

Non-conventional energy, wind energy, solar energy, environmental effect, climate change

1. INTRODUCTION

Energy is not only important for the survival of human being but its availability is also considered to be the backbone to the national growth and development. Since last few decades, India has been witnessing a rapid urbanization and industrialization.Unfortunately, in India the production of energy is far below to sustain our rapidly growing economy. It subsequently demands for more energy production. This enhanced demand for energy has built up a huge pressure on the conventional sourcesof energy such as coal, petroleum and natural gas. Most of these fossil fuels are imported from different country of the globe at the cost of limited foreign exchange reserve. However this is not the only saga, as generating electricity/energy from these fossil fuels has also seriously affectedour natural environment and human health [1].

In this perspective, India has been compelled to look towards its vast potential of renewable energy resources long before. Today India has one of the largest programs in the world for deploying renewable energy products and systems. Infact, it is the only country in the world to have an exclusive Ministry for New and Renewable Energy. Realizing the urgent need to utilize the non-conventional source of energy, the Ministry has launched one of the world's largest and most ambitious programs on renewable energy. Based on numerous promotional efforts put in place by Ministry for New and Renewable Energy, significant development is being made in power generation from renewable energy sources. Specifically, 3,700 MW are presently powered by renewable energy sources (3.5 percent of total installed capacity). It was projected to 10,000 MW from renewable energy by 2012 [2].

Non-conventional energy has the potential to minimize pollution, reduce global warming, create new industries and jobs, and move the nation toward a cleaner, healthier energy future. However, it is not without its challenges and impact on environment [3]. In this communication, it has been tried provide a potential of various non-conventional source of energy, their limitation. Besides, it also emphasizes the possible impact of non-conventional energy on environment.

2. ENERGY CONSUMPTION IN INDIA

India's current installed capacity from all sources comes around 1,70,229 MW at the end of 2010. Again, India is the 5th largest energy consumer in the world. The per capita energy consumption of India is surprisingly low, just 630 kWh per person per year, and on par with Swaziland. However, it is expected to grow to 1000 kWh in the near future. The Central Electricity Authority (CEA) of India stated that, the peak electricity demand in 2008 was 120 GW of power, while only 98 GW could be supplied and this deficit is likely to grow to 25 GW by 2012 [2].

3. WHY NON-CONVENTIONAL ENERGY

In 2010, peak power shortage of India was 12 % and electricity demand is expected to rise by 7.4% a year during the next quarter of a century. Unfortunately, India cannot consider to bridge this power deficit by increasing reliance and dependence on the fossil fuel footprint. These reasons are many from socio-economic to environmental and health problems. According to Energy Statistics 2012, India imports about 75% of its oil which in fact comprises one-third of its total imports. Similarly, India's coal imports are likely to touch a whopping 185 million tonnes (MT) by 2017. Hence, the Indian government has been also making serious efforts to enhance India renewable energy production since recent past. Some of the advantages of common non-conventional energy are as below:

4. STATUS OF INDIAN RENEWABLE POWER GENERATION

As on Feb 2011, the total installed capacity of electricity in India is 171.9 GW. The breakup of power generation from different sources is given in the Figure 1.

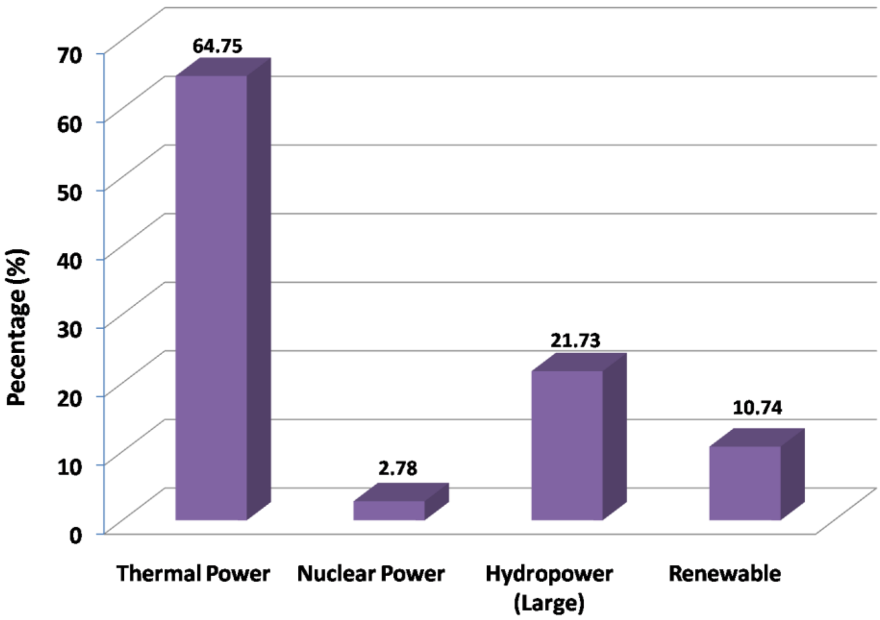

Figure 1: Source of Electric Energy in India

Thermal power plants accounted for an overwhelming 64% of the total installed capacity in our country, with an installed capacity of 131.2 x 10^3 MW. Hydro power plants come second with an installed capacity of 37.6 x 10^3MW, accounting for 21.73% of the total installed Capacity. For Nuclear energy it was only 2.31% (4.78 MW).

It is revealed from the figure that renewable energy contributes only 10.74% (i.e. 18.3 GW). In this wind represents about 13 GW (71%), small hydro represents 2.8 GW(15.2%), and the majority of the remainder i.e3.0 GW (13.3%) comes from biomass installations.However, the potential of wind and solar is estimated to be around 49.132 GW (55%), SHP (small-hydro power) potential of 15.4 GW (17%), Biomass power potential of 17.54 GW(20%) and 5 GW (6%) from bagasse-based cogeneration in sugar mills.

5. ADVANTAGES OF RENEWABLE ENERGY

A major advantage of renewable energy is that it can be regenerated; therefore it is sustainable and will never run out. It has several advantages over its counter parts and provides substantial benefits for our climate, our health, and our economy. Some of the important benefits of renewable energy are:

(i) *Little to No Global Warming Emissions:* The conventional methods of electricity production using fossil fuel such as coal, oil and natural gas account for around one-fourth of total global warming emission [4,5]. In contrast, most renewable energy sources produce little to no global warming emissions and hence help reducing effect of climate change.

(ii) *Improved Public Health and Environmental Quality:* Electricity generation from renewable energy is more environmental benign causing lesser air and water pollution as compared to fossil fuels [6]. In contrast, heavy pollution of water and air media by fossil fuels wind, solar, and hydroelectric systems generate electricity with no associated air pollution emissions. While wind and solar energy require essentially no water to operate and thus do not pollute water resources [7].

(iii) *A Vast and Inexhaustible Energy Supply:* Although renewable energy provides only a tiny fraction of total electricity generation, the diverse sources of renewable energy such as winds, sunny skies, plant residues have the potential to provide all the electricity need of the country uninterruptedly. Provided certain technological and environmental constraints will be resolved [8, 9].

(iv) *Jobs and Other Economic Benefits*: Compared with fossil fuel based technologies, the renewable energy industry requires more labor because of it is decentralized in nature- reaching to the grass root level of remote rural areas. This means that, on average, more jobs are created for each unit of electricity generated from renewable sources than from fossil fuels.

(v) *Stable Energy Prices:*Renewable energy is able to provide affordable electricity across the country right now, and can help stabilize energy prices in the future.

(vi) *A More Reliable and Resilient Energy System*:Keeping in view to recent grid failure in entire north India, it is impotant to understannd that wind and solar are less prone to large-scale failure because they are distributed and modular. As distributed systems are spread out over a large area, therefore a severe weather event at one location could not cut off power to the entire region. Modular systems are composed of various individual solar arrays or wind turbines. Even if some of the equipment in the system will damage, the rest can continue to operate.

6. ENVIRONMENTAL ISSUE RELATED TO NON CONVENTIONAL ENERGY

Non-conventional source of energy generation has some practical limitations. Some general disadvantages are: difficulty in generating huge quantity of electricity in centralized way as in case of fossil fuel, dependency on the weather conditions at the time and in the region of use,relatively more expensive to acquire and set up the equipments necessary for the generating electricity and technical constraints in (efficiency) generating electricity from the non-conventional resource. Besides some technological and economic constraints, it also have some associated environmental issues which are discussed below:

6.1 Wind Energy

Wind energy is considered to be one of the cleanest and most sustainable ways to generate electricity as it produces no toxic pollution or GHGs. Wind is inexhaustible andabundant, which can make it a viable and large-scale alternative to fossil fuels.Despite its huge potential, there are certainenvironmental impacts associated with wind power generation that should be identified and mitigated.

Environmental Impacts of Wind Power: Harnessing power from the wind is one of the cleanest and most sustainable ways to generate electricity as it produces no toxic pollution or GHGs emissions. Wind is abundant, inexhaustible, which makes it a viable and large-scale alternative to fossil fuels. Despite its vast potential, varieties of environmental impacts associated with wind power generation that should be recognized and mitigated.

*Land Use***:** Wind turbines placed in flat areas typically use more land than those located in hilly areas. It has been estimated that around one acre land per MW is disturbed permanently and less than 3.5 acres/ MW are disturbed temporarily during construction [10]. The remainder of the land can be used for a variety of other productive purposes, including agriculture, livestock grazing, construction of highways, and hiking trails. Subsequently, wind facilities can be installed near brownfields (abandoned or underused industrial land) which significantly reduces concerns about land use. Offshore wind facilities, which require larger amount of space because the turbines and blades are bigger than their land-based counterparts. It also hinders a variety of other marine activities, such as aquaculture, oil and gas extraction, fishing, recreational activities, sand and gravel extraction, and navigation. Employing best practices in planning and siting can help to minimize potential land use impacts.

Wildlife: The impact of wind turbines on wildlife, bats and birds, has been widely document and studied by researchers. Researchers found evidence of bird and bat deaths from collisions with wind turbines and due to changes in air pressure caused by the rotating turbines, as well as due to habitat destruction. The National Wildlife Conservation Council (NWCC) concluded that these impacts are relatively low and do not pose any threat to species populations [11].

*Public Health and Community***:** Noise and visual impact are the two main public health and community concerns associated with operating wind turbines. Reason of noise may be caused by the movement of turbine blades through the air (aerodynamic) or sound generated by the turbine itself (mechanical). Overall sound levels depend on turbine design and wind speed. People living close to wind facilities have complained about sound and vibration issues. However, it do not adversely impact public health [12]. The annoyance such as shadow flicker under certain lighting conditions can be minimized with careful siting, planting trees, or curtailing wind turbine operations when lighting conditions exist.

Water Use:Operation of wind turbines have no direct impact on water resources.But in all manufacturing processes, water is used to manufacture steel and cement for wind turbines.

Life-Cycle Global Warming Emissions: There are no GHGs emissions associated with operating wind turbines, emissions associated with other stages of a wind turbine's life-cycle, materials transportation, including materials production, on-site construction and assembly, operation and maintenance, and decommissioning and dismantlement. Most estimates of wind turbine life-cycle global warming emissions are between 0.02 and 0.04 pounds of CO_2 equivalent per KWh which is far less as compared to that of natural gas generated electricity (0.6 - 2.0 pounds of CO_2 equivalent per KWh) or coal-generated electricity (1.4- 3.6 pounds of CO_2 equivalent per KWh [13].

6.2 Solar Energy

Like wind, the sun is also a tremendous source for generating clean and sustainable electricity without toxic pollution or global warming emissions. The environmental impacts associated with solar power can include land use and habitat loss, water use, and use of hazardous materials in manufacturing. The types of impacts vary greatly depending on the scale of the system and the technology used -photovoltaic (PV) solar cells or concentrating solar thermal plants (CSP).

Land Use:Depending on their location, solar facilities can raise concerns about land degradation and habitat loss. Land area requirement varies depending on the adopted technology, the topography of the area, and the intensity of the solar radiation. Estimates for utility-scale Photovoltaic systems range from 3.5 to 10 acres/MW, while estimates for CSP facilities are between 4 and 16.5 acres per megawatt.There is less opportunity for solar projects to share land with other landuse activity. Proper siting at lower-quality locations such as brownfields, abandoned mining land, canal and transmission corridors, small scale solar PV arrays built on homes or commercial buildings, help to minimizing the land use impact [14].

Water Use: Solar PV cells do not use water for generating electricity. However, concentrating solar thermal plants (CSP), require water for cooling. Water use depends on the plant location, plant design, and the type of cooling systemto adopt.Concentrating solar thermal plants that use wet-recirculating technology with cooling towers withdraw between 600 and 650 gallons of water per MW-Hrof electricity produced. CSP plants with dry-cooling technology can reduce water use by approximately 90% but at high cost and significantly less effective at temperatures above 100 ^{0}F. Ironically,areas with highest potential for solar energy also very often tend to be the dry and water scarcity areas; hence a careful consideration of these water tradeoffs is necessary.

Hazardous Materials: The PV cell manufacturing process includes a number of hazardous materials, mostly used to clean and purify the semiconductor surface. These include HCl, H_2SO_4, HNO_3, HF, 1,1,1-trichloroethane, and acetone. The quantity and type of chemicals used depends on various types of cell, the amount of cleaning that is required, and the size of silicon wafer.

Thin-film PV cells contain a number of more toxic materials than those used in traditional silicon photovoltaic cells, including gallium arsenide, copper-indium-gallium-diselenide, and cadmium-telluride. If not properly handled and disposed off, these materials could cause serious environmental or public health threats. Thus, PV manufactures must ensure that workers are not harmed by exposure to these chemicals and thechemical waste products are either disposed of properly or recycled.

Life-Cycle Global Warming Emissions: Solar power generation do not emit any global warming emissions directly associated with generating electricity from, there are emissions associated with other stages of the solar life-cycle, including materials transportation, maintenance, and decommissioning, manufacturing, installation, and dismantlement. Calculations of life-cycle emissions for photovoltaic systems are between 0.07 and 0.18 pounds of CO_2 equivalent per kilowatt-hour.Most estimates for concentrating solar thermal plants produce 0.08 to 0.2 pounds of CO_2equivalent/kWh. In both cases, this is far less than the lifecycle emission rates for natural gas (0.6-2 lbs of CO_2equivalent/kWh) and coal (1.4-3.6 lbs of CO2E/kWh) [15].

6.3 Geothermal Energy

Geothermal power plant (known as hydrothermal plants) are located near geologic “hot spots” where hot molten rock is close to the earth’s crust and produces hot water or other regions of hot dry rock. Geothermal plants differ in terms of the technology they use to convert the resource to electricity and the type of cooling technology they adopt (water-cooled and air-cooled). Environmental impacts varies depending on the conversion and cooling technology adopted.

Water Quality and Use: Geothermal power plants can have impacts on both water quality. Hot water taken from underground reservoirs often contains high levels of sulfur, salt, and other minerals. [16].Water is also used by geothermal plants for cooling and re-injection. Depending on the cooling technology used, geothermal plants also require 1,700 to 4,000 gallons of water per MW-Hr. However, the use of geothermal fluids and closed loop technology (reinjection of same water again into reservoir) can not only reduce theoverall freshwater demand but also prevent contamination and land subsidence[17].

Air Emissions: In closed-loop systems, air emissions are minimal. But the, open-loop systems emit H_2S, CO_2, NH_3, CH_4, and boron. H_2S, which has a distinctive “rotten egg” smell, is the most common emission [18]. Its consequences can be observed in the form of acid rain, damages crops, forests, and soils, acidification of water body and health problems. However, SO_2 emissions from geothermal plants are approximately 30 times lower per MW-Hr than from coal plants. Small amounts of mercury emissions from geothermal plant can be mitigated using mercury filter technology, scrubbers can reduce air emissions, disposal of sludge at hazardous waste sites.

Land Use: The amount of land required by a geothermal plant varies depending on the properties of the resource reservoir, the type of energy conversion system, the type of cooling system,the amount of power capacity, the arrangement of wells and piping systems, auxiliary building and the substation needs [20]. Approximately 13 acres of land is required for production of 1MW power. Many geothermal sites are located in remote and sensitive ecological areas, so project planners must take this into account in their planning processes to avoid the risk of land subsidence. Hydrothermal plants are sited on geological “hot spots," which tend to have higher levels of earthquake risk. Earthquake risk associated with enhanced geothermal systems can be minimized by siting plants an appropriate distance away from major fault lines [20].

Life-Cycle Global Warming Emissions: In geothermal energy plant, approximately 10% of the air emissions are CO_2, and a smaller amount of emissions are CH_4, a more potent global warming gas. There are a still some emissions associated with plant construction and surrounding infrastructureas well as drilling and pumping water into hot rock reservoirs. Putting these all into account, in the entire life-cycle global warming emissions for geothermal plant generated electricity are between 0.6 and 2 pounds of CO_2 equivalent per KW-Hr as compared to are 1.4 to 3.6 pounds of CO_2 equivalent per KW-Hr for coal-generated electricity [21].

6.4 Biomass Electricity

Biomass power plants share some similarities with fossil fuel power plants: both involve the combustion of a feedstock to generate electricity. The feedstock of biomass plants can be sustainable harvested, while fossil fuels are exhaustible.Harvesting of biomass for producing electricity are diverse; including energy crops (like switchgrass, giant miscanthus), agricultural waste,forest products and waste,urban waste, and manure. Both the type of feedstock and the manner in which it is developed and harvested significantly affect land use and life-cycle global warming emissions impacts of producing power from biomass.

6.5 Small Hydropower

Hydroelectric power includes both massive hydroelectric dams and small run-of-the-river plants. However, the development of large hydropower has become increasingly problematic due to socio-environmental issues. And small-scale hydro development has not met expectations either.The environmental concerns as effect to fish habitat would constrain small hydropower development in the country. The impact of very large dams is so great that there is almost every time conflicts exist with development of such projects. The reservoirs created by such projects frequently inundate/submerge large areas of farmland, forest, wildlife habitats, scenic areas, and also towns. In addition, the dams can cause significant changes in river ecosystems including aquatic habitat both upstream and downstream.

Small hydropower plants using reservoirs can cause similar types of damage, but on a smaller scale. With increasing ly more stringent environmental regulations, development of cost-effective mitigation measures is crucial. In fact, hydropower is approaching the limit of its potential and its contribution to total power generation may decline in future due to increased demand on water resources for agricultural and drinking purpose, declining rainfall, and efforts to protect endangered fish and wildlife.

7. CONCLUSION

In the backdrop of deficit energy production and recently occurred world's largest blackout in July, 2012 due to failure of the northern power grid affecting 700 million people from New Delhi to Kolkata, India needs a drastic makeover in its energy sector. This unreliable supply of electricity and depleting natural resource and environmental conditions has become a big challenge to sustainable development. India's tremendous energy needs cannot be met solely with conventional method of electricity generation. To overcome this problems and to meet the future energy demands, India must towards harnessing its great potential of non-conventional source of energy as sustainable energy solutions. It has several advantages including decentralization of energy-particularly for meeting rural energy needs, and thereby empowering rural people at the grass roots level. Unfortunately, it has also got some associated environmental issue which must be resolved before aggressive deployment of electricity production from these sources. The exact type and intensity of environmental impacts varies depending on the specific technology adopted, the geographic location, and other operational factors. Thus, we must stress upon research and development not only to understand the current and potential environmental issues associated with each renewable energy source but also to develop cleaner technologies. It will help achieving the national security and economic goal at one hand and will provide enormous environmental benefits and combat climate change at the other end.

8. REFERENCE

1] UCSUSA (2013) Environmental Impacts of Renewable Energy Technologies. http://www.ucsusa.org/clean_energy/our-energy-choices/renewable-energy/environmental-impacts-of.html

[2]DarshanGoswami (2013) India's Renewable Energy Potential Remains Untapped.http://www.renewableenergyworld.com/rea/news/article/2013/07/indias-renewable-energy-potential-remains-untapped

[3] UCSUSA (2013) Benefits of Renewable Energy Use. http://www.ucsusa.org/clean_energy/our-energy-choices/renewable-energy/public-benefits-of-renewable.html

[4] Environmental Protection Agency. 2012. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010.

[5] Energy Information Agency (EIA). 2012. How much of the U.S. carbon dioxide emissions are associated with electricity generation?

[6] Intergovernmental Panel on Climate Change (IPCC). 2011. IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1075 pp. (Chapter 9).

[7]] National Renewable Energy Laboratory (NREL). 2012. Renewable Electricity Futures Study. Volume 1, pg. 210.

[8] Machol, Rizk. 2013. Economic value of U.S. fossil fuel electricity health impacts. Environment International 52 75–80.

[9] American Wind Energy Association (AWEA). 2012a. AWEA U.S. Wind Industry Annual Market Report: Year Ending 2011. Washington, D.C.: American Wind Energy Association.

[10] Denholm, P., M. Hand, M. Jackson, and S. Ong. 2009. Land-use requirements of modern wind power plants in the United States. Golden, CO: National Renewable Energy Laboratory.

[11] National Wind Coordinating Committee (NWCC). 2010. Wind turbine interactions with birds, bats, and their habitats: A summary of research results and priority questions.

[12] Bastasch, M.; van Dam, J.; Søndergaard, B.; Rogers, A. 2006. Wind Turbine Noise – An Overview. Canadian Acoustics (34:2), 7–15.

[13] IPCC, 2011: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1075 pp. (Chapter 7 & 9).

[14] National Renewable Energy Laboratory (NREL). 2012. Renewable Electricity Futures Study. Hand, M.M.; Baldwin, S.; DeMeo, E.; Reilly, J.M.; Mai, T.; Arent, D.; Porro, G.; Meshek, M.; Sandor, D. eds. 4 vols. NREL/TP-6A20-52409. Golden, CO: National Renewable Energy Laboratory.

[15] IPCC, 2011: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1075 pp. (Chapter 7 & 9).

[16] National Renewable Energy Laboratory (NREL). 2012. Renewable Electricity Futures Study. Hand, M.M.; Baldwin, S.; DeMeo, E.; Reilly, J.M.; Mai, T.; Arent, D.; Porro, G.; Meshek, M.; Sandor, D. eds. 4 vols. NREL/TP-6A20-52409. Golden, CO: National Renewable Energy Laboratory.

[17] Macknick, et al. 2011. A Review of Operational Water Consumption and Withdrawal Factors for Electricity Generating Technologies. Golden, CO: National Renewable Energy Laboratory.

[18] Kagel, A. 2007. A Guide to Geothermal Energy and the Environment. Washington, DC: Geothermal Energy Association.

[19] National Research Council (NRC). 2010. Hidden costs of energy: Unpriced consequences of energy production and use. Washington, DC: National Academies Press. Online at http://www.nap.edu/catalog.php?record_id=12794.

[20] National Renewable Energy Laboratory (NREL). 2012. Renewable Electricity Futures Study.

[21] IPCC, 2011: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1075 pp.