International Journal of Pollution and Noise Control
Vol. 1: Issue 2
www.journalspub.com

A Review of Renewable Energy Resources: Current Status and Their Enabling Technology

Khagendra Kushwaha*, Rahul Agrawal*, Govind Patel
Department of Mechanical Engineering, Poornima University, Jaipur, India

ABSTRACT

The increase in rapid industrialization for different development programs have created energy crisis for many developing countries. If this increase in demand will rely upon Coal based thermal power plants, it results in environment pollution and high cost of generation. So the best alternate solution is to develop plants based on renewable sources of energy in the country. The potential for renewable energy resources is enormous because they can, in principle, exponentially exceed the world's energy demand; therefore, these types of resources will have a significant share in the future global energy portfolio. The Renewable sources of energy include Energy from Biomass, Geothermal Energy, Hydro power energy, wind Energy and Solar Energy. Biomass can be explained as all organic material originating from plants, trees and crops, and is essentially the collection and storage of the sun's energy through photosynthesis. Geothermal energy is the energy contained as heat in the Earth's interior and considered as a cost effective, reliable, and environmentally friendly energy source. Hydropower is based on a simple process taking the advantage of the kinetic energy freed by the falling water and a source of clean energy and its generation is not linked to issues concerning fuel supply, especially the price volatility of imported fuels. Solar energy is radiant light and heat from the Sun harnessed using a range of ever-evolving technologies such as solar heating, photovoltaics', solar thermal energy, solar architecture and artificial photosynthesis. This paper presents current scenario, scientific developments and deployment of Renewable sources of Energy.

Keywords: energy, geothermal, hydro, resources, renewable

****Corresponding Author***
E-mail: rahul.agarwal@poornima.edu.in

INTRODUCTION

Energy is considered to be a key factor in the generation of wealth, social development and improved quality of life in all developed and developing countries in the world [1]. The global energy consumption is likely to grow faster than the population growth. Estimates of the world primary energy consumption are that 80% of the energy supply is provided by fossil fuels [2]. Conventional energy sources based on oil, coal, and natural gas have proven to be highly effective drivers of economic progress. However, with the rapid depletion of conventional energy sources and increasing energy demand, worldwide primary energy consumption has grown by 1.8% in 2012 [3].

Renewable energies are energy sources that are continually replenished by nature and derived directly from the sun (such as thermal, photo-chemical, and photo-electric), indirectly from the sun (such as wind, hydropower, and photosynthetic energy stored in biomass), or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy). Renewable energy does not include energy resources derived from

fossil fuels, waste products from fossil sources, or waste products from inorganic sources [4].

Global electricity generation from renewable energy sources is expected to grow 2.7 times between 2010 and 2035. Consumption of biofuels is projected to more than triple over the same period to reach 4.5 million barrels of oil equivalent per day (mboe/d), up from 1.3 mboe/d in 2010. Almost all biofuels are used in road transport, but the consumption of aviation biofuels will make an inroad towards 2035. The use of modern renewables to produce heat will almost double, from 337 Mtoe in 2010 to 604 Mtoe in 2035. [5]. Global electricity generation from renewable energy sources is expected to grow 2.7 times between 2010 and 2035, as indicated by Table 1.

Table 1. *World renewable energy use by type [5].*

	2010	**2020**	**2035**
Electricity generation(TW h)	4206	6999	11,342
Bioenergy	331	696	1,487
Hydro	3431	4513	5,677
Wind	342	1272	2,681
Geothermal	68	131	315
Solar PV	32	332	846
Concentrating solar power	2	50	278
Marine 1 5 57	1	5	57
Share of total generation	20%	25%	31%
Heat demand (Mtoe)	337	447	604
Industry	270	263	324
Buildings and agriculture	131	184	280
Share of total production	10%	12%	14%
Biofuels (mboe/d)	1.3	2.4	4.5
Road transport	1.3	2.4	4.4
Aviation	-	-	0.1
Share of total transport	2%	4%	6%

Renewable energies are energy sources that are continually replenished by nature and derived either directly or indirectly from the sun. The direct sources of energy includes thermal, photo-chemical, and photo-electric and indirectly sources includes wind, hydropower, and photosynthetic energy stored in biomass, or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy. Figure 1 shows the overview of renewable sources of energy. Renewable energy technologies turn these natural energy sources into usable forms of energy–electricity, heat and fuels.

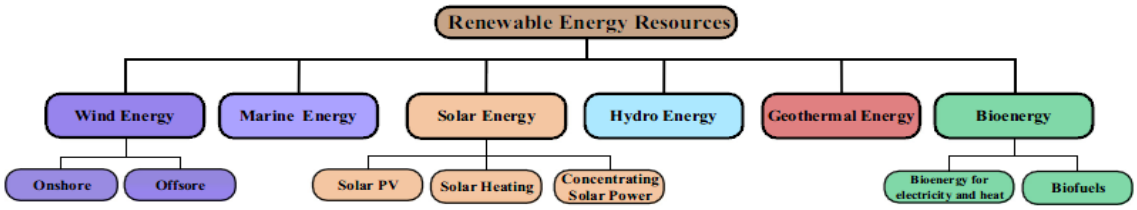

Fig. 1. *Overview of renewable energy sources.*

DESCRIPTION OF RENEWABLE ENERGY SOURCES

Biomass Energy

Biomass is the term used for all organic material originating from plants, trees and crops, and is essentially the collection and storage of the sun's energy through

photosynthesis. Biomass energy (bioenergy) is the conversion of biomass into useful forms of energy such as heat, electricity and liquid fuels (biofuels) [6]. The estimated biomass production in the world is 104.9 petagrams ($104.9 * 10^{15}$ g - about 105 billion metric tons) of carbon per year, about half in the ocean and half on land [7]. Wood remains the largest biomass energy source today. Biomass energy is renewable and sustainable, but shares with fossil fuels many characteristics. While biomass can be directly burned to obtain energy, it can also serve as a feedstock to be converted to various liquid or gas fuels (biofuels). Biofuels can be transported and stored, and allow for heat and power generation on demand, which is essential in an energy mix with a high dependence on intermittent sources such as wind. These similarities account for the major role biomass is expected to play in future energy scenarios [8]. Bio-energy is assumed to reduce CO_2-emissions (Nguyen et al., 2010), to preserve non-renewable resources, to enhance energy security, and to promote regional development (Ecosense, 2007) and rural diversification by creating jobs and income in usually underdeveloped rural areas (Elghali et al., 2007) [9]. The conversion of biomass into electrical energy has an efficiency of 25 percent [10]. This might be improved by using hot combustion gases to partially dry the incoming feedstock. A 100-megawatt power plant produces about 457 x 106 kilowatt-hours annually [11] and will supply electrical energy to a town of about 50,000 people [12]. The Figure 2 shows the conversion technologies from Biomass energy to other forms of Energy.

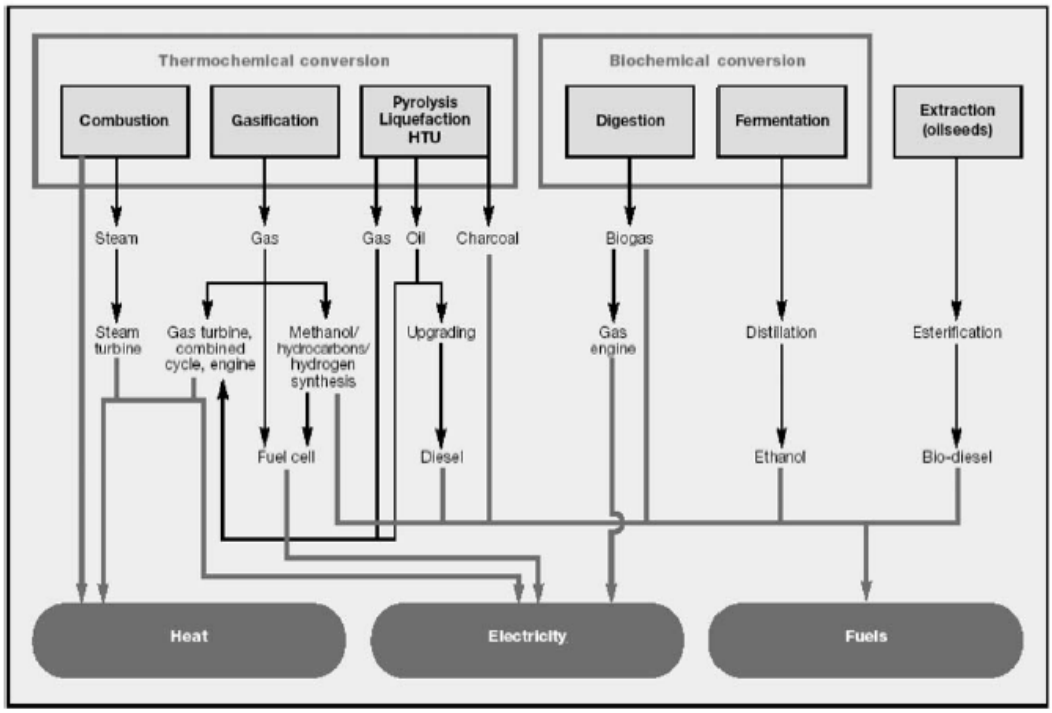

Fig. 2. *Main conversion options for biomass to secondary energy carriers [6].*

Geothermal Energy

Geothermal energy is the energy contained as heat in the Earth's interior and the origin of this heat is linked with the internal structure of our planet and the physical processes occurring there. The heat moves from the Earth's interior towards the surface where it dissipates, although this fact is generally not noticed. We are aware of its existence because the temperature of rocks increases with depth, proving that a geothermal gradient exists:

this gradient averages 30 ºC/km of depth

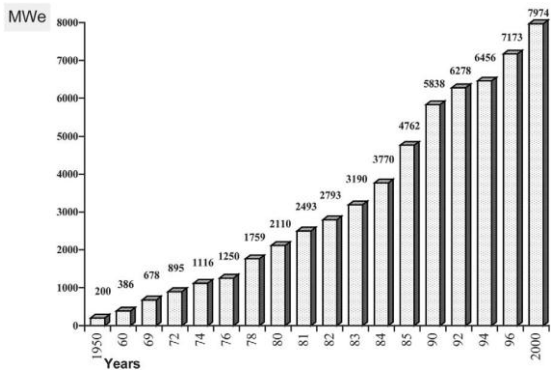

Fig. 3. *Evolution of world-wide electrical geothermal installed capacity.*

Geothermal power is considered a cost effective, reliable, and environmentally friendly energy source [14]. However geothermal energy is a powerful and efficient way to extract renewable energy from the earth by natural processes. Geothermal energy resources consist of thermal energy from the earth's interior stored in both rock and trapped steam or liquid water. Geothermal systems occur in different geological environments where the temperatures and depths of the reservoirs vary accordingly. Many high temperature hydro thermal systems (greater than 180 ºC) are associated with recent volcanic. Intermediate-temperature (between 100 and 180 ºC) and low temperature (less than 100 ºC) systems are also found in continental settings, where above normal heat production through radio- active isotope decay increases terrestrial heat flow or where aquifers recharged by water heated through circulation along deeply penetrating fault zones. Under appropriate conditions, high, intermediate and low temperature geothermal fields can be utilized for both power generation and the direct use of heat [15, 16].

The world geothermal electrical capacity installed in the year 2000 was 7974 MWe with the generation in that year of 49.3 billion kWh [17]. The total electricity produced world-wide from all sources in the year 1998 was 14,411 billion kWh (15,342 in 2000) [18] of which 2826 billion kWh were generated by renewable sources (2600 billion by hydropower alone, and 226 billion altogether by biomass, geothermal, wind, solar and tidal, [15]). These values show that renewable with the exception of hydro played a very minor role on the world energy scene in 1998 (and again in 2000), but geothermal ranked third after hydro and biomass (Table 2).

Table 2. *Installed geothermal generating capacities in the world in the year 2000 [17].*

Country	Installed MWe	GWh generated	% of national capacity	% of national energy
Australia	0.17	0.9	n/a	n/a
China	29.17	100	n/a	n/a
Costa Rica	142.5	592	7.77	10.21
El Salvador	161	800	15.39	20
Ethiopia	8.52	30.05	1.93	1.85
France	4.2	24.6	n/a	2
Guatemala	33.4	215.9	3.68	3.69
Iceland	170	1138	13.04	14.73
Indonesia	589.5	4575	3.04	5.12
Italy	785	4403	1.03	1.68
Japan	546.9	3532	0.23	0.36
Kenya	45	366.47	5.29	8.41
Mexico	755	5681	2.11	3.16
New Zealand	437	2268	5.11	6.08
Nicaragua	70	583	16.99	17.22
Philippines	1909	9181	n/a	21.52
Portugal	16	94	0.21	n/a
Russia	23	85	0.01	0.01
Thailand	0.3	1.8	n/a	n/a
Turkey	20.4	119.73	n/a	n/a
USA	2228	15,470	0.25	0.4
Totals	7974.06	49,261.45		

Hydropower Energy

Hydropower is based on a simple process taking the advantage of the kinetic energy freed by the falling water. In all hydroelectric generating stations, the rushing water drives a turbine, which converts the water's motion into mechanical and electrical energy [19, 20].

Hydroelectricity is clean energy and its generation is not linked to issues concerning fuel supply, especially the price volatility of imported fuels. It enhances our energy security and is ideal for meeting peak demand Hydropower or water
power is power derived from the energy of falling water or fast running water, which may be harnessed for useful purposes.

Hydro power plants (HPP) span a very large range of scales, from a few watts to several GW. The largest projects are Itaipuin Brazil with 14,000 MW and three Gorges in China with 22,400 MW, both producing between 80 to 100 TWh/yr [21]. Hydro power projects are always site-specific, and, thus, designed according to the river system they inhabit.

Over the next decade, hydropower should increase by approximately 180 GW of installed capacity if projects currently under construction proceed as planned. This increase corresponds to roughly one-quarter of the currently installed capacity. Hydro power plants are classified into three categories according to operation and type of water flow. Run-of-River (RoR), storage (reservoir) and pumped storage HPPs vary from small to large in terms of scale, depending on the hydrology and topography of the watershed.

In India Hydropower projects are generally categorized in two sectors i.e., small and large hydro. Hydro projects up to 25 MW station capacities have been categorized as SHP projects and Ministry of New and Renewable Energy (MNRE) are responsible for SHP projects. While Ministry of Power (MOP), Government of India (GOI) is responsible for large hydro projects [22]. Table 3 shows the estimated basin-wise hydropower potential in India.

Table 3. *Estimated basin-wise hydropower potential in India [20].*

River basin	No. of schemes	Potential at 60% load factor	Probable installed capacity (MW)
Indus	190	19,988	33,382
Brahmaputra	226	10,715	66,065
Ganga	142	2,740	20,711
Central Indian river system	53	6,149	4,152
West flowing rivers of Southern India	94	9,532	94,300
East flowing rivers of Southern India	140	34,920	14,511
Total	**845**	**84,044**	**148,701**
Pumped storage schemes	56	–	94,000

Marine Energy

Marine energy or marine power (also sometimes referred to as ocean energy, ocean power, or marine and hydrokinetic energy) refers to the energy carried by ocean waves, tides, salinity, and ocean temperature differences. The movement of water in the world's oceans creates a vast store of kinetic energy, or energy in motion. This energy can be harnessed to generate electricity to power homes, transport and industries.

Ocean energy has the potential of providing a substantial amount of new renewable energy around the world [23]. There is the potential to develop 20,000–80,000 terawatt-hours (TWh) of electricity generated by changes in ocean temperatures, salt content, movements of tides, currents, waves and swells [24].

Relatively few assessments have been conducted on the technical potential of the various ocean energy technologies and such potentials will vary based on future technological development [25–27].

Solar Energy

Solar energy is radiant light and heat from the Sun harnessed using a range of ever-evolving technologies such as solar heating, photovoltaics', solar thermal energy, solar architecture and artificial photosynthesis [28]. The large magnitude of solar energy available makes it a highly appealing source of electricity. The United Nations Development programme in its 2000 World Energy Assessment found that the annual potential of solar energy was 1,575–49,837 exajoules (EJ). This is several times larger than the total world energy consumption, which was 559.8 EJ in 2012 [29, 30].

Photovoltaics' (PV) is the name of a method of converting solar energy into direct current electricity using semiconducting materials that exhibit the photovoltaic effect. A photovoltaic system employs solar panels composed of a number of solar cells to supply usable solar power. The process is both physical and chemical in nature, as the first step involves the photoelectric effect from which a second electrochemical process takes place involving crystallized atoms being ionized in a series, generating an electric current [31]. PV cells are inter connected to form a PV module, typically up to 50 to 200 W. The PV modules,

combined with a set of additional application dependent system components (e.g., inverters, batteries, electrical components, and mounting systems), form a PV system. PV systems are highly modular, i.e., modules can be linked together to provide power ranging from a few watts to tens of megawatts [6].

The most established solar PV technologies are silicon based systems. More recently, so called thin film modules, which can also consist of non-silicon semiconductor material, have become increasingly important. Although thin films generally have a lower efficiency than silicon modules, their price per unit of capacity is lower. Concentrating PV, where sunlight is focused on to a smaller area, is on the edge of entering full market deployment. Concentrating PV cells have very high efficiencies of up to 40%. Other technologies, such as organic PV cells, are still in the research phase (Figure 4) [32].

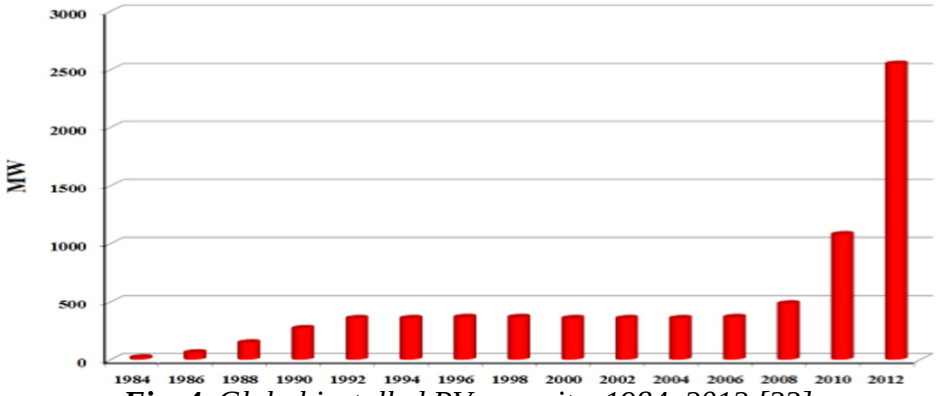

Fig. 4. *Global installed PV capacity, 1984–2012 [33].*

Wind Power

Wind power is defined by the conversion of wind energy by wind turbines in to a useful form, such as using wind turbines to make electricity, wind mills for mechanical power, wind pumps for pumping water or drainage, or sails to propel ships. The first wind turbines for electricity generation were developed at the beginning of the 20th century. The technology has gradually improved since the early 1970s. By the end of the 1990s, wind energy has re-emerged as one of the most important sustainable energy resources [33]. Generating electricity from the wind requires that the kinetic energy of moving air be converted to mechanical and then electrical energy, thus challenging the industry to design cost effective wind turbines and power plants to perform this conversion. The amount of kinetic energy in the wind that is theoretically available for extraction increases with the cube of the wind speed [6].

CONCLUSION

Due to the environmental problems caused by the emissions, and shortage of inexhaustible resources, power generation based on fossil fuels are generally considered to be unsustainable in the long term. Many developing countries like India are facing energy crisis due to increase in industrialization for various development programs. If this increase in demand rely upon Coal based thermal power plants, it results in environment pollution and high cost of generation. So the best alternate solution is to develop plants based on renewable sources of energy in the country. Renewable energy resources are innovative options for electricity generation and their potential is enormous as they can, in principle, meet the world's energy demand many times

over. In summary, the main advantages of Renewable sources are:

- It is a much more concentrated energy resource than coal based thermal plant
- Power is usually continuously available on demand
- No fuel and only limited maintenance are required
- It is a long-lasting technology
- It has almost no environmental impact.

ACKNOWLEDGMENT

Authors are grateful to Mechanical Department of Poornima University, Jaipur for their kind support in research activity. We appreciate the anonymous reviewers for their valuable comments, criticisms, and suggestions.

REFERENCES

[1] Capik M., Yılmaz A.O., Cavusoglu I. Hydropower for sustainable energy development in Turkey: the small hydropower case of the Eastern Black Sea region, *Renew Sustain Energy Rev.* 2012; 16: 6160–72p.

[2] Ummadisingu A., Soni M.S. Concentrating solar power-technology, potential and policy in India, *Renew Sustain Energy Rev.* 2011; 15: 5169–75p.

[3] BP Statistical Review of World Energy, (bp.com/statistical review); June2013 (accessed on13/8/2013).

[4] http://www.treia.org (accessed on 6/6/2013).

[5] World Energy Outlook 2012, (accessed on15/8/2013).

[6] Ellabban O., Abu-Rub H., Blaabjerg F. Renewable energy resources: Current status, future prospects and their enabling technology, *Renew Sustain Energy Rev.* 2014; 39: 748–76p.

[7] Field C.B., Behrenfeld M.J., Randerson J.T., et al. Primary production of the biosphere: integrating terrestrial and oceanic components, *Science*. 1994; 281(5374): 237–40p.

[8] Hall D.O., Scrase J.I. Will biomass be the environmentally friendly fuel of the future? *Biomass Bioenergy*. 1998; 15(4/5): 357–67p.

[9] Gold S., Seuring S. Supply chain and logistics issues of bio-energy production Pimentel D. *Environmental Biology Report.* Cornell University, Ithaca, NY; 1981, 81–1p.

[10] *The 1970 National Power Survey*. Federal Power Commission, Washington, D.C., 1970, part 4.

[11] Kemp C.C., Szego G.C. *Energy Sources.* 1975; 2: 263–68P.

[12] Barbier E. Geothermal energy technology and current status: an overview.

[13] Hammons T.J. Geothermal power generation worldwide, In: *2003 IEEE Bologna Power Tech Conference Proceedings.* 23–26 June, 2003.

[14] Fridleifsson I.B. Geothermal energy for the benefit of the people, *Renew Sustain Energy Rev.* 2003; 5: 299–312p.

[15] Yan Q., Wang A., Wang G. Resource evaluation of global geothermal energy and the development obstacles, In: *2010 International Conference on Advances in Energy Engineering.* June 2010, 19–20: 115–119p.

[16] Huttrer G. The status of world geothermal power generation 1995–2000, *Geothermics.* 2001; 30: 1–27p.

[17] British Petroleum (BP) statistical review of world energy, 2001. http://www.bp.com/centres/energy/world–sta–rev/electricity/generation.asp.

[18] Hydro development plan for12th five year plan (2012–2017), Central Electricity Authority Hydro

Planning & Investigation Division September 2008, New Delhi.

[19] Bhutto A.W., Bazmi A.A., Zahedi G. Greener energy: issues and challenges for Pakistan-hydel power prospective, *Renew Sustain Energy Rev*. 2012; 16: 2732–46p.

[20] Brown A., müller S., Dobrotko vá Z. Renewable energy: markets and prospects by technology, *Int Energy Agency Inf Paper*. 2011.

[21] Central Electricity Authority, India, Available: /http://www.cea.nic.inS; (accessed on September 28, 2012).

[22] Carbon Trust, Future Marine Energy. Results of the Marine Energy Challenge: Cost competitiveness and growth of wave and tidal stream energy, January 2006.

[23] Ocean—potential, *Int Energy Agency Arch* the original on 2015-05-22. Retrieved July 2015.

[24] Bhuyan G.S. World-wide status for harnessing ocean renewable resources, In: *2010 IEEE Power and Energy Society General Meeting.* 25–29 July, 2010.

[25] Aly H.H.H., Hawary M.E. State of the art for tidal currents electric energy resources. In: *24th Canadian Conference on Electrical and Computer Engineering (CCECE).* 8–11 May, 2011.

[26] Elghali S.E., Benbouzid M.E.H., Charpentier J.F. Marine tidal current electric power generation technology: state of the art and current status, In: *IEEE International Electric Machines & Drives Conference, 2007. IEMDC* '07. 3–5 May, 2007, 1407–12p.

[27] Solar Energy Perspectives: Executive Summary, *Int Energy Agency*. 2011. Archived from the original (PDF) on 2011-12-03.

[28] Key World Energy Statistics (PDF).http://www.iea.org/ publications/freepublications/. IEA. 2014. Archived from the original on 5 May 2014: 6, 24, 28p.

[29] Energy and the challenge of sustainability *(PDF). United Nations Development Programme and World Energy Council*. *September 2000*. Retrieved August 2015.

[30] Solar Cells – Chemistry Encyclopedia – structure, metal, equation, The pn Junction. Chemistryexplained.com. Retrieved on 2015-11-10.

[31] Bhuiyan A., Sugita K., Hashimoto, Yamamoto A. InGaN solar cells: present state of the art and important challenges, *IEEE J Photovolt*. 2012; 2(3): 276–93p.

[32] REN21, Renewables 2013: global status report, (www.ren21.net), (accessed on 25/6/2013).

[33] Kaygusuz K. Wind power for a clean and sustainable energy future, *Energy Sources Part B.* 2009; 4(1): 122–32p.