Indian Journal of Pure & Applied Physics
Vol. 59, November 2021, pp. 779-784

Energy Requirement, Resources and Future Management: A Review

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Received 5 April 2021; accepted 5 October 2021

This review paper investigates an up-to-date assessment and projection of the non-renewable energy sources (fossil and fissile energy sources) and renewable energy sources (RESs) and their various aspects. A concise analysis of the present status and future prospects of both the fossil energy sources (coal, natural gas and oil) and RESs is discussed. Furthermore, a concise analysis of the fossil fuels measured reserves and consumption for both global and Indian scenario are discussed. Problematic aspects of the non-renewable energy sources like adverse environmental impact, supply interruption fear and energy transition pathways are presented. A detailed summary of the RESs annual potential and a comparative analysis between fossil and RESs regarding carbon dioxide (CO_2) emission are presented and the main barriers and remedial approaches in adaptation of RESs are portrayed.

Keywords: Energy, Energy potential, Fossil sources, Renewable energy sources

1 Introduction

Energy is essential and mandatory for industrial and budgetary development[1]. Electrical energy influences entire facets of our life. It can be described as a main component in the augmentation course of all the countries across the world[2]. Energy requirement, availability and effective utilization of energy resources and their consumption is an indication of any nation's economical and sustainable growth[3]. In this regard per capita utilization of electrical energy is a prime parameter to calculate or to demonstrate the slope of economic growth of any country. Economic expansion rate varies linearly with per capita energy utilization. The developed countries across the globe have very high per capita electrical energy utilization, consequently these countries have accelerated economic expansion rate[4-6].

There is a conclusive relationship among energy generation/utilization and economic prosperity[7]. Studies shows that per capita electricity consumption is highest in the developed countries, moderate in the developing countries and lowest consumption in the poor countries. Energy demand is increasing remarkably across the world due to increase in population, rapid industrialization, urbanization and scientific development[8]. Global population is estimated to be two times by the end of this century[9-10]. So naturally to mitigate the growing demand of energy, researchers worldwide are focusing more and more on energy resources conservation methods, innovative technologies and new sustainable sources for power generation.

2 Energy Resources and Future management

Energy resources are mainly divided in two categories: non-renewable and renewable energy resources (RESs)[11].

2.1 Non-renewable/Fossil energy sources

Global non-renewable energy resources include fossil energy sources (coal, oil, natural gas) and fissile energy sources (nuclear fuels like uranium, thorium and plutonium). Due to the geographical diversity, non-renewable energy sources are unevenly distributed among different regions around the world. Oil and natural gas reserves are mainly found in Russian federation, USA, and in the Middle eastern countries. Coal is one of the main and plenteous source of non-renewable energy, with a net amount transcend 10^2 trillion tons. The restorable chunk of natural gas and oil is estimated to be 4.71×10^{14} m^3 and 4.878×10^{11} t, respectively around the world[12-15]. Table 1 and Table 2 present the measured reserves of fossil energy resources by using R/P ratio (reserve to production ratio), which is the resting flock of fossil

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Table 1 — Fossil fuels measured reserves and consumption globally.

S. No.	Fossil fuel type	Measured reserve	Lifetime (years)	Consumption (TWh)
1	Coal	10^2 trillion tons[12-15]	153.0[17,19]	43849[17]
2	Natural gas	4.71×10^{14} m^3[12-15]	52.5[17,19]	39292[18]
3	Oil	4.878×10^{11} t[12-15]	50.6[17,19]	53620[18]

Table 2 — Fossil fuels measured reserves and consumption in India.

S. No.	Fossil fuel type	Measured reserve	Consumption (TWh)
1	Coal	105.93 billion tons[16,19]	5172[16,18]
2	Natural gas	1.29×10^{12} m^3[16]	597[16]
3	Oil	4.48 billion barrels[16,18]	2844[16,18]

energy sources measured in time or usually in years. Globally, oil is a leading fuel source with 53620 TWh consumption and then coal having 43849 TWh and natural gas with 39292 TWh consumption, respectively. From Table 2 which is specifically focused on India's fossil fuels measured reserves and consumption, it is concluded that coal is leading and extensively used fossil fuel and natural gas is least used fuel among fossil sources[16-19].

2.1.1 Non-renewable energy consumption and their prospect

During last few decades to meet up the growing demand, non-renewable energy consumption percentage has increased many times and we see that consumption of oil and natural gas is increased and coal consumption decreased in comparison with their counterparts[20-22]. These resources are finite in nature and will get exhausted in the next few centuries. Approximately 80 percent of the primary energy consumption in the world is shared by fossil fuels, and major portion nearly 58 percent of it is used in transportation and are depleting speedily[23]. Non-renewable energy resources especially fossil energy sources have proven to be exceptionally efficient drivers of economic growth but at the same time they possess serious environmental pollution problems[24].

2.1.2 Non-renewable energy sources problematic aspects

(a) Environmental impact

Today, there are a lot of issues regarding climate change associated with the use of non-renewable energy sources[25]. The main problem with non-renewables is that they can produce abundant greenhouse gases in atmosphere[26]. Increasing carbon emission and other harmful pollutants like sulfates and short-lived climate forcing pollutants (methane, tropospheric ozone and fluorinated gases) cause air pollution, water pollution and ozone depletion. All these factors are cumulatively responsible for adverse climatic conditions which ultimately lead to global warming[27-30].

(b) Supply interruption fear

One more problematic aspect with non-renewable sources is their drooping nature and fear of interruption of fossil reserve (oil, natural gas and coal) supply due to geopolitical instability. Actually, these reserves are unevenly distributed across the world and many countries dependent upon imported fossil energy sources. As it was happened earlier in 1973 and causes oil embargo/shock, resultantly the cost of oil had sweep upward sharply[31-33]. Thus, diminishing nature of non-renewable energy sources has compelled researchers to look for alternative/ renewable energy sources which are environment friendly and those continually refill by natural course of action[34]. The aggregate impact of these happenings (price hike due to oil crisis, and energy security risks due to discontinue supply of fossil energy sources) was that all countries started looking towards the transition from non-renewable energy sources to RESs[35].

2.1.3 Energy transition pathways (Non-renewable energy sources to renewable energy sources)

Serious climatic problems are a consequence arising from utilization of the non-renewable energy sources especially combustion of the fossil energy sources. Environmental pollution and adverse climatic conditions are the main force for energy transition globally. A major portion almost two-thirds of greenhouse gases discharge is caused by non-renewable energy use[36-38]. It is the need of the hour to tackle these climatic adversities which are caused by fossil energy sources. With the help of RESs it is feasible to achieve clean and green energy, improved air quality concurrently while avert adverse environmental change[39]. Omnipresent resources, adaptable and innovative technology, affordable economics and important social advantages make inroads for such a transition[40]. Such energy transitions are progressed through government's public policy interventions like community renewable energy[41].

2.2 Renewable energy sources (RESs)

The adversities and shortcomings of non-renewable sources like global warming and depleting fossil fuel

reserves are effectively addressed by RESs[42]. Studies shows that with this potential RESs are becoming popular and gaining importance among general public and experts since last few decades[43]. The RESs are infinite in nature and naturally replenished. However, RESs are the exceptional substitute to the increasing challenges[44]. Renewable energy is obtained from renewable sources which are inexhaustible and is derived from the sun (directly or indirectly) or from other natural phenomenon prevalent in the environment that is available in abundance and is restored over and over by the nature[45-46]. There are a lot of advantages from the renewable energy sources that are mainly categorized into three types; greenhouse gas emission (GHG) reduction and environmental pollution reduction, energy security and enhanced economic activities[47]. It is available in different forms like solar energy, wind energy, biomass energy, geothermal energy, tidal energy and hydro energy. RESs have so much diverse in nature and their abundant availability makes them effective to encounter energy crisis[48-52]. RESs provides clean energy and are very important because they are nature friendly[53-55]. Renewables have the capability to replace fossil sources and to full fill the current and future global energy needs satisfactorily while they are used in an integrated manner[56-58]. Table 3 shows the annual potential of individual RESs. Annually, gross primary energy supply is approximately 1.6×10^{11} MWh across the world. Compared with the annual potential of the RESs given in the Table 3, it is only a small fraction. Harnessing even a small segment of these RESs would be capable enough to meet out the world's total energy demand[59].

2.2.1 Renewable energy sources various aspects

The main problem with fossil fuels is environmental pollution, greenhouse gas emission and other pollutants emission. So, in this way we see that clean and green energy is not achieved by using fossil fuels. RESs have the capability to generate clean and green energy with almost negligible emission of GHGs, carbon dioxide, and other harmful air pollutants[60-63]. Table 4 presents the carbon dioxide discharge rate during energy generation by using renewable and fossil sources. Fossil sources discharge CO_2 many more times than RESs[64].

The crucial issues of remote areas (mountainous and desert regions) like energy requirement fulfillment and sustainable development are successfully met up by RESs with proper environmental protection[65-66].

Table 3 — Renewable energy sources predicted annual potential[59].

S.No.	Renewable energy sources type	Annual potential[59] (MWh)
1	Biomass	4.5×10^{12}
2	Tidal	25×10^{9}
3	Geothermal	300×10^{9}
4	H_2O cycle (hydro, wave and wind)	360×10^{12}
5	Solar	700×10^{12}

3 Renewable Energies

As outlined earlier, the RESs have the capability to solve current and future global energy issues. Various forms of the renewable energy present in the nature are briefed below.

3.1 Solar energy

Solar energy is the main and leading RES and it possesses the immense capability to satisfactorily meet out the global energy demand[67]. Solar energy is available in ample amount across the world both in direct and indirect forms. The sun radiates energy at a rate of 3.8×10^{17} GW, of which nearly 1.8×10^{8} GW is received by earth[68-69]. It is estimated that global energy demand will increase to 1000 EJ (1 EJ = 10^{18} J) by mid of 21st century[70]. The advancement in new solar energy techniques is helpful in two ways: to mitigate the rising energy demand and to reduce the carbon emission[71].

3.2 Wind energy

Along with solar energy, wind energy is also a main RES and currently it shares a biggest portion in renewable energy generation. The wind energy is ubiquitous, nature friendly and available free of cost[72]. Likewise, the solar energy, it is also extensively dispersed and also derived indirectly from the solar energy. A wind energy system uses wind turbine for electricity generation. It converts kinetic

Table 4 — Comparative analysis between fossil and RESs regarding carbon dioxide (CO_2) emission[64].

S.No.	Energy source type	Energy generation mode	Carbon dioxide emission rate[64] (gCO_2/kWh)
1	Fossil	Coal	975.2
2		Oil	742.1
3		Natural gas	607.6
4	RESs	Nuclear fuel	24.2
5		Hydro power	11.3
6		Solar	53.4
7		Wind	29.5
8		Geothermal	15.0

energy of wind into mechanical power and further converts it to electrical power with the help of generator[73-74]. It is one of the fastest growing field in renewable sources with the advent of highly efficient and diverse wind turbines[75-76]. Currently wind power dominates over all renewables because it is a clean source of power generation and emits no toxic pollutants and easily available in some specific geographical locations like coastal areas, deserts, etc. All these factors contribute in exponential growth of wind powers installed capacity[77-78].

3.3 Biomass energy

Biomass is an effective primary source of power generation in poor or developing countries. It has been used since ancient times especially in household purposes[79-80]. The changeover of biomass (all biological materials emanating from trees and plants) is facilitated by bio-chemical and thermo-chemical conversion processes into suitable forms of energy like biofuels, heat and electricity is called as biomass energy[81-82]. Globally, total installed capacity of biomass plants was 76 GW in 2012. With 5 percent annual growth rate it is expected that, this will grow from 76 GW in 2012 to nearly 300 GW in 2030[83].

RESs supply a considerable amount of global energy demand. Apart from solar, wind and biomass energy there are also some important RESs like geothermal, hydro power, tidal and marine energy. All these are capable to meet our present energy demand if they are harnessed in a well and efficient manner. They find great importance and applications in both conventional power generation and in domestic applications especially in remote and rural areas[84-85]. Table 5 shows various applications of RESs and their future potential by 2040[86-87].

4 Renewable Energy Sources Prospects: Challenges, Barriers and Remedial Approaches in Adaptation of RESs

There are some problems in the adaptation of RESs. While acknowledging the constraints of non-renewable energy sources, it is the need of the hour to shift focus on RESs. But in doing so, there are a lot of challenges and barriers. One of the main challenges is RESs societal acceptance. It has following three dimensions[88-90]:

(i) Socio-political acceptance of technologies by the public and main participants.
(ii) Community acceptance
(iii) Market acceptance (conviction of customers and investors).

Along with these challenges some barriers are also present and need to be cleared with proper actions. Here a throughout study of existing literature regarding RESs help in understanding these barriers and problems. Also, it investigates on the choices, perspectives and perceptions of native residents towards renewable energy projects[91]. The main barriers are limited technological knowledge, societal adaptation and economic feasibility as shown in Table 6[92-95].

Table 5 — Application and future potential of various RESs.

RESs	Applications	Future capacity in Mtoe (million tonnes of oil equivalent) by 2040
Solar energy	Thermal power generation, solar water heater, solar home system[86]	1332[87]
Wind energy	Power generation, windmills and water pumps[86]	688[87]
Biomass energy	Power generation, bio-fuels and biogas[86]	3271[87]
Geothermal energy	Power generation, hot dry rocks and urban heating[86]	493[87]
Hydro power	Power generation[86]	547[87]
Marine energy	Power generation, water desalination and water pumping[86]	20[87]

Table 6 — Barriers and remedial approaches in adaptation of RESs[92-95].

Barriers	Examples	Remedial approaches
Technological barriers	I Limited knowledge about new and innovative technologies II Limited local manufacturing of specialised equipment	1 Research development and II demonstration of new technologies
Social barriers	I Social customs II Attitudes III Ethics and Values IV Personal habits	I Alternative lifestyles II Education III Policy initiatives IV Intuitional reforms
Economic barriers	I High cost II Lack of access to credit & insufficient govt. financial support III Trade barriers IV Inadequate information	I Subsidy reforms II Micro credit III Rural electrification IV Co-operative agreements

These barriers are still a potent force and adversely affect the growth of RESs sector. The reason behind this is prevailing negative impression and lack of knowledge of renewable energy as a complicated, technical subject and an inconsistent, high-priced substitute[96]. The role of media (especially print media) which is a prime science communication tool in creating public awareness on renewables is important. Its coverage shapes public perception on renewables and further public perception can influence policy makers[97]. Research studies show that scientific advancements continually reverse these trends. The existing negative or neutral perception about RESs need to be changed. Through proper science communication tools or strategies, it is easy to influence public perceptions in a positive way towards RESs projects. When coverage of renewables increases in newspapers then public awareness, literacy level and behavior also change and this is reflected into adoption of new RESs projects[98].

5 Conclusions

In this paper, a detailed literature review about energy requirement, resources and future management has been conferred and discussed. Global population is increasing rapidly hence demand of energy requirements also increases. Due to this, there is a lot of burden on conventional energy resources. Also, there is a fear of their depletion and some serious climatic problems are caused by non-renewable energy sources like GHG emissions and other harmful pollutants emission. In this way non-renewable energy sources are not suitable for long term future. consequently, worldwide researchers have shifted their focus on alternative or RESs. Renewables have the capability to replace fossil sources and to full fill the current and future global energy needs satisfactorily with almost negligible emission of GHGs, carbon dioxide, and other harmful air pollutants. This review paper demonstrates an up-to-date present status and future prospects of various RESs. In addition, the main barriers and remedial approaches in adaptation of RESs are also discussed.

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