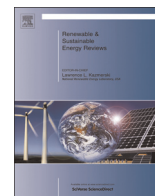




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Fuel cell technology for sustainable development in Pakistan – An over-view



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ABSTRACT

Fuel cell technology holds the combination of benefits, which are barely offered by any other energy generating technology. Because the fuel used in this technology is found in abundance in nature and can also be renewed/sustained. Pakistan is blessed with renewable energy resources which are suitable for fuel cell technology. Therefore, fuel cell technology offers a great opportunity to meet the demand of energy and for the sustainable development of Pakistan. The energy research group at COMSATS Institute of Information Technology (CIIT), Lahore has made efforts to study the technical aspects of fuel cell technology and its commercial benefits. The research group is interested in finding ways and means of generating and storing the energy produced by using fuel cells. In this paper, the research activities on fuel cell technology in Pakistan have been reviewed and it is also discussed how this technology can resolve the current energy crises in Pakistan and can be the source of sustainable energy. It has been also reviewed that the country would greatly benefit from fuel cells and fuel cell hybrid system (environmental friendly technology), which could be the best solution for electricity production as well for automobile industry.

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1. Introduction

The world is gradually moving towards serious power crises due to increase in the demand of energy [1]. Currently, Pakistan is facing worst energy crisis due to its growing population and poor

future planning of energy based infrastructure [2,3]. Pakistan is basically an agricultural country with five major rivers flowing all the year across the country starting from the north with several inter-river linked canals and many seasonal canals based on monsoon rainfall [4]. These rivers and link canals offer several

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locations where run-of-water power plants and water-reservoirs can be built. However, the power generation from hydel sources and construction of new water reservoirs has been ignored during last 35 years [5]. Mostly, the emphasis has been on short-term solutions by installing thermal power plants [6].

Thermal power plants use fossil fuels for power generation for which fuel is imported to Pakistan. The energy produced from the imported fuel offers a very expensive solution which a developing country like Pakistan cannot afford [7]. Power plants using nuclear energy have also been constructed but with a little capacity [8]. These thermal power plants pose a potential environmental threat which is also ignored. The principal sources of energy generation in Pakistan are oil (35.20%), hydel (29.90%), natural gas (29.00%), and nuclear and imported (5.80%) [9].

Currently, in Pakistan, the demand for energy is 17,000 MW on the average while the shortfall is 4000–5000 MW [9]. It is expected that energy demand could rise by 4–5% in the coming 10 years, which is about 1500 MW [9]. The predicted energy demand and supply in Pakistan for the years 2002–2030 are shown in Fig. 1. The reasons for this disastrous prediction are lopsided energy mix, lack of vision for utilization of indigenous fuel reserves and poor future energy planning infrastructure. Gas reserves have been depleted almost and prices of imported oils are rising expeditiously which cannot be afforded [10]. Recently, a large number of coal reservoirs have been discovered in central parts of Pakistan and continuous efforts have been made to get energy using coal [11]. The usage of fossil fuels especially the carbon in power generation is not environment friendly. On the other hand, renewable energy sources offer cheaper solution and are also environmental friendly [12,13].

Pakistan has to face challenges with proper energy planning with the use of renewable energy resources [14]. Therefore, beside focusing on such conventional energy sources, there is a need to explore non-conventional energy sources e.g., solar power, hydel power, geothermal, wind power, tidal, and biomass using fuel cell (FC) technology [15,16]. FC technology offers certain benefits which no other energy generating technology can offer [17].

In Pakistan, there are about 90 R&D organizations and 130 higher education institutes offering higher education and research [14]. However, due to certain economical factors exploration of alternative energy resources has been overlooked. The current government of Pakistan is focusing on the economic revival by promoting the R&D culture with a special priority to the energy production. To give direction to R&D in Pakistan, a National Research Agenda has been proposed. This agenda has targeted the certain key research areas including renewable energy technology

(RET) and FC technology. The major ruling party PML(N) is emphasizing on holistic science and technology strategy. In addition to the exploration of conventional power resources and nuclear energy resources, the government has shown interest in development and usage of non-conventional energy resources including wind, solar, biomass and renewable energy from FC technology. Several R&D organizations and higher education institutes have responded to the exploration of the cheap and alternative resources of energy. CIIT Lahore campus has proposed a center for FC technology and submitted a comprehensive proposal which is under approval. Beside this, many under-graduate, post-graduate and Ph.D. students have also been involved in FC related research areas e.g., materials for low temperature FC, high temperature FC, fuel flexible FC, direct carbon FC, bio FC and FC hybrid system.

The FC technology has a variety of application ranging from stationary power plants to portable energy consumption [18,19]. Internationally, different countries are focusing on FC based energy sources and FC technology is successfully launched in different countries like Sweden, UK, Japan and USA. Also, India has spent billions of dollars on fuel cell and hydrogen energy research and educational programs. In USA, FC system/stack has been developed which can be integrated with hydrocarbon fuels like gasoline and diesel etc., due its operational temperature range 500–800 °C. In FC technology different type of fuels are used e.g., air, hydrogen gas, biogas, natural gas etc. [20,21]. The abundantly found fuel in nature and variety of applications of FC technology makes it a prime candidate to provide a great revolution for the sustainable development of Pakistan. The use of FC technology must be extensively explored as it offers cheaper alternatives to conventional and expensive power sources.

In this contribution, a comprehensive overview of FC technology and its applications is proposed to advance this technology through research and development, particularly in Pakistan. This work is highly desired because of its value and utility for the general public. By starting from the basics of different types of fuel cells, the advantages and usefulness of diverse applications of FC technology has been briefly discussed. FC integrated hybrid system, FC based polygeneration systems and the potentials of different renewable energy resources in Pakistan are also presented. The status and involvement of different research institutes and higher education universities in developing FC technology in Pakistan is also discussed. At the end, certain challenges which are being faced to implement FC technology for sustainable development of Pakistan is described and several recommendations have been suggested which can help in solving these challenges.

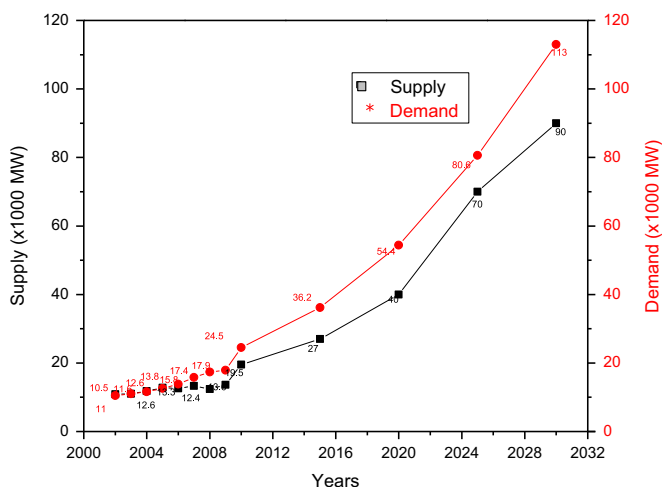


Fig. 1. Pakistan power sector need for reforms [77].

2. Vision of political entities for renewable energy technology in Pakistan

Pakistan is blessed with several renewable energy resources in abundance like wind, solar, hydel, biomass, tidal, geothermal, bio-fuels, etc [22–25]. These can be a prolific choice to not only combat the current crisis but also for fulfilling our energy needs for the -growth of industries, socio-economic and development in modern technologies [26]. In general, energy sources can be grouped as renewable sources and non-renewable sources, as shown in Fig. 2.

The shortfall of the energy has the potential to hinder the economic growth of Pakistan and, therefore, different political parties have proposed policies to solve the energy crisis. In the general election of 2013, major political parties put the solution of energy shortage as the top priority in their manifestos [27]. Pakistan Muslim League Nawaz (PML-N) which currently holds the central/federal government is interested to create Ministry of Energy by merging the Ministries of Water & Power and Petroleum

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