World Energy Outlook and Place of Renewable Resources

Abdullah Muratoglu (Corresponding author)
Civil Engineering Department, Batman University, Batman, Turkey
E-mail: abdullah.muratoglu@batman.edu.tr

Mehmet Ishak Yuce
Civil Engineering Department, University of Gaziantep, Gaziantep, Turkey

Abstract
The world energy consumption has increased with rising of living standards, since the industrial revolution. Conventional power production methods trigger the climate change with environmental pollution. A considerable number of scientists believe that the current rate of fossil fuel consumption will not provide enough energy to human being for more than a few centuries. The concerns about fossil fuel based energy methods have led researchers to explore alternative, renewable, environmental friendly, cheaper and sustainable energy methods. The aim of this study is to provide an overview of global energy consumption by drawing attention to the environmental impacts of both fossil and renewable resources. In this study, an outlook of the world's energy production methods has been given and different type of energy production methods have been evaluated. The environmental impacts of current energy production methods have been outlined. The interrelation between the energy and climate change was illustrated.

Keywords: Renewable energy, World energy outlook, fossil fuels, climate change.

1. Energy, Human and Climate

The term energy could be defined as the ability to do work (Cleveland and Morris, 2006). All living organisms need energy to perform their vital activities. All forms of life are in a continuous process of consuming, using and storing energy (Maczulak, 2010). The sun is accepted as the ultimate source of energy for the ecosystem. All natural events including winds, nourishment of plants, rain, snow, evaporation, ocean waves, tides and river currents take place by the effect of the sun (Cruden, 2005) either directly or indirectly.

Human being has deeply attached to energy in all ages of the history. Until French Revolution, the most important sources of energy were the animal muscle power and firewood (Quaschning, 2010). By the eighteenth century, people found a new source of energy; the coal (Cruden, 2005). This was the beginning of the industrial revolution. Invention of steam engine had brought a rapid development of industry. New machines have been developed and unsustainable fuel consumption had gain a dramatic speed. Since the industrial revolution, world energy consumption has increased rapidly due to the use of mechanical power (Maczulak, 2010).

There is a rapid growth in human population on the planet. According to World Bank's database, the human population has increased linearly from 3 to 7 billion from 1960 to 2011. Also per capita energy use has expanded from 1335 to 1850 kilograms of oil equivalent (kgoe) between the years of 1971 and 2010 (World Bank, 2013). Expanding human population and increasing per capita energy use has triggered the primary energy consumption and the amount of emitted greenhouse gasses to increase. This caused a shift in the environmental balance and led to global warming and climate change.

The close relationship between the carbon dioxide emission and primary energy use has been illustrated in Figure 1. As seen in the figure, after 2008, the effect of the primary energy consumption on energy based carbon dioxide emission was decreased which shows that the utilization of non-carbon dioxide-emission energy resources has been accelerated. This date corresponds to the beginning of the first commitment of the Kyoto Protocol.

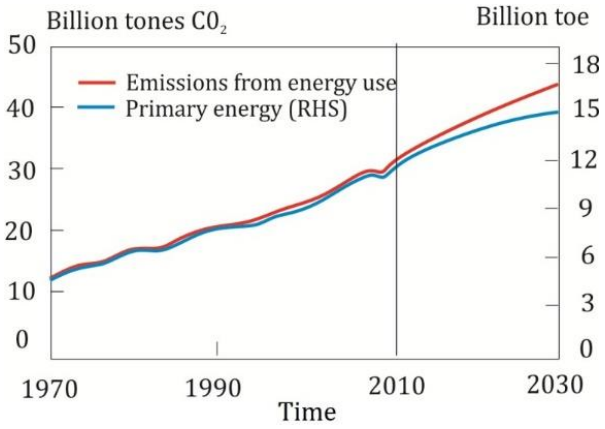

Figure 1. World primary energy demand and CO_2 emission (Modified from BP, 2013)

2. Fossil fuels and climate change

Mainly, energy resources can be divided into three categories as fossil fuel, nuclear and renewable resources (Demirbas, 2007; Agugliora et al., 2013). Fossil fuels such as oil, natural gas and coal are concentrated energy sources that evolved from animal and plant remains over very long periods of time (Quaschning, 2010). They are usually called the main sources of energy. Widespread resources of fossil fuels are used in order to meet nearly all type of energy requirements from powering cars to running factories. They offer convenient, effective and inexpensive ways of meeting energy needs (Schlager and Weisblatt, 2006). Figure 2 demonstrates the historical trends of fossil fuel consumption with dramatic records of the last century. Prior to the Industrial Revolution, and Watt's steam engine (until 1890's) the energy production from fossil fuels was insignificant. It has been increased from unsubstantial levels to nearly 10 billion tons of oil equivalents (Btoe) (BP, 2012). According to Statistical Review of World Energy Report, in the year of 2011, globally 12 billion tons of oil equivalent primary energy was consumed and 10.6 Btoe was supplied from coal, natural gas and oil (BP, 2012). Figure 3 shows the share of world's primary energy by different sources. At present, about 80% of energy is produced from fossil fuels (Höök and Tang, 2013). Most scientists believe that if oil and gas are being consumed at present rate, all acknowledged petroleum and gas reserves will be used up by the beginning of the twenty-second century (Schlager and Weisblatt, 2006).

The energy crisis of 1970s motivated policy makers and scientists to find new energy resources and to provide several policies for energy conservation. The detrimental impacts of fossil fuel consumption on global environment, especially the role of CO_2 emission have also been noted in the scientific studies (Cruden, 2005).

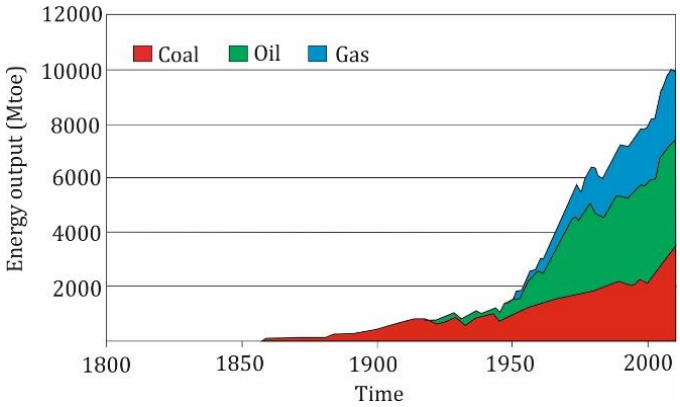

Figure 2. Global historical energy production from fossil fuels

(Modified from Höök and Tang, 2013 and Höök et. al., 2012)

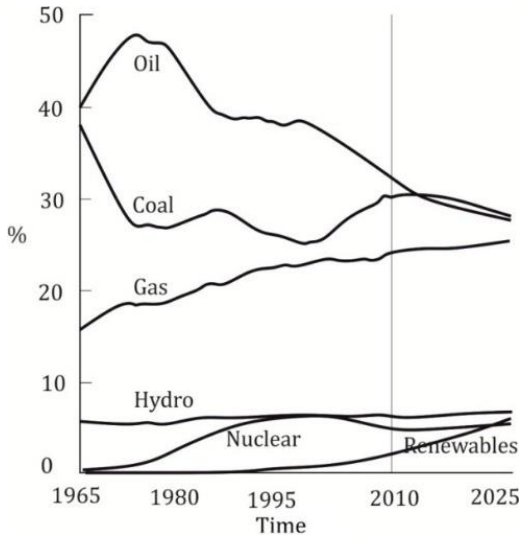

Figure 3. Share of world primary energy sources
(Modified from BP, 2013)

Extraction of fossil fuels through mining and drilling has destructive effects on human, animal and plant habitats. Dispersion of high amounts of particle pollutants and gaseous materials e.g. ozone, sulfur dioxide, nitrogen oxide, carbon monoxide and carbon dioxide threats the natural environment causing acid rains and global warming (Schlager and Weisblatt, 2006). CO_2 is the primary greenhouse gas emitted through human activities (EPA, 2013). Fossil fuels are responsible for 74% of CO_2 emission (Sims et al., 2007). Figure 4 shows the historical trends of global temperatures and sea level. Global average surface temperature has been pushed up by 0.74°C and global average sea level has risen by 20 cm, over the past century (IPCC, 2007a). According to Intergovernmental Panel on Climate Change (IPCC), the average global temperature increment should not exceed 2-2.4°C, otherwise the most severe consequences of climate change will be inevitable (EREC, 2010).

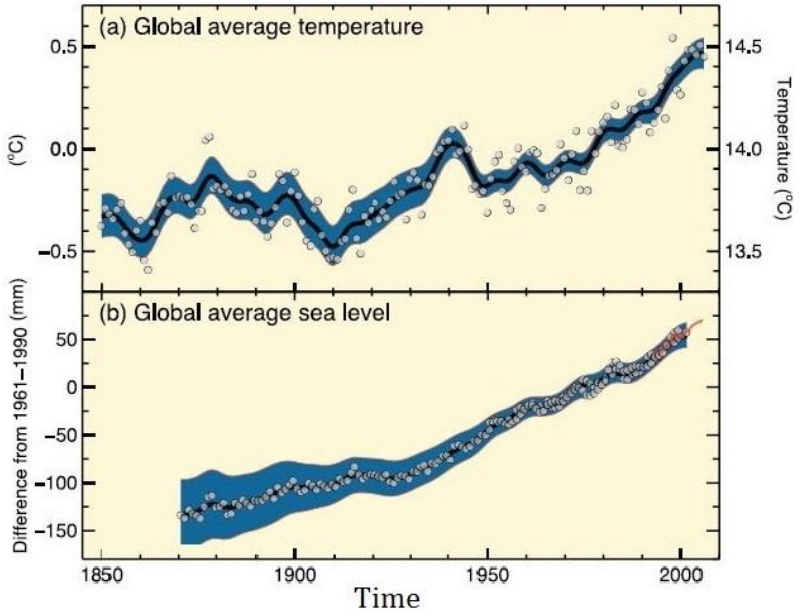

Figure 4. Changes in global average temperature and sea level (IPCC, 2007).

3. Nuclear Energy

Nuclear energy is described as the energy in the nucleus (core) of an atom (Benett, 2007). Nuclear fission produces abundant source of energy with low carbon emissions (WWF, 2011). The energy acquired from

one ton of uranium is equal to energy obtained from 20,000 tons of coal (Andrews and Jelley, 2007). One large nuclear power plant can save more than 50,000 barrels of oil per day (Raja et al., 2006). Although, this large scale carbon free energy generation can provide a good solution to global warming problem (Andrews and Jelley, 2007), nuclear power production includes serious and permanent risks on the environment. The major problems are disposal of highly radioactive wastes without causing environmental damage and necessity of protection of wastes for a long time (Raja et al., 2006). The USA which is the biggest nuclear energy producer with 30.4% of world's nuclear capacity (IEA, 2012) disposes and protects radioactive wastes in Yucca Mountain (Bodansky, 2006). There is nowhere on the world to store nuclear disposals safely (WWF, 2011). A long term solution for disposal of nuclear wastes has not been provided yet (Andrews and Jelley, 2007). According to U.S. Environmental Protection Agency (EPA), the decay duration of radioactive wastes is very long spanning from ten thousand to one million years (Bodansky, 2006; NARA, 2013).

Global uranium reserves are estimated to be 14 Mt (million tons) and can provide energy for 200 more years with current production rate (Andrews and Jelley, 2007). According to U.S. Nuclear Energy Institute (NEI), by February 2013, there were totally 436 nuclear reactors world widely in operation and 70 under construction (NEI, 2013). About 5% of world's total primary energy has been supplied from nuclear energy, in 2011 (BP, 2012) (Figure 3). Electricity production from nuclear resources has been increased from 203 TWh to 2756 TWh between 1973 and 2010 (IEA, 2013).

Impairment of nuclear power plants and nuclear wastes are the biggest anthropogenic damage to the nature. Ability to build nuclear weapons is also very dangerous for human being and environment in an unstable world (WWF, 2011). Up to 2010, 99 nuclear accidents have been reported (Sovacool, 2010) world widely. The Stationary Low-Power Reactor Number One (SL-1), Three Mile Island, Chernobyl and Fukushima Daiichi nuclear disasters have seriously affected public confidence on nuclear energy. When the necessary precautions are not taken, the grave effects of nuclear disposals and nuclear accidents can be much more harmful than that of fossil fuels (Muratoglu, 2015).

4. Renewable Energy

Increasing energy demand, harmful environmental and social effects of conventional energy production technologies, running out of fossil fuels with increasing costs, climate and spreading health problems have led scientists and engineers to find alternative non-consuming, harmless, cheaper and sustainable energy production methods.

The energy is called renewable if it can be replenished within the average lifecycle of human being (Gaur, 2008). Renewable energy is the energy that is generated from natural resources such as wind, solar, waves, currents and geothermal heat (Shi and Chew, 2012). Renewable energy sources are inexhaustible and offer many environmental benefits over conventional energy sources and each has unique advantages over others (Kaygusuz and Kaygusuz, 2002). If these sources are properly managed, they have very little or no harmful environmental impacts with insignificant emission of greenhouse gas and other contaminants. Majority of renewable energy systems collect the natural flow of energy, therefore, once the capital investment is made, there are no recurring fuel costs in the collection systems (Dorf, 2001).

In 2010, about 16.7% of global final energy consumption was acquired from renewable sources. In this total, modern renewables (wind, solar, geothermal biofuels, modern biomass and hydropower) supplied 8.2% and traditional biomass (the energy for cooking and heating in rural areas) supplied 8.5% of global energy (Ren 21, 2012). The percentage of the global electrical energy supplied from renewable resources has risen to a total of 22% in 2011 which is equal to 4,309 TWh (USDOE, 2013).

Figure 5 illustrates the global percentages of electricity production from renewable sources at the end of the year 2011. As seen in the figure, hydroelectricity is the mostly used renewable energy resource with 71% of electricity production which is nearly 18% of world's total electrical energy generation (Ren 21, 2012). Wind energy meets about 4.5% of world's electrical energy corresponding to nearly 18% of the other renewable sources. Power generation from water and wind seems to be the optimum choice among other renewables (Güney and Kaygusuz, 2010). More than 70 GW electrical power is obtained from solar systems (PV and thermal) corresponding more than 5% of total renewable power production.

Table 1 shows the electrical power capacity of renewable energies for top country and regions. China and the USA are the two biggest renewable power generating countries with 282 and 147 GW electricity, respectively. BRIC's (Brazil, Russia, India and China) and EU-27 produce 35% and 22% of global renewable electric power from renewables with 484 and 294 GW electricity, respectively (Ren 21, 2012).

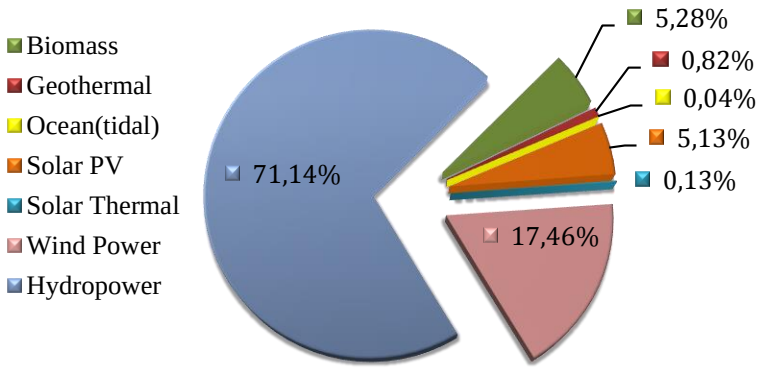

Figure 5. The percentages of electricity production from renewables in 2011

(Data is based on Ren21, 2012)

Table 1. Renewable electric power capacity in 2011 for world and top regions (Ren 21, 2012).

Source/Region	EU-27	BRICS	China	USA	Germany	Spain	Italy	India	Japan	Total
Biomass power	26	17,5	4,4	13,7	7,2	0,8	2,1	3,8	3,3	72
Geothermal power	0,9	0,1	~0	3,1	~0	0	0,8	0	0,5	11,2
Ocean (tidal) power	0,2	~0	~0	~0	0	~0	0	0	0	0,5
Solar PV	51	3,7	3,1	4	25	4,5	13	0,5	4,9	70
Concentrating solar thermal power	1,1	~0	0	0,5	0	1,1	~0	~0	0	1,8
Wind power	94	80	62	47	29	22	6,7	16	2,5	238
Total capacity (without hydropower)	174	101	70	68	61	28	22	20	11	390
Per capita capacity (kW/inhabitant, without hydropower)	0,35	0,03	0,05	0,22	0,75	0,6	0,37	0,02	0,09	0,06
Hydropower	120	383	212	79	4,4	20	18	42	28	970
Total capacity (with hydropower)	294	484	282	147	65	48	40	62	39	1360

Plenty of projections and scenarios have been generated world widely by different agencies to present possible future situation of energy sources. According to European Renewable Energy Council (EREC), in the year of 2040, approximately half of the global energy need is expected to be supplied from renewables (Demirbas, 2009). EU aims to eliminate fossil fuel usage and to acquire all of its energy need from renewables by the year 2050 (EREC, 2010). According to Energy Technology Perspectives of International Energy Agency (IEA, 2012) moderate scenario (2DS), renewables will have a share of more than 40% of total global energy by 2050 (Ren 21, 2013). According to some other projections, it has been foreseen that, the share of renewables in global energy can reach up to 75 % by 2050 (Greenpeace, 2012; Riahi et al., 2012).

There have been various studies to reveal the potential of renewable energy resources. Table 2 shows the minimum and maximum ranges of technical potential of renewable energy sources. Theoretical potential all renewables is above $1.4x10^8$ EJ and the solar and geothermal sources produce the vast majority of this

potential (Resch et al., 2008). The technical potential which means the obtainable potential by fully implementation of technologies and practices varies considerably in the literature because of employing different techniques. According to IPCC, the maximum technical potential of renewable energy resources is around 1660 TW (Moomaw et al., 2011).

Table 2. Global technical renewable energy potentials* (Moomaw at. al., 2011)

Energy type	Min (TW)	Max (TW)
Geothermal Energy	3,7	35,2
Hydropower	1,6	1,6
Ocean Energy	0,2	10,5
Wind Energy	2,7	18,4
Biomass	1,6	15,9
Direct Solar Energy	49,9	1579,8
Total	59,8	1661,4
*Global primary energy supply was about 16 TW in 2011.		

5. Results and conclusion

In this study, the situation of fossil fuel and renewable energy resources have been illustrated on a global scale. Energy is one of the primary needs of mankind and there has been a great increment on the energy requirement after the industrial revolution. Per capita energy use increased rapidly and the human population on the earth has been doubled at the last fifty years. It has been observed that the more prosperous a country is the higher the country's per capita energy consumption. The fossil fuel resources which provide more than 80% of world energy are believed to have reached a level very close to its peak production. Carbon dioxide is the primary greenhouse gas emitted through human activities and the fossil fuels are responsible for 74% of carbon dioxide emission.

In 2010, about 17 per cent of the global energy consumption has been covered from renewables. The hydropower is the mostly utilized renewable energy resource. The 71 % of world's electricity is supplied from hydropower. Wind energy conversion is the second biggest renewable energy resource with about 17 % of all renewables. According to the projections, at least more than 40% of total global energy will be supplied from renewable resources by until 2050. The technical potential renewable energy resources are estimated to be around 60 TW, at least.

Consequently, expanding human population, increasing energy consumption and detrimental effects of fossil fuels on the climate and environment have led the scientists and engineers to find new non-polluting, carbon free energy resources. However, the rate of use of renewables among energy resources is still insufficient. The scientific and technological researches on sustainable resources should be increased. The clean and great source of energy should not be neglected (Yuce and Muratoglu, 2015).

References

Agugliora FM, Alcayde A, Montaya FG, Sirra AZ. (2013). Scientific production of renewable energies worldwide: an overview, *Renewable and Sustainable Energy Reviews*, **18**, 134–143.

Andrews J, Jelley N. Energy science: Principles, technologies and impacts. (2007). New York: Oxford University Press.

Bennett S. (2007). Encyclopedia of energy.1st edition. Global Media.

Bodansky D. (2006). The status of nuclear waste disposal. *A Forum of the American Physical Society*, **35**(1), Available at:

http://www.aps.org/units/fps/newsletters/2006/january/article1.html#_edn5. Accessed February 2013.

BP statistical review of world energy. (2012). Available at: http://bp.com/statisticalreview. Accessed February 2013.

BP energy outlook 2030. (2013). Available at: http://bp.com/statisticalreview. Accessed February 2013.

Cleveland CJ, Morris C, editors. (2006). Dictionary of energy. Italy: Elsevier.

Cruden G. (2005). Energy alternatives. USA: Thomson Gale.

Demirbas A. (2007). Energy issues and energy priorities, *Energy Sources*, **3**(1), 41–49.

Demirbas A. (2009). Global renewable energy projections. *Energy Sources*, **4**, 212–224.

Dorf RC. (2001). Technology, humans and society toward a sustainable world. USA: Academic Press.

EPA (United States Environmental Protection Agency). (2013). Available at: http://www.epa.gov/climatechange/ghgemissions/gases/co2.html. Accessed March 2013.

EREC (European Renewable Energy Council). (2010). Re-thinking 2050: A 100% renewable vision for the European Union.

Gaur RC. (2008). Basic environmental engineering. New Age International Publishers.

Greenpeace, European Renewable Energy Council (EREC) and Global Wind Energy Council (GWEC). (2012). Energy [R]evolution: a sustainable world energy outlook. Amsterdam.

Güney MS. Kaygusuz K. (2010). Hydrokinetic energy conversion systems: a technology status review. *Renewable and Sustainable Energy Reviews*, **14**, 2996–3004.

Höök M, Johansson LJ, Snowden S. (2012). Growth rates of global energy systems and future outlooks. *Natural Resources Research*, **21**(1), 23–41.

Höök M, Tang X. (2013). Depletion of fossil fuels and anthropogenic climate change-a review, *Energy* Policy, **52**, 797–809.

IEA (International Energy Agency). (2012). Energy Technology Perspectives: pathways to a clean energy system. Paris.

IEA (International Energy Agency). (2013). Key world energy statistics. Available at: http://www.iea.org/publications/freepublications/publication/kwes.pdf. Accessed February 2013.

IPCC (Intergovernmental Panel on Climate Change). (2007a). Climate change 2007: Mitigation. Metz B, Davidson OR, Bosch PR, Dave R, Meyer LA, editors. Cambridge and New York: Cambridge University Press.

IPCC (Intergovernmental Panel on Climate Change). (2007b). Climate Change 2007: The physical science basis. Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averty KB, et al., editors. UK and USA: Cambridge University Press.

Kaygusuz K, Kaygusuz A. (2002). Renewable energy and sustainable development in Turkey. *Renewable Energy*, **25**, 431–453.

Maczulak A. (2010). Renewable energy: sources and methods. New York: Infobase Publishing.

Moomaw W, Yamba F, Kamimoto M, Maurice L, Nyboer J, Urama K, et al. (2011). Introduction. In IPCC special report on renewable energy sources and climate change mitigation. Cambridge and New York, USA: Cambridge University Press.

Muratoglu A. (2015). Design and simulation of a riverine hydrokinetic turbine. Ph. D. dissertation. University of Gaziantep.

NARA (US National Achieves and Records Administration, Environmental Protection Agency). (2005). Public health and environmental radiation protection standards for Yucca Mountain. NV. Federal Register. Vol.70 No. 161, 2005. Available at:

http://www.epa.gov/radiation/docs/yucca/70fr49013.pdf. Accessed February 2013.

NEI (US Nuclear Energy Institute). Available from:

http://www.nei.org/resourcesandstats/nuclear_statistics/worldstatistics/. Accessed February 2013.

Quaschning V. (2010). Renewable energy and climate change. Singapore: Wiley.

Raja AK, Srivastava AP, Dwivedi M. (2006). Power Plant Engineering. New Age International Publishers.

Ren 21. (2012). Renewables 2012 Global Status Report. Paris.

Ren 21. (2013). Renewables global futures report. Paris.

Resch G, Held A, Faber T, Panzer C, Toro F, Haas R. (2008). Potentials and prospects of renewable energies at global scale. *Energy Policy*, **36**, 4048–4056

Riahi K. et al. (2012). Energy pathways for sustainable development. In: Global energy assessment–toward a sustainable future. Cambridge, U.K: Cambridge University Press. p. 1203–1306.

Schlager N, Weisblatt J, editors. (2006). Alternative energy. Vol 1. China: Thomson Gale.

Shi L, Chew MYL. (2012). A review on sustainable design of renewable energy systems. *Renewable and Sustainable Energy Reviews*, **16**,192–207.

Sims REH, Schock RN, Adegbululgbe A, Fenhann J, Konstantinaviciute I, Moomaw W, et al. (2007). Energy supply. In: Metz B, Davidson OR, Bosch PR, Dave R, Meyer LA, editors. (2007). Climate change 2007: Mitigation. Cambridge: Cambridge University Press. p. 251–322.

Sovacool BK. (2010). A critical evaluation of nuclear power and renewable electricity in Asia. *Journal of Contemporary Asia*, **40**(3), 369–400.

USDOE (US Department of Energy). (2013). The Office of Energy Efficiency and Renewable Energy. 2011 Renewable Energy Data Book.

World Bank. (2013). World Bank Open data. Available at: http://data.worldbank.org. Accessed February 2013.

WWF (World Wide Fund For Nature). (2011). The energy report: 100 % renewable energy by 2050.

Yuce and Muratoglu (2015). Hydrokinetic energy conversion systems: A technology status review. Renewable and Sustainable Energy Reviews 2015;43.72–82.