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Review of Current Status of Fossil Fuel, Renewable Energy and Storage Devices: Context Bangladesh

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Abstract *– This article highlights the current status of various energy sources both non-renewable and renewable and various storage devices that are in market practice in Bangladesh. The country, the eight most populated one in Asia has an installed electricity generation capacity of 20,000 MW. On an average only 77.9% of the population has access to electricity. The upliftment of the socio economic status of people leads to the growing demand for power. The power demand will be more than 30,000 MW by 2030. The depletion of fossil fuel leads to rethink the use of renewable sources of energy. The increased demand of power is overcome by the proper utilization of solar energy in recent years from 2017 to 2018 by having the maximum generation of 200 MW. Unlike regular storage devices in the conventional system, the ever-increasing power demand has led to increase in the utilization of the storage devices especially the battery. Usage of electromagnetic and mechanical storage systems will reduce the amount of carbon and toxic metals like lead, sulphur, etc. released to the atmosphere. Bangladesh has an estimated target of meeting its 50% power demand in 2030 by only using renewable sources and non-polluting storage systems. Moreover, the article gives lot of research focus to the market researchers with various advanced storage techniques discussed in one place. The availability of energy sources, power demand, and storage options clearly indicate that the sustainable development depends on energy conservation rather than energy utilization.*

Keywords *– batteries, fossil fuels, global warming, renewable energy sources, storage devices.*

1. INTRODUCTION

The economic reform and growth of population urge the utilities to meet the increased demand for energy. But the fossil fuels depletion and environmental issues like greenhouse gas emissions, global warming sea level rise, flooding owing to glacier melt is leading the society to focus towards renewable energy sources [1]. According to business standard 18.9.2020, the global climatic risk index 2020 listed Bangladesh as the nation in seventh place among 10 countries greatly affected by climatic change impacts for a span of 20 years 1999-2018. The intermittent nature of renewable energy sources (wind, solar, *etc*.) creates necessity for storage of energy in off-peak hours and supply for matching peak demand. Energy storage systems (ESS) can carry out the above work and eliminate the investment for additional generation, transmission and distribution for meeting the supply-demand gap due to intermittency [2].

Table 1. Power generation by type of fuel [3].

Fuel type	Installed capacity in MW	Percentage
Hydro	230	1.00
Natural gas	9413	61.00
Furnace oil	3443	22.00
Diesel	1380	6.49
Coal	524	3.00
Renewable energy	3	0.00
Power import	660	4.00

2. CURRENT POWER GENERATION STATUS OF BANGLADESH

The power grid of Bangladesh has installed capacity of 15,953 MW in 2017-18 and the fuel wise installed capacity is shown in Table 1 [3].

The installed capacity has been upgraded to 20,000MW up to September of 2019. The power generation by fuel type for the year 2017-18 is in Table 2. The total power generation is 62,677.91 GWh.

Table 2. Power generation in Bangladesh by type of fuels in 2017-18 in GWh [3].

Type of fuel	Power generation in GWh	Percentage
Hydro	1024.31	1.60%
Natural gas	39804.2	63.50%
Furnace oil	10849.71	17.30%
Diesel	4520.31	7.20%
Coal	1692.87	2.70%
Renewable energy	3.79	0.10%
Power import	4782.72	7.60%

From Tables 1 and 2 it can be seen that the major contributing source of power generation is natural gas. Natural gas contributes 63.5% of power generation of Bangladesh. Further natural gas utilization share is 17% in industrial sector, 12% for household purposes, 8% in manure preparation and 16% for transport sector was

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clearly mentioned in Figure 1. Because of the above contribution of natural gas the enslavement on natural gas is rising drastically. The natural gas production chart and the position of gas reserves up to 2041-42 were depicted in Figures 2 and 3. The production of natural gas for the year 2018-19 is 25.18 billion cubic meters (bcm) [3].

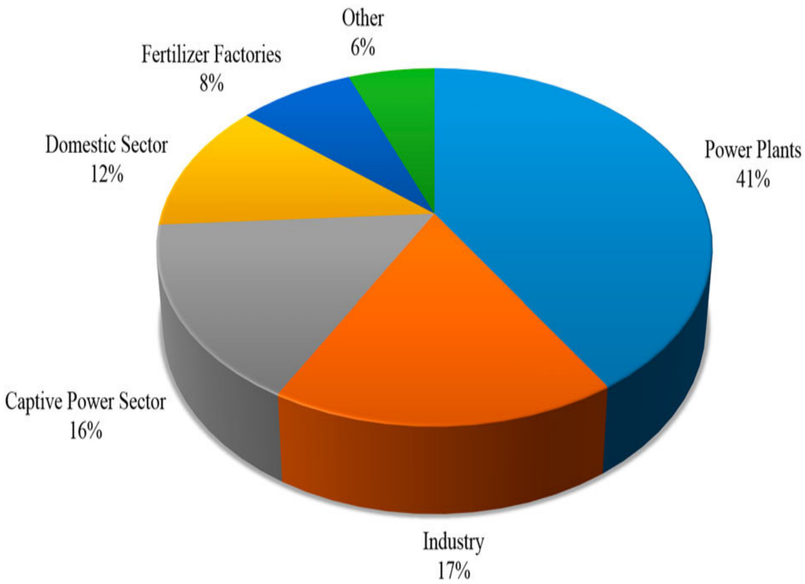

Fig. 1. Specification of natural gas utilization [5].

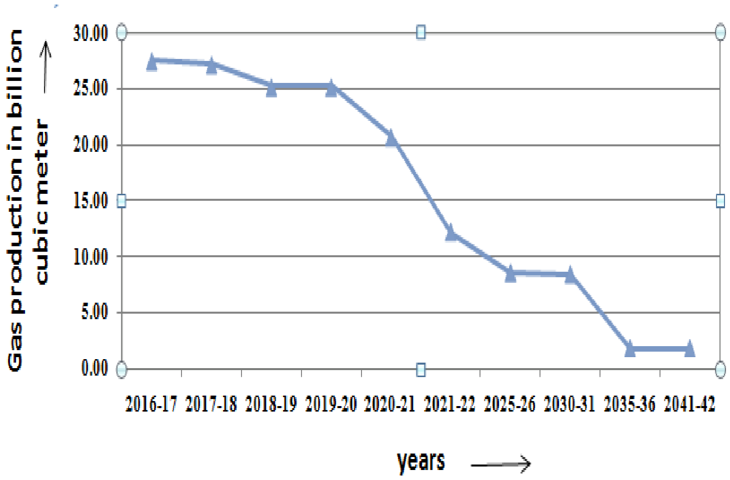

Fig. 2. Projection of gas production in Bangladesh [6].

Next to natural gas, oil occupies the second position in the power generation sector. For oil, Bangladesh mainly depends on refined and unrefined petroleum fuel.

Petroleum products such as diesel, petrol, furnace oil were used for power generation which fulfils 20% of the power needs of the country. Only 6% of the liquid fuel consumption is indigenous production by condensing gas the remaining part imported. About 1.2 million metric tons of crude oil and 5.5 million metric tons of refined petroleum products were under trade in process.

Bangladesh is enjoying a coal reserve of 31,000 million tons which can be an alternate source for natural gas and can serve the energy requirement for nearly 50 years. Fortunately, coal of Bangladesh possesses good heat generation capacity and low sulpur content [3]-[5].

Further, the point to be noted is that other than hydro all other power generating stations will pollute the atmosphere and contribute to the greenhouse gases which in turn leads to global warming. The global warming is responsible for the rise of temperature, health hazards, floods and storms, *etc.* in Bangladesh [6].

The greenhouse gas emission (GHGs) from agriculture, land use and waste are the emissions from non-energy sources and emissions from power, transport, buildings and industry are energy related emissions [7]. The sector wise greenhouse gas emission is pictured in Figure 4.

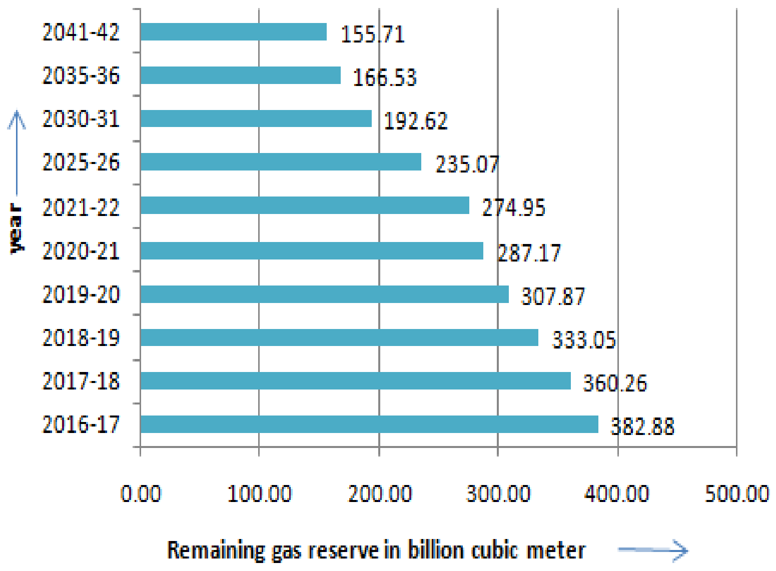

Fig. 3. Remaining gas reserve (km^3) in Bangladesh [6].

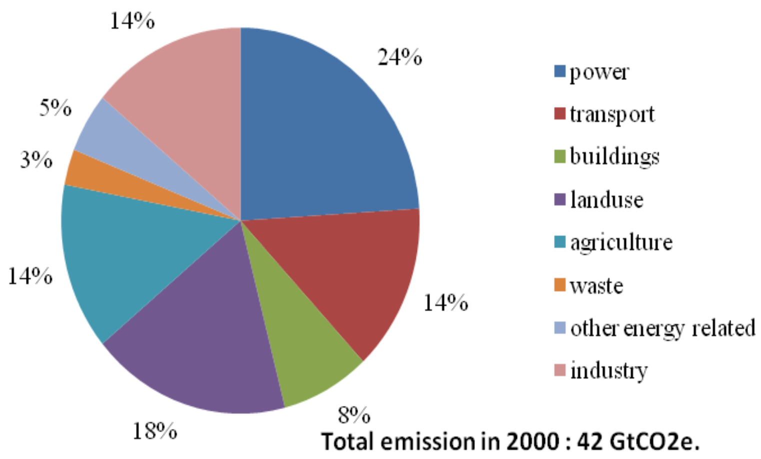

Fig. 4. Sector share of GHG emissions in 2000 [7].

It can be noticed that the major emission comes from the power sector. Power sector mainly depends on fossil fuels. The fast depletion of fossil fuels such as natural gas, coal, diesel, *etc*. and their continuously increasing cost and the environmental pollution due to the usage of fossil fuels are the motivations to think of some alternate sources which are non-polluting and non-exhaustible in nature.

According to International Energy Agency the fossil fuels will get depleted in about hundred years. At this juncture moving to renewable energy sources will help to reduce the emission of greenhouse gases and to come out from the dependency on fossil fuels.

3. RENEWABLE POWER GENERATION STATUS OF BANGLADESH

Among all renewable energy sources (Figure 5) the major renewable energy sources of the country are solar, biomass, bio-gas, hydro and wind [9].

3.1 Solar Energy

Bangladesh is in perfect location for solar energy harvesting, between 20˚34' and 26˚39' latitudes north and longitudes 80˚00' and 90˚41' east. The average solar radiation/day is 4-5 kWh/m^2 in Bangladesh which is sufficient for solar power generation. The solar home systems (SHS) mostly used photovoltaic (PV) power generation systems in Bangladesh which can be clearly understood from Figure 6.

The Bangladesh government has a goal of having "Electricity to everyone" within 2021, this SHS acts as a tool to achieve the goal. This SHS programme is considered as the best one ever in solar power progress by the global society. The SHS conserves the usage of 18,000 tons kerosene/year and creates 70,000 job opportunity. The SHS was started by Infrastructure Development Company Limited (IDCOL) [10]-[11].

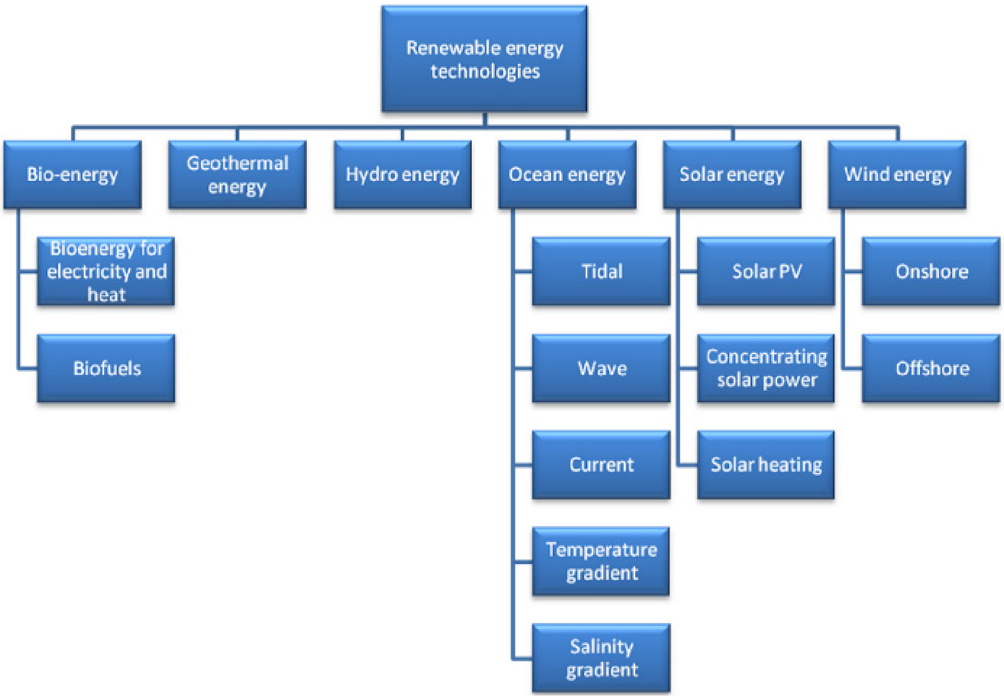

Fig. 5. Renewable energy sources– an overview [8].

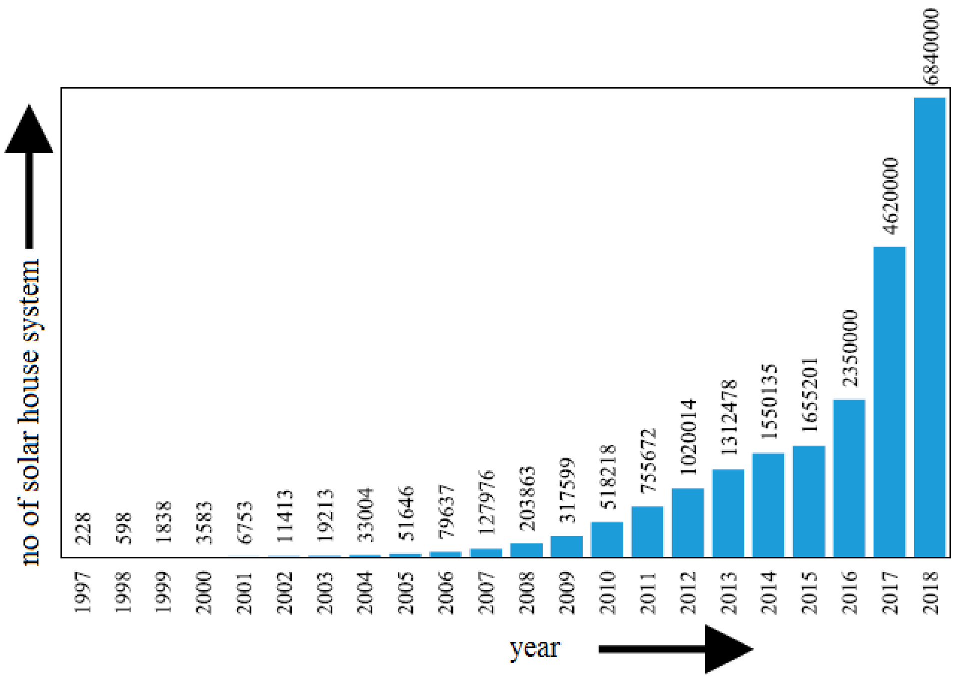

Fig. 6. SHS in Bangladesh up to 2018 [5].

3.2 *Wind Energy*

The kinetic energy of wind rotates wind turbines which produces electricity. The geographical location of Bangladesh restricts the use of small scale wind turbines for power generation. The wind power depends on the velocity of the wind. In the islands and southern maritime face of Bangladesh the average wind speed lies between 3-4.5 m/s from March to September and 1.7-2.3 m/s for the rest of the months of the year. Hence in islands and coastal areas wind mills were erected for pumping and electrification purposes. Bangladesh power development board (BPDB) is taking charge of wind mill and hybrid wind power generation and aiming to contribute to 10% power requirement of the nation. [10]-[11].

3.3 Biomass Energy

The biomass sources are cattle dung, poultry wastages, farming residues, rice husks, wood, jute sticks, municipal wastes, *etc.*, which are utilized for power generation. Around 25,000 biogas plants and 0.2 million upgraded ovens are under operation [10]-[11].

3.4 Biogas Energy

Biogas is a bio-fuel formed out of the biological breakdown of organic materials in the absence of oxygen. Animal waste, plant waste and kitchen waste are used for biogas generation. Around 13,500 biogas plants are completed by the NGO Grameen Shakthi. The IDCOL has a plan to erect 25% of biogas plants in the northern side of the country [10]-[11].

3.5 Hydro Energy

Kinetic energy of water flow is utilized in hydro power plants. Hydro power plants of large type (>10 MW) and small type (<10 MW) are common in Bangladesh. A 230 MW hydro power plant was constructed in Karnaphuli. Micro hydro plants are also in Chittagong and nearby hill areas [10]-[11].

The power generation by hydro, solar PV, wind and bio-mass from 2008 to 2018 is illustrated in Figure. 7. The losses, poor power factor, blackouts are some of the general problems faced by the power sector in the country.

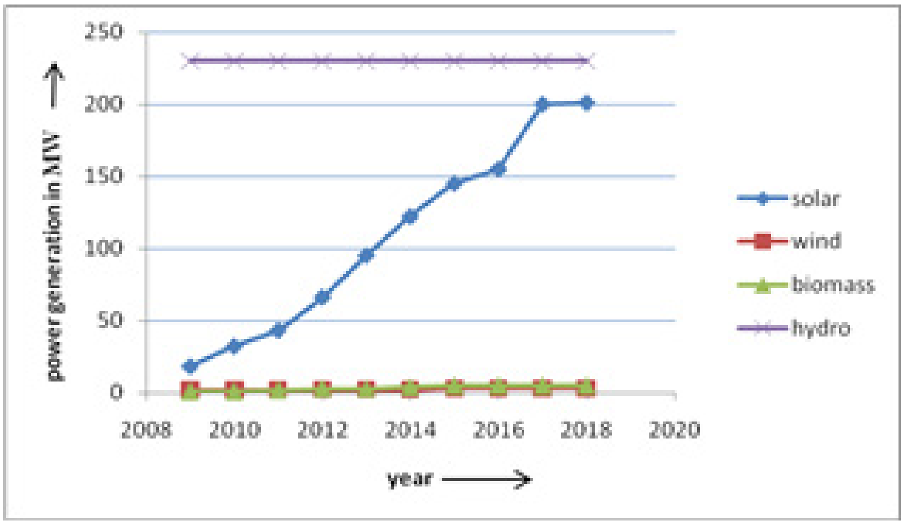

Fig. 7. Bangladesh's source wise renewable energy generation during 2009-2018 [12].

The renewable energy sources are pollution free, free of charge and abundant in nature. Its intermittent nature is the major drawback. To provide uninterrupted supply storage devices can be used.

4. INTRODUCTION TO ENERGY STORAGE DEVICES

Energy storage devices are categorized into two types based on power capacity and run time. They are, devices having high energy with slow discharge and devices having high power with fast discharge. High energy devices like pumped storage devices, compressed air storage devices and electrochemical batteries can be used from few kilowatts (domestic purposes) to several megawatt power requirements (managing of energy distribution, backup system, seasonal reserving purpose). Employing high power storage devices (super capacitors, magnetic energy storage devices and flywheels) for fast charging and discharging needs (power systems having critical pulse loads, transportation systems and power grids) will lead to good results where high efficiency is expected [13].

According to the form by which energy storage is carried out, storage devices can be categorized as mechanical, electrochemical, electrical, chemical and thermal storage devices as portrayed in Figure 8. Mechanical storage devices were further split up into kinetic energy storage devices (flywheel) and potential energy storage devices (pumped hydro and compressed air system) [14].

In all devices storage occurs by the conversion of electrical energy into storable form and when needed, stored energy can be reconverted into electrical energy as in Figure 9.

Based on the time of discharge storage devices are classified into three types. Devices having few seconds or few minutes of storage are called as short-term devices. Devices having few minutes or few hours of storage are called medium-term devices and long term devices will have storage duration of several hours to few days. Short duration storage technology is appropriate for improving the quality of power during transient's occurrence by keeping voltage stable. Medium term storage technology is useful in power system for frequency regulation, managing energy and energy jam in grids. The long term storage technology is suitable to fill the space between the supply and demand for a day to few days [14]-[15].

The worldwide utilization of various energy storage devices is illustrated in Figure 10. The pumped hydro storage system enjoys 99% global bulk storage. Compressed air storage system stands in the second position [16].

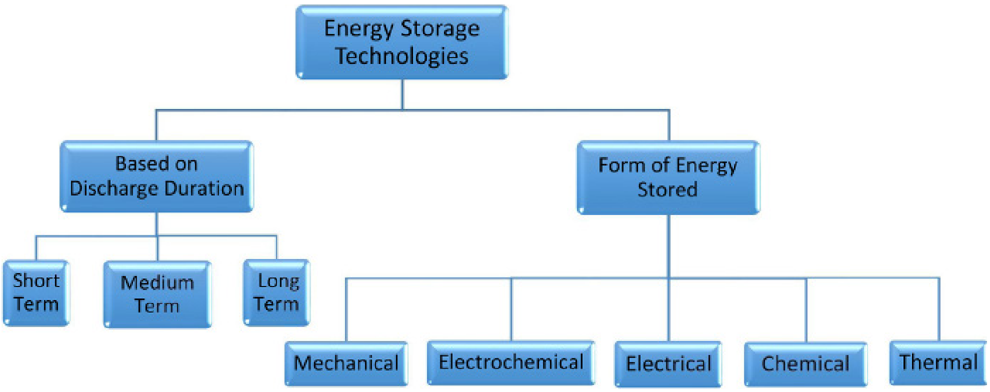

Fig. 8. Taxonomy of energy storage technologies [14].

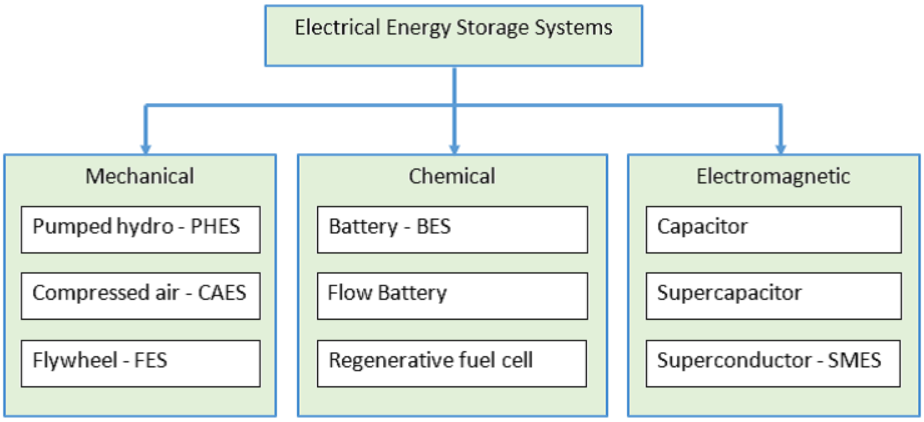

Fig. 9. Energy storage systems classification.

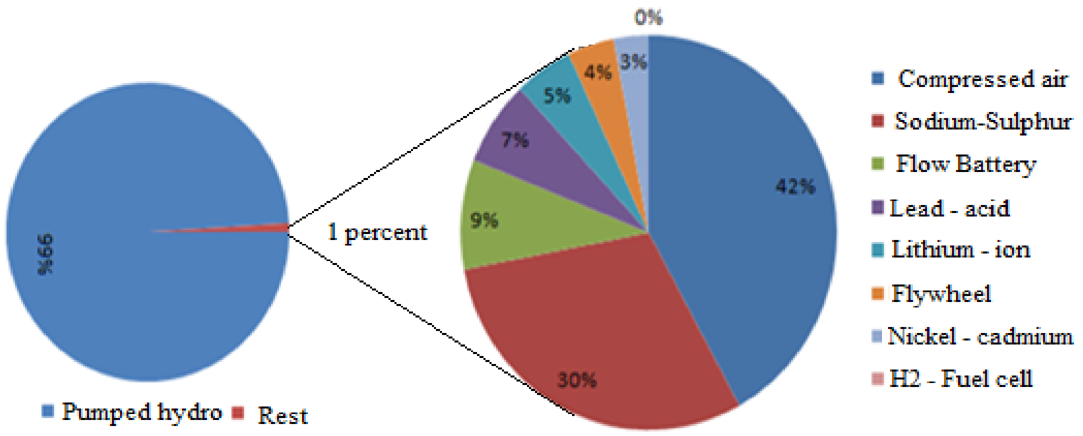

Fig. 10. Global electrical energy storage [16].

4.1 Pumped Hydro Storage (PHS) System

The system needs two water reservoirs as demonstrated in Figure 11. The water pumped during off-peak time is stored in a reservoir called upper reservoir and the water discharged during peak time is stored in the lower reservoir.

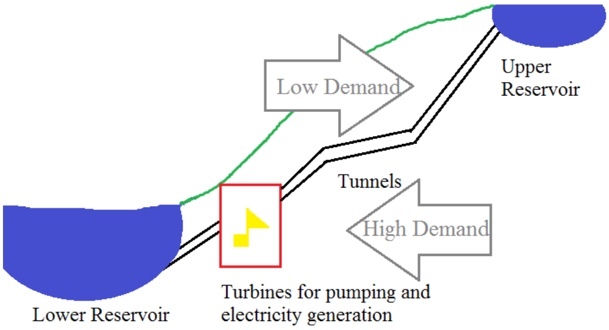

Fig. 11. Pumped storage system [29].

The stored energy computation is carried out based on the volume of the stored water and the height difference of the two reservoirs. Power rating of the unit depends upon the water pressure, rate of flow through turbine, power rating of pump/turbine and number of units of generator and motor [17]-[18].

4.1.1 Special features

- Efficiency 70-85%
- Life time >40 years

4.1.2 Applications

- Energy management purpose during time shifting like spinning reserve and supply reserve.
- Frequency control
- Supply reserve

4.1.3 Limitations

- Initial investment high
- Long construction time

4.1.4 Recent trends

- Usage of flooded mine shafts
- Usage of underground caves and oceans as basin
- Forming hybrid systems with solar and wind power generating units

4.2 Compressed Air Energy Storage (CAES) System

During low load period of power grid CAES compress air to high pressure by the use of electrical energy, and the high pressure air may be stored in scrap mine, seabed gas tank, run out oil and gas wells, new gas wells and rock cave. During high load period of power grid the air under compression is released to run steam turbine for electricity generation [17]-[18].

4.2.1 Special features

- Effective functioning during partial load conditions
- Fast change of mode from generation to compression
- Lengthy storage period
- Low principal investment
- Efficiency of 70-89%
- Rating 50-300 MW

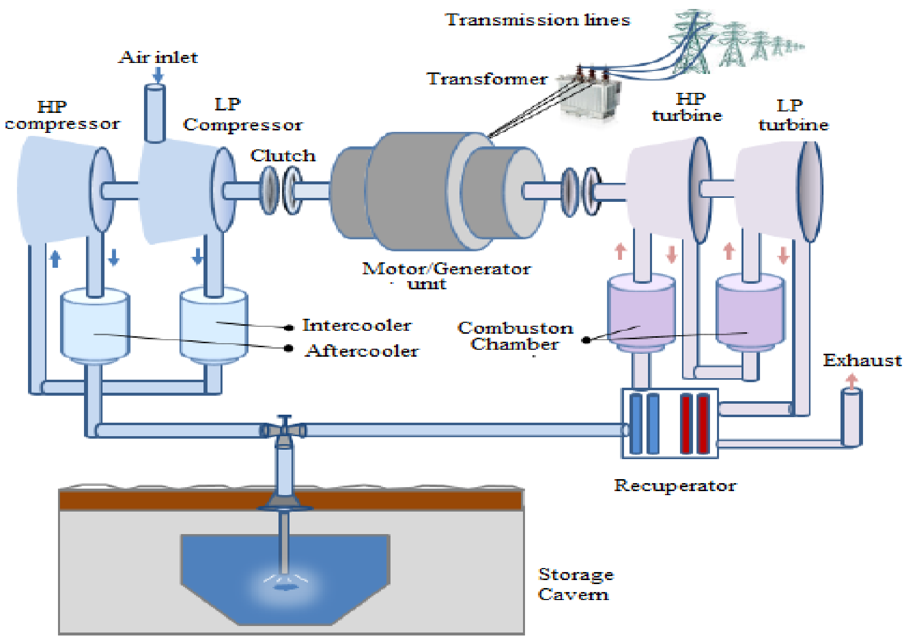

Fig. 12. Compressed air storage system [16].

4.2.2 Applications

- To top up power grids at the time of peak load
- During power outage can be utilized as backup supply

4.2.3 Limitations

- In depleted gas reservoirs the gas residues, water and oxide gases may make disturbances in the erecting surface.
- In rock caves the pressure drop may occur due to the oxygen loss, microbial growth and reservoir permeability reduction.
- Fuel is necessary for combustion process which in turn increases the cost of operation and emission of greenhouse gases.

4.3 Flywheel Energy Storage (FES) System

In this system the storage of kinetic energy is carried out by a rotating mass and hence called as mechanical battery. The renewable energy or off peak load electricity is used to rotate the rotor mounted in an empty cylinder at excessive speed and store the energy as rotational energy as in Figure 13. During energy storage the rotating device performs the work of a motor and during discharging of energy it functions as a generator [19]-[20].

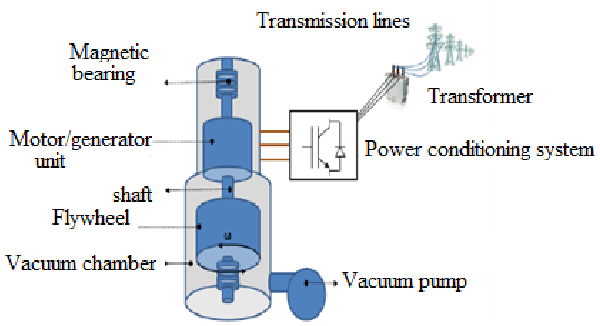

Fig. 13. Flywheel storage system [16].

4.3.1 Special features

- Less maintenance
- High reliability
- High efficiency (>85%)
- Long life time (420 years)

4.3.2 Applications

- Swapping between medium and large power (KW to MW) for short duration in seconds
- Railway power systems
- Power frequency regulation
- Renewable energy systems power quality progress

4.3.3 Limitations

- High cost of acquisition
- Less storage capacity
- Fast rate of discharge

4.4 Capacitor and Super Capacitor Energy Storage (SCES) System

A capacitor is formed by two electrodes separated by dielectric material (ceramic, glass or plastic). When voltage is applied between electrodes, energy storage occurs in the electrostatic field. Capacitors are fast charging devices. Super capacitors have two electrodes with carbon surfaces as shown in Figure 14.

A porous membrane separates the electrodes, and performs the function of an electronic insulator as well as ionic conductor. The capacitance value depends on the effective area of electrodes (A), distance (d) between the electrodes and the dielectric constant of the electrolyte (ε).

Super capacitors capacitance will be 100-1000 greater than capacitors ($C = \varepsilon A/d$) capacitance. The energy stored is given by $E = .5CV^2$, is 1V for aqueous and 3V for organic electrolyte [20].

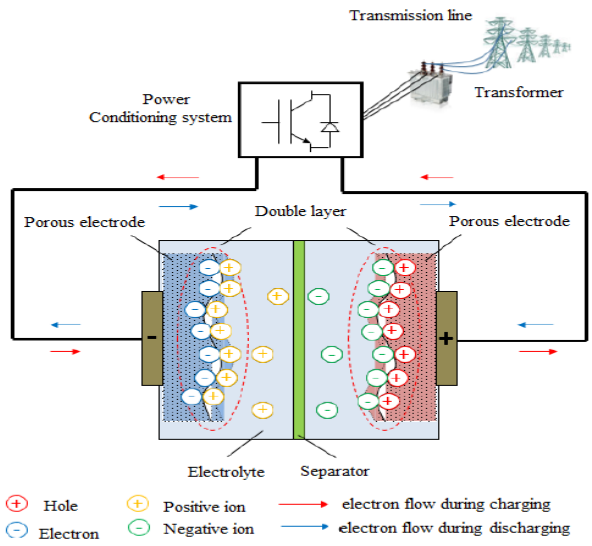

Fig. 14. Super capacitor storage device [16].

4.4.1 Special features

- High efficiency
- High life cycle
- Low environmental effects

4.4.2 Limitations

- Capacitors have low energy density
- Self-discharge rate is high

4.4.3 Applications

- Used in places where short-time and high-power fast discharge is needed
- For the storage of regenerative braking energy in transport sector

4.5 Superconducting Magnetic Energy Storage (SMES) Systems

In SMES electrical energy is stored by the passage direct electric current through coil (inductor) fabricated using superconducting material as in Figure 15.

The current circulates in the coil indefinitely causing zero loss. Since SMES contains inductor energy can be stored in its magnetic field also. The inductor acts as superconductor by keeping it immersed in helium liquid kept in a vacuum-insulated cryostat. Niobium-titanium is used as conductor and the coolant may be liquid helium (4.2 K) or super fluid helium (1.8 K). The three major units of SMES are superconducting unit, cryogenic unit and a unit of power conversion. Considering coil inductance as L and the flow of current through the coil as I, the energy (E) stored in the coil is $.5LI^2$ [19]-[20].

4.5.1 Special features

- High efficiency (> 97%)
- Fast response (few milliseconds)
- High life cycle

4.5.2 Limitations

- Storage time is short
- The rate of discharge determines the output of the system.

4.6 Thermal Energy Storage (TES) Systems

TES utilizes materials that can be kept at high or low temperatures in shielded containments. Energy recovered (from hot or chill condition) is utilized for generation of power. For storage, required energy is supplied either by heating or cooling process as input. If the operating temperature is lower than the room temperature then the TES is called as low temperature TES. If the operating temperature is higher than the room temperature then the TES is called as high temperature TES.

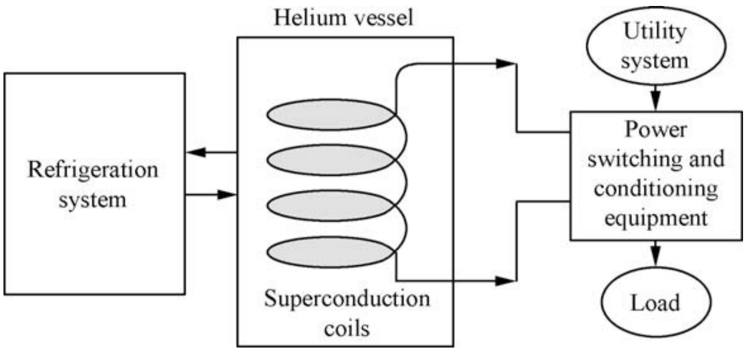

Fig. 15. SMES system [20].

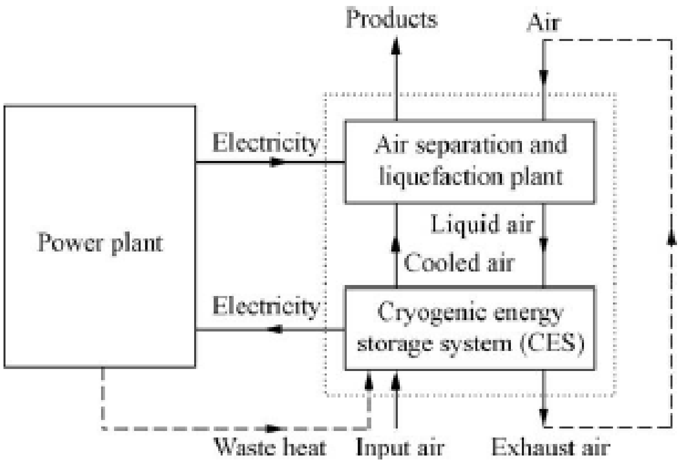

Fig. 16. CES TES system [20].

4.6.1 Low temperature TES

Aquifer low temperature thermal energy storage TES (AL-TES): At the time of off peak load, water is cooled to refrigerating temperature and at the time of peak load the stored energy is utilized. The energy storage is based on the temperature difference between the cold water in the storage tank and the hot water coming out of the heat exchange unit. This TES is useful for cooling commercial and industrial buildings during peak time.

Cryogenic TES: Cryogen (nitrogen or air in liquid form) is produced during off-peak time or from alternate energy source. During peak time cryogen is heated by the heat from the surroundings and used for power generation using cryogenic heat engines. CES have good energy density, low capital cost and environmental friendly [20].

4.6.2 High temperature TES

Molten salt storage and room temperature ionic liquids (RTILS): RTILs use natural salts at a relevant temperature range and melting temperature of 25°C where pressure is immaterial.

Concrete storage: This method makes use of concrete or ceramics for storing energy at high temperature for parabolic trough collectors utilizing man made oil as heat transfer agent [14]. Thermal energy storage units are employed for cooling purposes in industries (< 18°C) and buildings (at 0-12°C). For heating purposes in buildings (at 25-50°C) and industries storage (> 175°C) [21].

4.7 Chemical Energy Storage

4.7.1 Hydrogen energy storage (HES) system

A HES system is constituted by a fuel cell, a storage tank for hydrogen and an electrolyzing unit. The electrolyzing unit converts water into hydrogen and oxygen by the usage of electricity by electrochemical process. For power generation both hydrogen and oxygen flow into the fuel cell, where both the gases react leading to water formation, the heat discharge during the reaction produces electricity.

4.7.2 Synthetic Natural Gas (SNG)

It is also called as methane synthesis. It is another form of chemical storage of electricity. Following the splitting of water by an electrolyzing unit, hydrogen, carbon dioxide and methane are allowed to react in a methane reactor. Then SNG produced is stored in pressure tanks or send to gas grid. The SNG units are suitable for places where CO_2 and surplus electric energy are available [14].

4.8 Battery Energy Storage (BES) System

The battery is formed by single or more electrochemical cells. Every cell in the battery includes a liquid or solid electrolyte, a positive electrode (anode) and a negative electrode (cathode) [20].

All secondary batteries and flow batteries store electrical energy in chemical form. Cells can be arranged in series or in parallel to get the voltage or power rating as needed for storage system.

4.8.1 Types of batteries

Lead acid battery: It consists of lead anode, lead dioxide cathode and aqueous sulphuric acid as an electrolyte.

Nickel-cadmium battery: It consists of Cadmium hydroxide anode, nickel hydroxide cathode with a separator and soluble electrolyte.

Sodium sulphur battery: It consists of fluid sodium anode, fluid sulphur cathode and ceramic electrolyte.

Redox flow battery: A rechargeable battery having two electrolytes each with a Redox couple. Energy expansion can be done by increasing the quantity of electrolyte and power increase can be done by the increase of cell dimensions [16]-[19]. The BES structure is described in Figure 17. Comparison of different batteries performance is listed out in Table 3.

Lithium-ion battery: It consists of carbon anode, lithium cathode and lithium salt electrolyte.

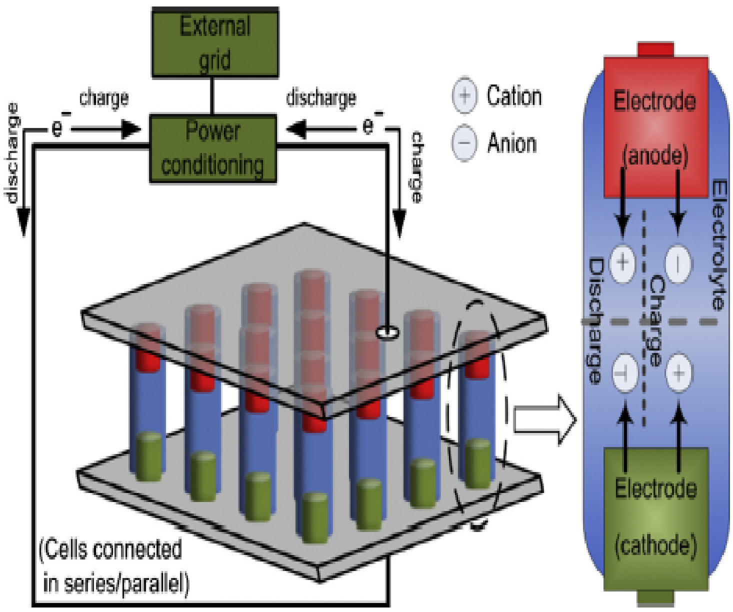

Fig. 17. BES system [15].

Table 3. Comparison of batteries performance [23].

Device	Merits	Drawbacks
Lead-acid battery	Cheap, trouble free replacement, easy availability in the market, suitable for upgrading the quality of power and uninterruptible power supply applications	Requires high maintenance, short cycling capability, less power and energy density, charging is slow, ratio of energy to power is less, noxious components
Sodium - Sulphur	High power and energy density, cheaper source for power quality improvement and peak saving purpose	Needs heat source, costly
Nickel- Cadmium	moderate energy density, cycling capacity is low, good mechanical resistance, less maintenance, best for power tools, emergency lighting, generator start , telecom and handy devices	costly, toxic, memory effect
Lithium-Ion	Moderate power density, 100% efficient, good cycling capacity, fast response during charging and discharging actions	Significant expense, debases at high temperature
Vanadium Redox Battery	High round trip efficiency (RTE), suitable for upgrading the quality of power and uninterruptible power supply applications, incorporation of renewable sources	
Redox Flow battery	Density of power and energy in this device is reasonably good, can be used for large scale requirements	Cost is high, standardizing is intricate

4.9 Fuel Cell (FC)

It is an electrochemical energy conversion device in which electrical energy is produced from the supply of fuel from anode side and oxidant from cathode side as shown in Figure 18.

The reaction between the fuel and oxidant occurs in the presence of electrolyte. The reactants flood inside and the product of the reaction flood out and the electrolyte stay in the cell. Fuel cell operates continuously till the supply of fuel and oxidant is stopped [22]-[26].

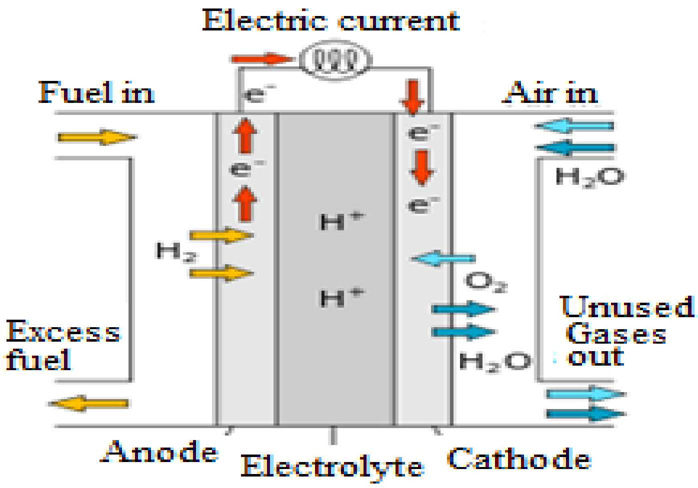

Fig. 18. Basic structure of fuel cell system [28].

Table 4. Fuel cell specifications.

Fuel cell	Fuel	Oxidant	Cell Voltage in V
Alkaline fuel cell	Pure H2	O2 in atmosphere	1.0
Phosphoric acid fuel cell	Pure H2	O2 in atmosphere	1.1
Solid oxide fuel cell	H2, CO, CH4	O2 in atmosphere	0.8 – 1.0
Molten carbonate fuel cell	H2, CO, CH4	O2 in atmosphere	0.7 – 1.0
Proton exchange membrane fuel cell	Pure H2	O2 in atmosphere	1.1
Direct methanol fuel cell	CH4OH	O2 in atmosphere	0.2 – 0.4

5. STORAGE DEVICES USED IN BANGLADESH

In order to provide continous power supply from renewable power generation system storage devices are used. In Bangladesh storage batteries are used along with home solar energy units and in wind turbines. In Banglaesh, lead acid batteries are used as energy storage devices for energy generated from renewable energy sources. For industrial applications either tubular plate type or flat plate type batteries are used.

The robustness of tubular plate batteires make its utlization higher than flat type batteries. Local manufacturer's contribution plays a major part in the fabrication of tubular plate batteries. The companies taking part in battery fabrication are Rahimafrooz, Rimso, Hamko, Navana, Pannaand, and few others and their share in fabrication are cleary plotted in Figure 19. However, 70% of the raw materials are imported [27-29].

Rahimafrooz batteries limited (RBL) is the biggest battery manufacturer of Bangladesh manufacturing around 300 types of quality batteries for industries and automotive purposes by having technical association with Lucas batteries of UK, Hawker batteries, Invensys and Hawker batteries, Eltek batteries of Norway and AEES of France [27].

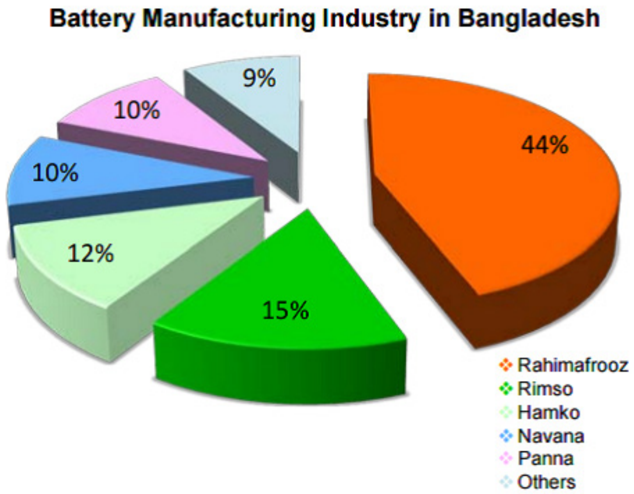

Fig. 19. Battery manufacturing industry in Bangladesh [27].

6. CONCLUSION

This paper briefly discussed the installed capacity for power generation from various sources in Bangladesh. In response to global warming and depleting fossil fuel sources renewable energy penetration need to increase in installed capacity. To overcome intermittency in various renewable energy resource based energy supply systems storage devices can play very important role. The need for renewable energy sources and the types of widely used renewable sources in Bangladesh were analyzed. The need for storage devices and the types of storage devices along with their pros and cons were explained. Finally, the storage device widely used in Bangladesh and the leading manufactures' are listed. The paper provides information on wide range of options for storage technology which can help in taking decision towards diversifying current storage practices in Bangladesh.

REFERENCES

[1] Rahman R., 2019. Impact of global warming: perspective of Bangladesh. *International Journal of Scientific Research and Engineering Development* 2(3): 906-911.

[2] Zhang W., Qiu M., and Lai X., 2008. Energy storage technology in power system (J). *Power System Technology* 32(7): 1-9.

[3] Bangladesh Power Development Board, 2017-2018. *Annual Report*. Retrieved August 21, 2020 from the World Wide Web: http://www.bpdb.gov.bd/bpdb_new/resourcefile/annualreports/annualreport_1542104191_Annual_Report_2017-18_2.pdf.

[4] Hydrocarbon Unit, Energy and Mineral resource Division, Ministry of Power, Energy and Mineral Resources, 2019. Energy Scenario in Bangladesh 2017-18. Retrieved August 15, 2020 from the World Wide Web: http://hcu.portal.gov.bd/sites/default/files/files/hcu.portal.gov.bd/publications/1eb522c0_8f5f_4f34_b133_d617b3d5c9ef/2020-01-15-11-06-d59870a995b815 3dcc5d88fdf19318c.pdf.

[5] Masud M.H., Nuruzzaman Md., Ahamed R., Ananno A.A., and Amanullah Tomal A.N.M., 2019. Renewable energy in Bangladesh: current situation and future prospect. *International Journal of Sustainable Energy*: 1- 44.

[6] Elahi F. and N.I. Khan. 2015. A study on the effects of global warming in Bangladesh. *International Journal of Environmental Monitoring and Analysis* 3(3): 118-121.

[7] Review S., 2009. The Economics of Climate Change. Retrieved January 6, 2019 from the World Wide Web: http://mudancasclimaticas.cptec.inpe.br/~rmclima/pdfs/destaques/sternreview_report_complete.pdf

[8] Karim M.E., Karim R., Islam M.T., Muhammad-Sukki F., Bani N.A. and Muhtazaruddin M.N., 2019. Renewable energy for sustainable growth and development: an evaluation of law and policy of Bangladesh. *Sustainability*: 1-30.

[9] Uddin M.N., Rahman M.A., Mofijur M., Taweekun J., Techato K. and Rasul M.G., 2018. Renewable energy in Bangladesh: status and prospects. *Energy Procedia*: 655-660.

[10] Islam S., and M.Z.R. Khan. 2016. A review of energy sector of Bangladesh. *Energy Procedia*: 611-18.

[11] Sharif S.I., Anik M.A.R., Al-Amin M., and Siddique M.A.B., 2018. The prospect of renewable energy resources in Bangladesh: a study to achieve the national power demand. *Energy and Power* 8(1): 1- 6.

[12] Energypedia. 2019. *Bangladesh Energy Situation*. Retrieved September 16, 2020 from the World Wide Web: https://energypedia.info/wiki/Bangladesh_Energy_Situation#Biogas

[13] Farhadi M. and M. Osasama. 2016. Energy storage technologies for high-power applications. *IEEE Transactions on Industry Applications* 52(3): 1953 – 1961.

[14] Rohit A.K., Devi K.P., and Rangnekar S., 2017. An overview of energy storage and its importance in Indian renewable energy sector-Part-I Technologies and Comparison. *Journal of Energy Storage*: 10-23.

[15] Luo X., Wang J., Dooner M., and Clarke J., 2015. Overview of current development in electrical energy storage technologies and the application potential in power system operation. *Energy*: 511-536.

[16] Nikolaidis P. and A. Pollikkas. 2017. A comparative review of electrical energy storage systems for better sustainability. *Journal of Power Technologies*: 220-245.

[17] Mallick K., Sengupta A., Das S., and Chattaraj S., 2016. Modern mechanical energy storage systems and technologies. *International Journal of Engineering Research and Technology*: 727-730.

[18] Elliman R., Gould C., and Al-Tai M., 2015. Review of current and future electrical energy storage devices. In *Proceedings of the 50th International Universities Power Engineering Conference (UPEC),* United Kingdom.

[19] Lazarewicz M.L. and A. Rojas. 2003. Flywheel-based recycling of electrical energy for grid frequency regulation. In *Proceedings of 2003 Conference of Electrical Energy Storage Applications and Technologies (EESAT)*, USA.

[20] Chen H., Cong T.N., Yang W., Tan C., Li Y., and Ding Y., 2009. Progress in electrical energy storage system: a critical review. *Progress in Natural Science*: 291-312.

[21] Amrouche S.O., Rekioua D., and Redkioua T., 2015. Overview of energy storage in renewable energy systems. *In the Proceedings of 3rd International Renewable and Sustainable Energy Conference (IRSEC).*

[22] Nadeem F., Hussain S.M.S., Tiwari P.K., Goswami A.K., and Ustun T.S., 2018. Comparative review of energy storage systems, their roles and impacts on future power systems. *IEEE Access* 7: 4555 – 4585.

[23] Akinyele D., Belikov J., and Levron Y., 2017. Battery storage technologies for electrical applications: impact in stand-alone photovoltaic systems. *Energies*: 1-39.

[24] Ratniyomchai T., Hillmansen S., and Tricoli P., 2013. Recent developments and applications of energy storage devices in electrified railways. *IET Electrical Systems in Transportation* 4(1): 9-20.

[25] Vazquez S., Lukic S., Galvan E., Franquelo L.G., Carrasco J.M., and Leon J.I., 2011. Recent advances on energy storage systems. In Proceedings of *IECON 2011 - 37th Annual Conference of the IEEE Industrial Electronics Society,* Melbourne, Australia.

[26] SAARC Energy Center, 2016. Study on the potential for energy storage technologies (ESTES) in the electricity sector of SAARC member states. Retrieved January 2, 2019 from the World Wide Web: https://www.saarcenergy.org/wp-ontent/uploads/2018/05/ESTES-Study-Report-SEC-PRG-91-2016-PETREN-FY-2016-IM.pdf

[27] Biswas M.M., Das K.K., Baqee I.A., Said M.A.H., and Farhad H.M.S., 2011. Prospects of renewable energy and energy storage systems in Bangladesh and developing economics. *Global Journal of Researches in Engineering: J General Engineering* 11(5): 23-31.

[28] Jayashree S. and K. Malarvizhi. 2018. An overview of electrical energy storage technologies in microgrid Applications: performance perspective, *International Journal of Pure and Applied Mathematics*, 118(20): 733-743.

[29] Boysen A., 2010. Pumped Storage Hydroelectricity. *Physics 240 Coursework Submission*. Stanford University, Fall 2010. Retrieved January 2, 2019 from the World Wide Web: http://large.stanford.edu/courses/2010/ph240/boysen2/.