Renewable Energy (RE) for a Clean Energy Future!

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Key points

Renewable energy (RE) is energy which can be obtained from natural resources that can be constantly replenished (renewed) at a rate that equals or exceeds its rate of use. The renewable energy technologies include bioenergy, hydropower/hydroelectricity, wind energy, solar energy, geothermal energy and ocean energy. On a global basis, RE accounted for 12.9% of primary energy supply in 2008, of which the largest RE contributor was biomass (10.2%), with the majority (roughly 60%) being traditional biomass used in cooking and heating applications in developing countries. Hydropower represented 2.3%, whereas other RE sources accounted for 0.4%. Globally, there appears to be more potential for bioenergy and hydroelectricity followed by solar and wind energy. There are significant potential for expansion of RE technologies (bioenergy, wind energy and solar energy) as a source of energy supply in **Australia** and **Bangladesh**. RE are clean sources of energy and provide an opportunity for mitigating climate change (global warming), reducing greenhouse gas emissions, supplying sustainable energy supply and overcoming the negative impact of load shedding in many of the third world countries being experienced (e.g. Bangladesh, India, Nepal and Pakistan).

Contents

1. Introduction

Energy is required to meet basic human needs such as lighting, cooking, space comfort, mobility and communication and to serve other productive processes. Until now global use of fossil fuels/ fossil-carbon fuels (coal, oil and gas) have been the dominant sources of energy supply (85.1% energy supply) (Table 1) leading to a rapid growth in greenhouse gas (GHG) emissions. The combustion of fossil fuels accounted for 56.5% of all anthropogenic GHG emissions causing increase of global average temperatures or global warming. Coal, oil and natural gas are non-renewable resources, which are declining and would be exhausted at some point of time (Figure 1), therefore alternative energy resources need to be found that emit significantly less or nil GHG emissions such as renewable energy (RE) resources [1] (Table 1).

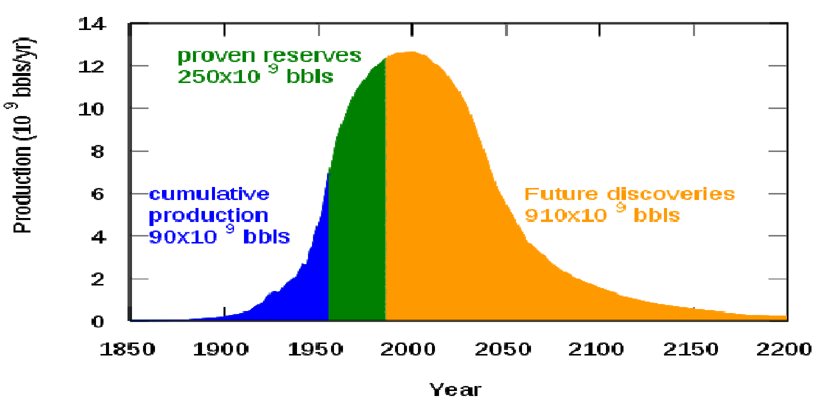

Figure 1: Hubbert curve or logistic distribution shaped production curve (suggested by M. King Hubbert in 1956). This bell shaped curve shows that at some point of time the world oil supplies will go into irreversible decline after reaching a peak (=peak oil or the point of maximum production). Therefore, alternative energy resources need to be found that emit significantly less or nil GHG such as renewable energy resources for a future clean energy supply [image source-[2].

2. Renewable energy resources

Power shortages in many developing countries (e.g. Bangladesh, India, Nepal, Pakistan) (Figure 2), recent increases in oil price and uncertainties concerning its availability, the dependency on foreign energy sources, and the environmental consequences of carbon emissions from coal, oil and gas and government policies for clean and environment friendly fuels caused worldwide interest on RE sources such as bioenergy, hydro energy, wind energy and solar energy (also called clean and green energy [3] (see section 3, Table 1). RE are abundantly available all over the world, therefore RE sector can play an important role in the future energy supply and mitigating the negative impact of load shedding in many of the third world countries being experienced (Figure 2).

Bangladesh	India	Nepal	Pakistan

Life is under mounting stress in Bangladesh due to severe shortage of power supply (April 30, 2012) [4].	Losing electricity for a day or two every week or for few hours every other day is so much a part of living in India (August 1, 2012) [5].	The Nepal Electricity Authority (NEA) has increased the load-shedding to 46 hours from 35 hours a week with effect from August 20, 2012 [6].	Thousands of people take to streets over extended load shedding and low voltage in Barikot tehsil, Swat, Pakistan (August 10, 2012) [7].

Figure 2: Energy Crisis in the Sub-Continet.

2.1: Advantages of RE

RE is energy which can be obtained from natural resources that can be constantly replenished (renewed) at a rate that equals or exceeds its rate of use [1]. The RE sources are described as green and clean energy forms of energy because of their minimal environmental impact compared to fossil fuels (e.g. RE releases relatively smaller or nil amounts of GHGs compared to fossil fuels). Since RE releases relatively smaller or nil amounts of GHGs, therefore use of RE will help in mitigation of climate change [8, 9]. The operating cost of electricity generation with RE is comparatively less compared to fossil or nuclear fuels [10,11]. Furthermore, RE can help accelerate access to energy for the 1.4 billion people, who are currently without access to electricity and 1.3 billion people, who are currently using traditional biomass. For instance, RE will allow the above people to access energy via use of solar energy for water heating, crop drying, biofuels for local transport, and biogas and modern biomass for heating, cooking, lighting and wind energy for water pumping. Nonetheless, RE can contribute to a more secure energy supply such as it might reduce the vulnerability to supply disruption and market volatility in many poor countries [1]. The other advantages of RE technologies is that they can be deployed at the point of use in rural or urban environments and can be integrated into all types of electrical systems from large, interconnected continental-scale grids down to small autonomous buildings. Various types of RE can supply electricity, thermal energy and mechanical energy, as well as produce fuels that are able to satisfy multiple energy service needs in both developed and developing countries (Table1).

Table 1: Current share of energy sources in total global primary energy supply in 2008 [1].

Category	Energy sources	Percentage	RE technologies	Primary energy sector (electrical, thermal, mechanical, transport)
Non-renewable resources (fossil fuel) (85.1%)	Oil	34.60%		
	Coal	28.40%		
	Gas	22.10%		
Non-fossil fuel (2%)	Nuclear	02.00%		
Renewable resources (12.9%)	Bioenergy	10.20%	Traditional use of fire wood/charcoal	Thermal
			Cook stoves	Thermal
			Domestic heating systems (pellet based)	Thermal
			Small and large scale boilers	Thermal
			Anaerobic digestion for biogas production	Electricity/thermal/transport
			Combined heat and power (CHP)	Electricity/thermal
			Co-firing in fossil fuel power plant	Electricity
			Combustion-based power plant	Electricity
			Gasification based power plant	Electricity
			Sugar- and starch- based crop ethanol	Electricity
			Plant- and seed oil-based biodiesel	Transport
			Lignocellulose sugar-based biofuels	Transport
			Lignocellulose syngas-based biofuels	Transport

			Pyrolysis-based biofuels	Transport
			Aquatic plant-derived fuels	Transport
			Gaseous biofuels	Thermal
	Hydropower	02.30%	Run-of-river	Electricity/mechanical
			Reservoirs	Electricity
			Pumped storages	Electricity
			Hydrokinetic turbines	Electricity/mechanical
	Wind energy	00.20%	Turbines for water pumping/other mechanical	Mechanical
			Wind kites	Transport
			High-altitude wind generators	Electricity
	Geothermal energy	00.10%	Hydrothermal, condensing flash	Electricity
			Hydrothermal, binary cycle	Electricity
			Engineered geothermal systems (GS)	Electricity
			Submarine geothermal	Electricity
			Direct use applications	Thermal
			Geothermal heat pumps (GHP)	Thermal
	Solar energy	00.10%	Photovoltaic (PV)	Electricity
			Concentrating PV (CPV	Electricity
			Concentrating solar thermal power (CSP)	Electricity
			Low temperature solar thermal	Thermal
			Solar cooling	Thermal
			Passive solar architecture	Thermal
			Solar cooking	Thermal
			Solar fuels	Transport
	Ocean energy		Wave	Electricity
			Tidal range	Electricity
			Tidal currents	Electricity
			Ocean currents	Electricity
			Ocean thermal energy conversion	Electricity/thermal
			Salinity gradients	Electricity

Bioenergy: *energy derived from any form of biomass (plants or animal matter);* ***Gasification:*** *the process of changing into gas; "coal gas is produced by the gasification of coal;* ***Lignocellulose-*** *A complex of lignin and cellulose present in the cell walls of woody plants;* ***Pyrolysis****= thermochemical decomposition of organic material at elevated temperatures without the participation of oxygen.* ***Thermal****= related to heat.*

3. Renewable energy technologies

Renewable energy technologies (Table 1) include technologies that use—or enable the use of—one or more renewable energy sources. Types of renewable energy technologies include: **bioenergy**, **hydropower/hydroelectricity**, **wind energy**, **solar energy**, **geothermal energy** and **ocean energy**. On a worldwide basis, there appears to be more potential for bioenergy and hydroelectricity followed by solar and wind energy (see Figure 3).

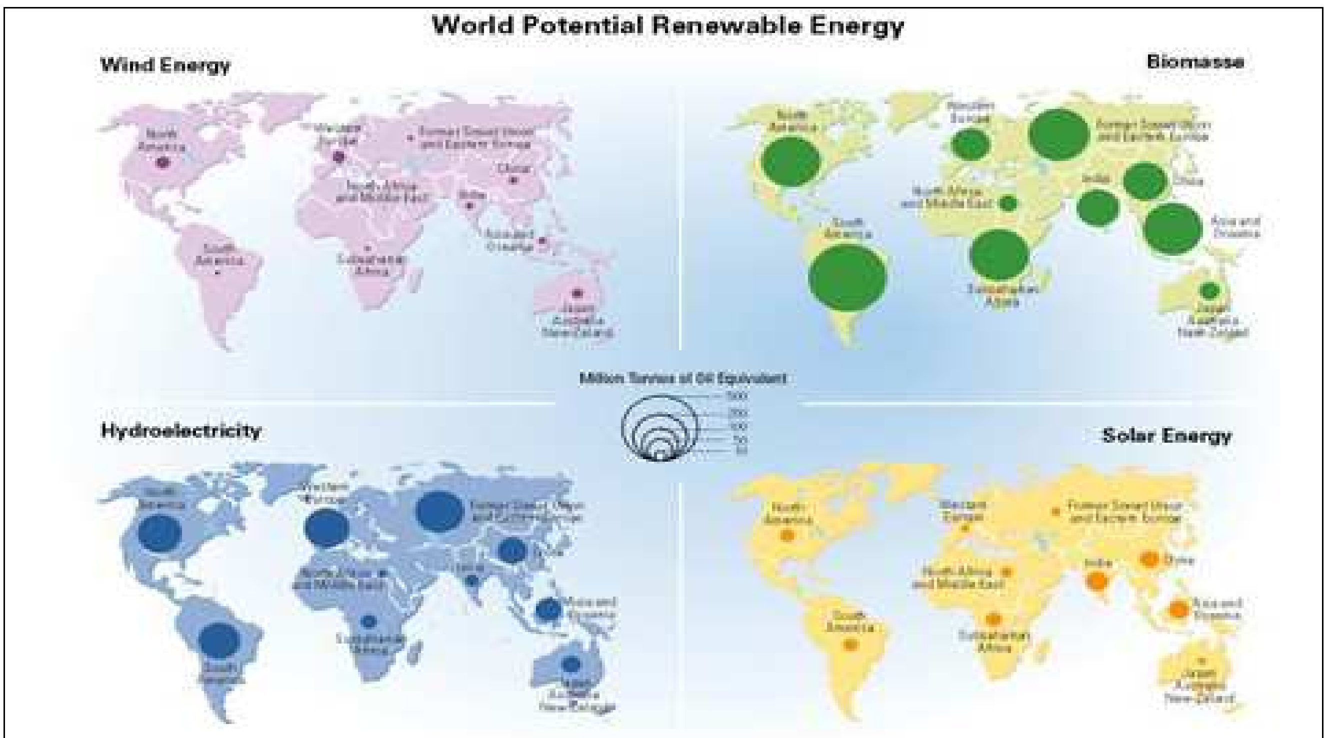

Figure 3: World potential renewable energy [12].

3.1: Global Use of RE

On a global basis, RE accounted for 12.9% of primary energy supply in 2008, of which the largest RE contributor was biomass (10.2%), with the majority (roughly 60%) being traditional biomass used in cooking and heating applications in developing countries. Hydropower represented 2.3%, whereas other RE sources accounted for 0.4% (Table 1). In 2008, RE contributed approximately 19% of global electricity supply (16% hydropower, 3% other RE) and biofuels contributed 2% of global road transport fuel supply. Traditional biomass (17%), modern biomass (8%), solar thermal and geothermal energy (2%) together fuelled 27% of the total global demand for heat. The contribution of RE to primary energy supply varies substantially by country and region.

3.2: Bioenergy [1,13,14,15,16,17].

Bioenergy is sourced from biological materials (called biomass) (Figure 4). It involves generation of electricity from plant materials (which has stored sunlight in the form of chemical energy such as wood, wood waste, straw, manure, sugarcane) or methane gas from rubbish tips. Bioenergy can be produced from various biomass feedstocks (raw materials) as listed below:

- **Oil crops** (rape, sunflower, soya), waste oils, animals fats
- **Sugar and starch crops**
- **Lignocellulose biomass** (wood, straw, energy crops, municipal solid waste)
- **Biodegradable Municipal solid waste** (sewage sludge, manure, wet waste (farm and food wastes), macroalgae.
- **Photosynthetic microorganisms** (micro-algae and bacteria)

Figure 4: Wood, straws are typical sources of biomass [17].

Major biomass uses can also be classified into two broad categories:

- **Low-efficient traditional biomass:** wood, straws, dung and other manures used for cooking, lighting and space (e.g. used for heating by poorer population in third world countries).
- **High-efficiency modern bioenergy**: it uses solids, liquids and gases as secondary energy carrier to generate heat, electricity, combined heat and power (CHP), transport fuels for various sectors. Liquid biofuels from oil crops (biodiesel) and ethanol (sugar and starch crops) used for global road transport and some industrial uses; and biomass derived gases (methane from anaerobic digestion of agricultural residues and municipal solid waste (MSD)).

Biomass is one of the most promising renewable energy sources since it can be burned to produce steam for making electricity, or to provide heat to industries and homes. In addition, biomass can be converted to other usable forms like methane gas, ethanol fuel and biodiesel fuel (Figure 5). Currently biomass power plants exist in over 50 countries around the world and supply a growing share of electricity. A number of European countries are expanding their total share of power from biomass, such as Austria (7% of renewable energy generation), Finland (20%), and Germany (5%).

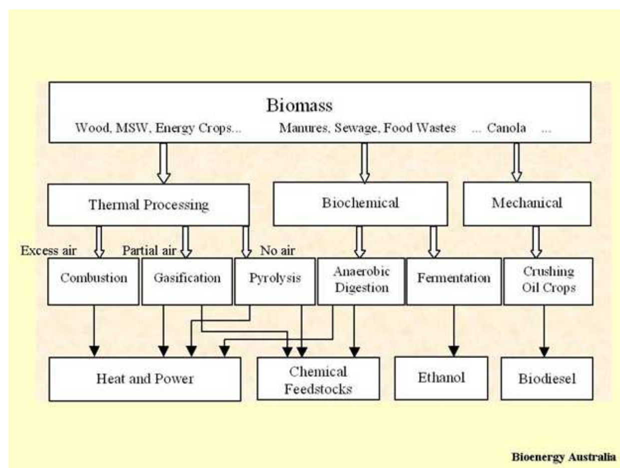

Figure 5: Biofuel poduction Biofuels are liquid fuels, produced by chemical conversion processes that result in the production of ethanol and biodiesel. First generation biofuels are based on fermentation and distillation of ethanol from sugar and starch crops or chemical conversion of vegetable oils and animal fats to produce biodiesel. First generation technologies are being used at a commercial scale. *Note*: *Fermentation is the chemical breakdown of a substance by bacteria, yeasts, or other microorganisms without oxygen).*

Biogas use for power is a growing trend in many countries (e.g. methane, produced by the fermentation of organic matter and captured from landfill sites, sewage treatment plants, livestock feedlots and agricultural wastes). Biogas can be converted by a combustion engine to heat, power, and transport. *Biodiesel* fuel can be made from new or used vegetable oils and animal fats, which are non-toxic, biodegradable, renewable resources. The use of biomass as a source of energy has been further enhanced in recent years and special attention has been paid to biomass gasification. Examples are small- and large-scale boilers; and domestic pellet-based heating systems. *Ethanol* produced (from sugar and starch) can be used in modern diesel vehicles and the production is increasing in particular in Brazil and USA (Figure 6). According to the International Energy Agency, biofuels have the potential to meet more than a quarter of world demand for transportation fuels by 2050. Agriculturally produced biomass fuels can be burned in internal combustion engine or broiler.

The majority of the world's bioenergy is used directly for heat production in particular in third world countries (e.g. burning of solid biomass) and only 4 per cent is used for electricity generation and another 2.5 per cent is in the form of biofuels used in the transport sector. The main growth markets for power generation from bioenergy are the European Union, North America, Central and Eastern Europe and Southeast Asia. China continues to increase power generation from industry-scale biogas (mainly livestock farms) and straw from agricultural residues. The sugar industry in many developing countries continues to build *bagasse*-fuelled power plants (bagasse is the fibrous matter that remains after sugarcane stalks are crushed to extract their juice). A small share of sugar, grain and vegetable oil crops is also used for the production of biofuels. There is increasing interest in transport biofuels in Europe, Brazil, North America, Japan, China and India. Biofuels from commercially available technology are more prospective in regions where energy crop production is feasible for example, sugar cane in subtropical areas of South America and sub-Saharan Africa, and sugar beet in more temperate regions such as the United States, Argentina and Europe.

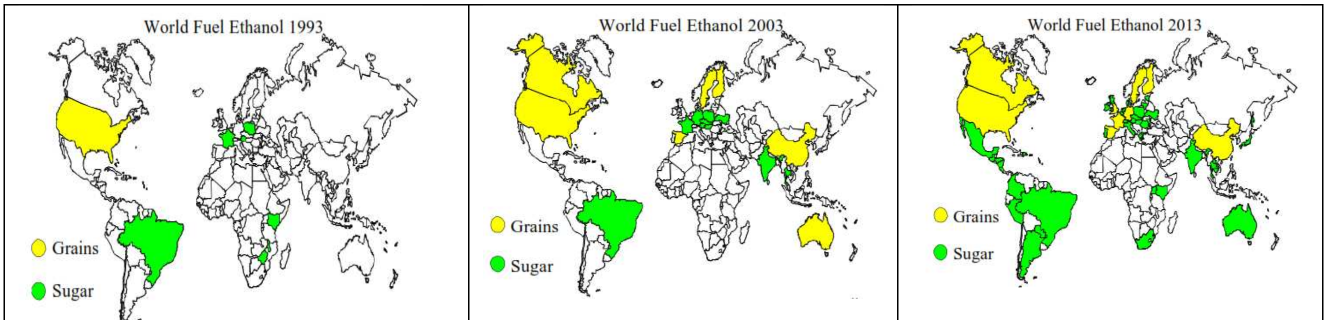

Figure 6: World ethanol production from sugar crops and grains over the years and projected for 2013. Ethanol fuel is widely used in Brazil and in the United States. These two countries represent 87.1% of the world's ethanol fuel production in 2011. Most cars on the road in the U.S.A. can run on blends of up to 10% ethanol and the Brazilian government has made it mandatory to blend ethanol with gasoline, and the legal blend is around 25% ethanol and 75% gasoline in Brazil [18,19].

3.3: Hydropower [20,21,22].

Hydraulic power or water power is power which involves using flowing water (run of river, reservoir/dam) to turn turbines to generate electricity (Figure 7). Hydroelectricity is an example of hydropower. Hydropower is the most advanced and mature renewable energy technology and provides some level of electricity generation in more than 160 countries worldwide. As water is much denser than air, therefore a slow flowing stream of water, or moderate sea swell can yield considerable amounts of energy. The most common type of hydroelectric power plant uses a dam on a river to store water in a reservoir. Water released from the reservoir flows through a turbine, spinning it, which in turn activates a generator to produce electricity. Hydroelectric power doesn't necessarily require a large dam. Some hydroelectric power plants just use a small canal to channel the river water through a turbine. Hydro is a renewable energy source and has the advantages of low greenhouse gas emissions; low operating costs (see Table 2 for advantages and disadvantages of various RE resources).

Figure 7: Hydroelectric power generates about 10% of the USA's energy need [22].

3.4: Wind energy [1,23,24].

Wind energy is one of the most promising sources of alternative energy. It involves using the energy of wind to turn blades of windmills to produce electricity (Figure 8). In general, areas where winds are stronger and more constant, such as offshore and high altitude sites are preferred locations for wind farms. The operational scheme of wind energy systems relates to an accurate estimation of wind speed distribution, the site selection of wind farms, and the operations management of wind power conversion systems. Wind energy is primarily used for electricity generation, both onsite and for transport to the grid. It is (wind energy) also used to pump bore water, particularly in rural areas. The industry is growing fast in many countries and current production of wind energy is largely concentrated in Europe and the United States. However, there has also been rapid growth in the wind energy industries in China and India.

Figure 8: Wind turbines [24].

3.5: Solar energy [1,20,25 26].

Solar energy is radiant energy that is produced by the sun. It involves using solar cells (photovoltaics (PV) or concentrated solar power (CSP) to covert the sunrays into electricity. It is regarded as one of the cleanest and best prospective sources of energy. The main ways to convert solar radiation into energy are active and passive solar design. Passive solar design is often based on the optimal design of buildings that capture the sun's energy in order to reduce the need for artificial light and heating. Active solar design is based on water heating converting solar radiation into heat using photovoltaic panels and solar cells to convert the solar radiation into energy. Solar PV systems can be installed on rooftops, integrated into building designs and vehicles, or scaled up to megawatt scale power plants.

Figure 9: Solar technology can provide clean and affordable alternative energy and can significantly reduce the costs of climate change [26].

3.6: Geothermal energy [1,27,28].

It utilizes the accessible thermal energy from the Earth's interior. Geothermal heat pumps are a highly efficient, renewable energy technology for heating and cooling. The main advantage of using geothermal energy is that this renewable energy source can provide power 24 h a day due to the fact that it is constant, without intermittence problems compared to other renewable resources such as wind or solar energy. Though it is expensive to build a geothermal power station but operating costs are low, resulting in low energy costs for suitable sites. Geothermal power plants now exist in 19 countries, and new plants are commissioned annually such as in Indonesia, Italy, Turkey, and the United States. Geothermal energy with its proven technology and abundant resources, can make a significant contribution towards reducing the emission of greenhouse gases. Advantages of geothermal energy are especially visible in arid areas, where the establishment of human habitats strongly depends on the availability of fresh water. Further, geothermal resources are also used to heat greenhouses and to provide fresh water. Geothermal energy has been used for bathing, space heating; spas, industrial processes, desalination and agricultural applications.

Figure 10: Geothermal energy is an important energy source [28].

3.7: Ocean energy [1,29,30].

Ocean energy can be defined as energy derived from technologies that utilize seawater as their motive power or harness the waters chemical or heat potential. There are two broad types of ocean energy: mechanical energy from the tides and waves, and thermal energy from the sun's heat. Tidal energy (tidal rise and fall) is the result from the gravitational attraction of the Earth-Moon-Sun system acting on the Earth's oceans. Tidal energy can be harnessed through creating tidal barrages (or lagoons), for example, seawater can be allowed to enter to a basin through sluice gates in the barrage and is released through low-head turbines to generate electricity. Wave energy is generated by converting the energy of ocean waves (swells) into other forms of energy (currently only electricity). Oceans cover more than 70 per cent of the Earth's surface. The sun's heat results in a temperature difference between the surface water of the ocean and deep ocean water, and this temperature difference creates ocean thermal energy. Ocean energy can be harnessed to generate electricity to power homes, transport and industries. There is only a small market at present for tidal, wave and ocean thermal energy.

Figure 11: Tidal energy from the ocean. The mechanical energy created by the rising and falling of the ocean's tides is known as tidal energy. When tides flood and ebb, the resulting current can be used to turn turbines and generate electricity [30].

Table 2: Advantages and disadvantages of RE technologies [1,16,20].

RE technologies	Advantages	Disadvantages
Bioenergy	-uses renewable fuel. -can contribute to climate change mitigation, a secure and diverse energy supply and economic development in developed and developing countries. -well-managed bioenergy projects can reduce GHG emissions significantly compared to fossil alternatives, e.g. lignocellulose biomass used in power generation and heat. -biomass direct power, anaerobic digestion biogas to power can provide significant GHG savings compared to fossil fuels. -bioenergy plantations on marginal and degraded soils can lead to assimilation of CO_2 into soils and above ground biomass. -biofuels can provide opportunities for developing countries to make progress in rural development and agricultural growth.	-a large area of land is required for the production of fuel. -requires fertilizer for crops. -burning of biomass may create pollution. -a reduction in food or feed production may occur if existing lands are used to produce bioenergy feedstock. -biomass releases carbon dioxide (CO_2) and small amounts of other greenhouse gases when it is converted into another form of energy. However CO_2 is absorbed during the regrowth of the restored vegetation (biomass) through photosynthesis process.
Hydropower	-sustainable, non-polluting, a clean source of energy. -hydropower can meet both urban and rural electricity needs. -create new freshwater storages. -improve living conditions of local area via irrigation, navigation, tourism, fisheries and water supplies	- impair migration of native species. -can disrupt rivers sediment transport due to dams, dikes and weirs. -causes cold water pollution since water released from the bottom of dams is cold affecting the native species (fish). -hydropower projects may cause relocation of communities and livelihoods of the downstream populations. -may emit GHGs due to decomposition of organic material.
Wind energy	-produces no GHGs during operation. -requires little or no cooling water.	-doesn't produce power when wind is not blowing. -need numerous turbines spread over large areas. -wind electricity is both variable and unpredictable. -can impacts wildlife through bird and bat collisions. -can cause noise pollution.
Solar energy	-solar energy is sustainable, and non-polluting. -solar thermal and PV technologies donot generate any types of solid, liquid or gaseous by-products when producing electricity. -solar energy can bring in significant benefits for rural people of developing countries (e.g. replacing indoor polluting kerosene lamps, inefficient cook stoves, increased indoor reading, reduce time gathering firewood for cooking, street lighting for security, improved health by providing refrigeration for vaccines and food products and communications (TV, radios). -create local job (solar PV has the highest job-generating potential).	-requires large space. -may also require substantial amount of cooling water. -solar energy is variable and unpredictable. -solar electricity could be expensive.
Geothermal energy	-sustainable, non-polluting and low cost. -when used to generate electricity, geothermal power plants typically offer constant output. -the energy harnessed is clean and safe for the surrounding environment. -geothermal energy reduces reliance on fossil fuels.	-can be developed only in selected volcanic areas.
Ocean energy	-does not directly emit CO_2 during operation. -environmental risk from ocean energy technologies appear to be relatively low.	-may reduce visual amenity. -loss of access to competing users, noise during construction and operation. -disruption to biota and habitats, water quality changes/pollution from accidental chemical and oil leaks.

4. Case studies: current renewable energy resources in Australia and Bangladesh

4.1: Australia [8]

Coal is the main sources in generating electricity in Australia, accounting for 76.20%, followed by natural gas (14.9%). RE contributes about 7.9% electricity production in Australia (Figure 12) and the Federal Australian Government has a target to produce at least 20 per cent of Australia's electricity needs from RE resources by 2020 Currently, the main RE sources are hydroelectricity, wind energy, bagasse (sugar cane waste/residues), wood and wood waste', which combined accounted for about 87% of total renewable energy. Almost all bagasse fuelled energy production facilities are located in Queensland (Table 3) while wind farms are mostly in South Australia and Victoria (Table 3). New South Wales is leading in solar energy production compared to other states. The hydroelectric capacity is located mostly in New South Wales, Tasmania, Victoria and Queensland (Table 3).

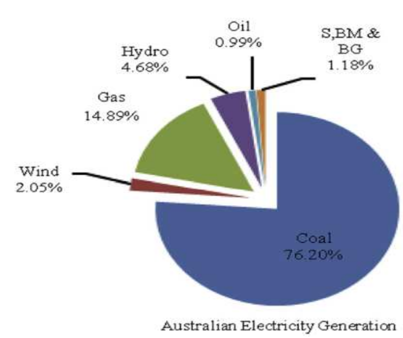

Figure 12: Existing Australian electricity generation in percentage by fuel [8].*Note: S=solar; BM=biomass; BG=*

Table 3: Existing RE generation capacity in Australia [8].
Note: Highlighted box represent the maximum RE production of each RE category.

States ⇒ Sources of energy (MW) ⇓	New South Wales (NSW)	Tasmania (TAS)	Victoria VIC)	Queensland (QLD)	South Australia (SA)	Western Australia (WA)	Northern Territory[a] (NA)	Other	Australia
Hydroelectricity	4293.0	2284.0	769.0	667.0	4.0	32.0	-	-	8049
Wind energy	226.0	144.0	458.0	12.0	1000.0	203.0	0.1	-	2043
Bagasse (sugar cane residues)	43.0	-	-	377.0	-	-	-	-	420
Biogas	74.0	4.0	83.0	19.0	22.0	28.0	1.0	-	231
Solar energy	5.1	0.2	1.2	0.5	1.9	0.9	1.1	177.0	188
Wood waste	42.0	-	-	15.0	10.0	6.0	-	-	73
Biomass and biodiesel[b]	-	-	34.0	4.0	-	-	-	-	41
Ocean and geothermal	-	-	0.2	0.1	-	-	-	-	0.3
Total MW	**4686**	**2432**	**1345**	**1095**	**1038**	**270**	**2**	**177**	**11045**

[a]*Solar PV installations at unspecified locations;* [b]*Mixed biomass feedstock's, municipal waste and black liquor*

4.1.1: Bioenergy [8,14,31].

There is a range of bioenergy resources (feedstocks) available for multiple conversion technologies to generate electricity and heat and produce biofuels in Austraia. Australia's potential bioenergy resources are large which are currently under-utilized such as crop residues, plantation and forest residues and waste streams. There is a significant expansion into a new range of non-edible biomass feedstocks with the development of second generation technologies. Potential feedstocks of the future include modifying existing crops, growing of new tree crops, saw mill residues, pulp wood chipped and algae. Currently, bioenergy generates an estimated 2,500 gigawatt-hours (GWh) of electricity in Australia per year (a contribution of around one per cent to Australia's electricity and around 8.5 per cent of total renewable energy generation) (Figure 13). The Australian Federal Government estimates that bioenergy could provide between 20 and 30 per cent of Australia's electricity generation by 2050.

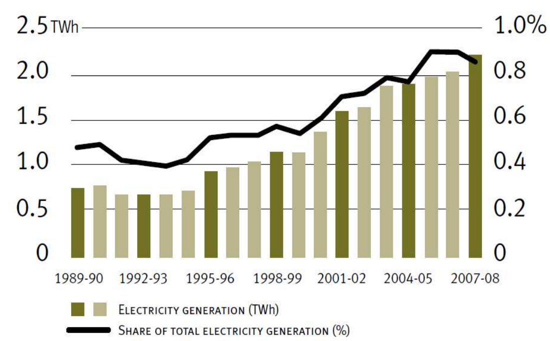

Figure 13: Australian bioelectricity production during 1989-90 to 2007-08 [31].

4.1.2: Hydropower [32].

Since Australia is the driest continent (low rainfall, high evaporation rates), therefore there is limited scope for hydroelectricity and most of hydro energy resource has already been harnessed. At present, more than 100 hydropower stations (total capacity of 7800 megawatts) are located in the areas of highest rainfall and elevation in New South Wales (55%) and Tasmania (29%), of which the Snowy Mountains is Australia's largest hydro scheme with a capacity of 3800 MW) (= half of Australia's total hydroelectricity). Hydro energy is a major source of electricity in Tasmania from six major water catchments and involving 50 major dams, numerous lakes and 29 power stations (total capacity of over 2600 MW). There are also hydroelectricity schemes in north-east Victoria, Queensland, Western Australia, and a mini-hydroelectricity project in South Australia.

4.1.3: Wind energy [8,23].

At present the electricity generation from RE sources in Australia is only 11,045 MW (Table 3), however there is huge potential for electricity generation since Australia has many sites with better wind speed (Table 4) and solar irradiation (Table 5) as well as less pronounced seasonal variations compared to overseas sites. Australia has some of the best wind resources in the world. Australia's wind energy resources are located mainly in the southern parts of the continent in particular in the coastal regions of western, south-western, southern and south-eastern Australia. Coastal regions with high wind resources (wind speeds above 7.5m/s) include the west coast south of Shark Bay to Cape Leeuwin, along the Great Australian Bight and the Eyre Peninsula in South Australia, to western Victoria and the west coast of Tasmania. In recent time, wind energy has experienced strong growth and now represents 2.05% of total electricity generation of Australia. Wind speed data (Table 4) further reveals that abundant electricity generation can be possible in most states except Northern Territory.

Table 4: The yearly average seasonal wind data for different regions of Australia (km/h) [8].

	NSW	VIC	WA	SA	TAS	QLD	NT
Summer	19.05	20.23	20.12	18.08	18.75	18.70	7.68
Autumn	14.73	19.10	17.20	15.77	17.59	20.21	8.50
Winter	13.56	21.98	16.97	16.61	18.45	17.85	10.47
Spring	18.75	21.83	19.01	19.39	19.75	18.51	7.69
Average	**16.52**	**20.78**	**18.32**	**17.46**	**18.63**	**18.81**	**8.58**

4.1.4: Solar energy [25].

The Australian has the highest solar radiation per square metre of any continent and consequently some of the best solar energy resource in the world. The regions with the highest solar radiation are the desert regions in the northwest and centre of the continent. The solar resource of Australia is equal to the world's best and the annual average solar irradiation is greater than 6 kWh/m (Table 5). Due to the superior condition of renewable sources, wind and solar PV sources can contribute in large scale electricity generation of Australia. However, Australia's current use of solar energy is low with solar energy accounting for only about 0.1 per cent of Australia's total primary energy consumption. The most common use of solar energy is solar thermal water heating. Solar PV systems play an important role in off-grid electricity generation in remote areas.

Table 5: Monthly solar data (kw h/m^2/day) of some selected Australian sites [8].

	January	February	March	April	May	June	July	August	September	October	November	December	**Average**
Australia (Longreach)	6.63	6.36	6.63	6.54	6.38	6.61	7.05	7.30	7.54	7.05	7.18	7.13	**6.87**
Australia (Carnarvon)	9.63	8.80	8.27	7.13	6.42	6.33	6.66	7.72	8.78	9.57	9.98	8.25	**8.26**
Australia (Mildura)	7.52	7.10	6.71	5.76	4.56	4.13	4.25	4.92	5.62	6.49	6.89	7.17	**5.92**

kWH m^2/d= is the irradiation unit

4.2: Bangladesh [33]

The primary energy sources in Bangladesh are natural gas and coal (Figure). In 2004, the shares of natural gas, oil, coal and hydroelectricity to total primary energy consumption were 70.8%, 25%, 2.4% and 1.8%, respectively. The main renewable energy resources in Bangladesh are biomass, solar, wind and hydropower.

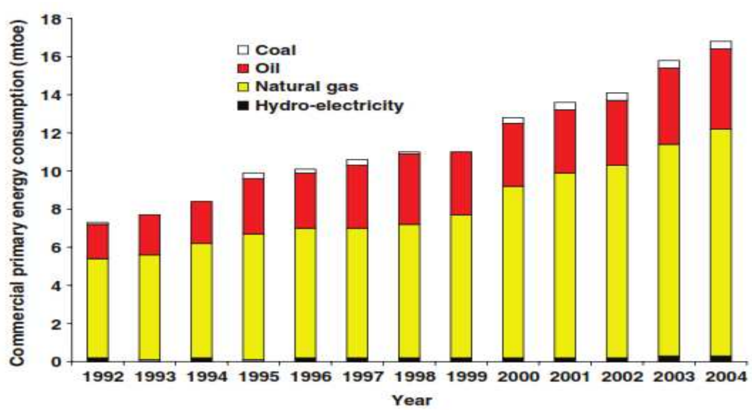

Figure 14: Commercial primary energy consumption trends in Bangladesh [33].

4.2.1: Bioenergy

The biomass resources in Bangladesh include: **agricultural residues** (41.99 Mtonne annual recoverable crop residues of which 62.5% are field residues and 37.5% are process residues) such as *field residues* (rice straw, wheat straw, sugarcane tops, jute stalks, maize stalks, millet stalks, groundnut straw, cotton stalks, residues from pulses) and *processed residues* (rice husk, rice bran, sugarcane bagasse, coconut shells, coconut husks, maize cob, maize husks, groundnut husks); **animal waste** (20.62 Mtonne total annual amount of recoverable animal waste) including manure from cattle, goats, buffaloes, sheep and poultry droppings); **human and municipal solid waste** (14.79 Mtonne total annual amount of recoverable biomass of human and municipal solid waste); **forest biomass** (8.87 Mtonne total annual amount of recoverable forest biomass including *fuel wood* (tree trunks, branches); *tree residues* (twigs, leaves, bark and roots); *wood processing residues* (saw dust from the forestry industry) and *recycled wood* (demolished building materials, pallets and packing crates). Agricultural residues represent 48.7% of the total recoverable biomass, followed by a 23.9% contribution from animal wastes and poultry droppings and the energy potential of the annually recoverable 86.28 million tonne of biomass is estimated at 1125.4 PJ (equivalent to 26.795 mtoe or 312.613 TWh) (*Note: TWH= 1 terawatt-hour per year; Mtoe= million tonne oil equivalent)*. Biomass is widely used in both rural and urban areas as a domestic fuel for cooking and heating, in particular domestic cooking in rural areas represent the largest single consumer of biomass. Many commercial and industrial facilities employ biomass for the provision of process heat. It has been estimated that the annual available biomass energy potential for electricity generation in Bangladesh is in the range of between 183.865 and 223.794 TWh.

4.2.2: Hydropower

There are low potential for hydropower in Bangladesh due to flatness of the country. The only hydroelectric power plant, the Kaptai Dam is located on the river Karnaphuli at Kaptai, Chittagong and represents about 5% of the nation electricity supply (230 MW).

4.2.3: Wind energy

The seasonal variation in wind speed poses some limitations to expand wind power generation and its widespread application in Bangladesh. Based on various surveys, the potential sites for wind energy is located only in the coastal regions (Figure 15) (average wind speed ranged between 3.00 m/s and 4.52 m/s; Table 6) with strong potential between April to September. Among the coastal regions, Patenga (Chittagong) appears to be the most potential to harness the wind power due to constant wind speed prevails at this area. Currently there are some wind energy farms located at Muhuri Dam (Feni), Moghnama Ghat (Coxs Bazar), and some wind turbine generators were also installed at some selected coastal regions. Recently, the Local Government Engineering Department (LGED), and Bangladesh Centre for Advanced studies (BCAS) installed a number of locally manufactured wind pumps in Tangail, Kustia, Chittagong (Patenga) and Cox's Bazar districts to assess the viability of wind pumps. Wind pumps can be used for irrigation of vegetables in winter months in the coastal region and lifting of underground fresh water for drinking in coastal islands.

Figure 15: Prospective area for wind energy utilization [33].

Table 6: Monthly average wind speeds at 25m height at seven coastal stations measured [33].

		Monthly average wind speed (m/s) at the monitoring stations						
Year	Month	Patenga	Coxs bazar	Teknaf	Noakhali	Char Fassion[a]	Kuakata	Kutubdia
1996	June	8.75	-	-	-	-	-	-
	July	5.87	5.42	5.77	-	-	-	-
	August	5.32	5.33	4.90	4.70	5.20 (4.60)	5.70	-
	September	3.36	3.69	3.46	2.94	3.34 (2.80)	3.77	3.58
	October	3.20	3.74	3.30	2.83	3.70 (3.07)	2.18	3.98
	November	2.61	2.93	2.29	1.91	-	1.98	3.23
	December	2.97	1.78	1.44	1.35	3.09 (2.38)	3.35	3.38
1997	January	3.25	2.33	1.99	1.31	2.80 (2.19)	3.18	3.67
	February	2.66	1.99	1.90	1.90	2.69 (2.02)	3.37	3.29
	March	3.13	2.42	2.26	2.38	3.54 (3.09)	4.84	3.53
	April	2.88	1.84	1.65	2.25	3.29 (2.28)	4.93	3.11
	May	4.96	3.97	3.09	3.99	4.81 (3.71)	6.28	4.89
	June	5.83	4.64	3.26	5.00	5.76 (4.42)	7.31	5.90
	July	5.67	4.80	4.33	4.92	5.22 (3.94)	7.34	6.17
	August	5.13	4.31	4.03	3.85	5.17 (4.01)	-	5.34
	September	-	2.96	1.83	2.77	3.08 (2.20)	-	3.97
Annual average		**4.37**	**3.48**	**3.03**	**3.00**	**3.98 (3.21)**	**4.52**	**4.16**

**values in brackets represent wind speeds measured at 10 m height.*

4.2.4: Solar energy

Bangladesh is well placed for tapping solar energy with daily solar irradiation intensity varies from 3 to 6 kWh/m with a maximum during March–April and a minimum in December–January. Different Universities and research institutes are carrying out research on solar water heaters, solar cookers and solar dryers etc. PV power systems are being accepted in Bangladesh, for example, two solar PV water pumps are being used for irrigation in the Dhaka and Moulovibazar districts and low-cost improved lanterns (of capacity 5, 7.5 and 10 W) for home lighting in rural areas are being designed and tested. Solar PV could be a viable option in supplying electricity for rural homes, rural markets, rural health clinics, street lighting, water pumping and telecommunication. Solar home systems (SHSs) are gaining popularity in Bangladesh.

5. Conclusion

Renewable technologies are clean sources of energy and provide an opportunity for mitigation of climate change (global warming), and reducing greenhouse emissions. Electricity generation from RE sources can play an important role to enhance reliability and efficiency of the power system (i.e. energy security- availability, reliability and affordability of energy supply). At present electricity generation from renewable sources is becoming an essential part all over the world as clean energy. It is recognized that renewable energy sources need to be a part of the energy mix for sustainable future to meet the needs of the present and the future generations. RE can help to lower greenhouse gas emissions in order to meet the challenges posed by climate change driven by rising levels of carbon dioxide in the earth's atmosphere from fossil fuel use.

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