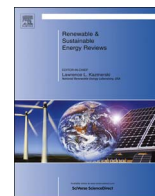




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Energy security and renewable energy policy analysis of Pakistan

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ABSTRACT

Sustainable energy supply is an important factor for continued economic growth of any society. Pakistan is among those developing countries which are facing severe shortages of energy now-a-days. The current and past governments in the country have designed various energy policies to fulfill energy demands but could not fill the demand-supply gap; there has been a shortage of about 5000 MW of electrical supply during summer 2016. A policy for development of renewable energy was framed in 2006 which was aimed to supply sustainable energy to all consumers including those households which have not been supplied electricity and natural gas in rural and far-flung areas. The policy was extended for implementation in 2011 and is still in use. The basis of this policy rests on energy security and self-sufficiency, social equity and economic benefits. This study aims at analyzing renewable energy policy of Pakistan and examining and finding the ways to secure energy supplies in future using LEAP. Four Scenarios, business-as-usual, green Pakistan, nuclear and optimization, have been developed to assess the validity of the energy plans. The study concludes that green Pakistan scenario employing renewable energy technologies, having minimum operation and externality costs, is the most suitable option in future.

1. Introduction

The demand-supply gap of Pakistan's energy sector is increasing mainly due to high population growth rate which is currently estimated around 2%, the demand is increasing while supply has shown growth at snail's pace [1]. The slow growth of energy supply is due to poor infrastructure, huge capital involved to build supply resources and delayed policies on implementation level. The demand supply gap of electricity was noted as 31.6 TW h in 2010, which resulted in 2.5% GDP loss and unemployment of more than half million workers of industrial sector [2]. The soaring demands of the country's energy sector is met by oil, natural gas, electricity, coal and LPG. The country's energy consumption was reported as 38.8 MTOE in 2010–2011 [3] which raised to 66.8 MTOE with an estimated per capita availability of energy as 0.36 TOE in 2014–2015 [4]. Energy remained as cornerstone during country's five year plans and shifting of energy-mix from cheap hydel to imported oil due to the policies of early nineties pushed the country into energy deficit situation. The government of Pakistan formulated 'Policy for development of Renewable Energy (RE) for

power generation' in 2006 [5,6] whose scope was subsequently enhanced and is still the primary planning framework in the field [7]. Presently, country's energy sector is facing worst ever shortage of its history and the people of the country bear long term electricity outages in tortuous heat of summer and natural gas shortage in cold winter. Pakistan has sizeable energy reserves but vast areas of the country are deprived of commercial energy access, hence there is a dire need to develop all form of available resources to reduce demand-supply gap [8].

2. Related work and contribution

Energy sector encounters challenges globally in relation to sustainability, environment and economics and many research studies have been conducted in this regard. A scenario-building framework based on the global business network to help energy industries to develop more resilient conservation policies subject to unpredictable and external uncertainties has been developed in [9]. The impact of energy prices on economic growth in Pakistan has been examined empirically using

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various channel variables in [10]. Qazi et al. [11] studied the future dynamics of power market of Pakistan after the structural spin-off by pre-assessment of upcoming wholesale power market. A broad overview and power sector issues of the country along with energy policies analyses and their impact on power generation sector has been presented in [12]. An approach based on new institutional economics to elucidate reasons for the failure of power sector reforms in Pakistan has been presented in [13].

Pakistan has sizeable renewable resources which are comparable with India, Bangladesh and other countries in the region [14]. The country's current energy mix, key dimensions, gap between supply and demand and potential of energy sources to meet future demand have been presented in [15,16]. An overview of energy status and development in Pakistan has been provided in [17] and the structure of electric power sector of Pakistan and a summary of historical electricity demand & supply data, current status of divergent set of energy policies as a framework for development and application of a LEAP (Long-range Energy Alternate Planning) model of electric power sector has been presented in [18]. The overall condition of the electricity supply sector as well as its potential and recent progress in the implementation of alternative energy projects in the context of the targets set in the national energy security plan (NESP) has been provided in [19]. The relationship between macroeconomic factors and renewable energy in Pakistan is given in [20] and an overview of renewable energy potential in Pakistan for continuous energy sustainability has been outlined in [21] where a survey of the availability of various renewable energy sources, including hydel, solar, wind and biomass, and their current and future penetration prospects in the total energy mix have been carried out.

The relationship between renewable energy consumption and economic growth using auto-regressive distributed lag model and rolling window approach for cointegration in context of Pakistan has been studied in [22]. Lin and Ahmad [23] attempted to analyze the energy related CO₂ emissions in Pakistan for a sample period of 1990–2014 using logarithmic mean division index method. The overall condition of the electricity sector as well as the potential and recent progress in the implementation of alternative energy projects in the context of the national energy security plan (NESP) has been examined in [24]. An overview for renewable energy potential for continuous energy sustainability has been presented in [25] and a critical analysis of the key dimensions of the crisis, that is, growing gap between demand and supply and rising energy cost and security concerns and sustainable energy options for Pakistan has been provided in [26]. There has been a lot of activities on solar energy lately and the recent exponential rise of solar energy use for power generation has been reviewed in [27]. Stephen et al. [28] attempted to create a validated solar atlas for Pakistan based on a combination of satellite data and ground measurements to support country-driven efforts to improve renewable energy resource awareness and exploitation. A review of current state of affairs in solar PV with a focus towards the technological shortcomings has been presented in [29]. Jaffery et al. [30] proposed to utilize solar energy for the development of a solar powered railway transport system in the country. The past, the present and the future of wind energy use in Pakistan has been described in [31,32] and the wind power production potential of sites in south-eastern Pakistan has been investigated in [33]. The outlooks of the country energy profile situation vis-à-vis wind energy potential characteristics of the wind corridor in the southern part of the country has been studied in [34]. Siddique and Wazir [35] reviewed the developments in the wind power sector of the country and listed suggestions that could help to improve the wind power penetration in the national energy mix. The wind speed data for three provinces has been studied in [36] with an objective of integrating wind energy with national grid.

A sizeable literature is available on energy issues of Pakistan but most of the published studies focus on single resource or consumption sector. This strategy is helpful in finding potential of resources and

contribution of individual sectors but interdependence of different energy resources and consumption factors require an integrated approach. This study focuses on an integrated energy approach; all fuels like natural gas, oil, electricity, coal and LPG are included in the analysis for demand and supply forecast which is helpful for investigation of dependence of the country on individual fuels. Long range energy alternative planning system (LEAP) is the framework used for analysis to forecast demand and supply assessing the validity of electricity generation scenarios, environmental emissions and cost of electricity production in this study. In order to get optimized capacity and output with least cost, optimization is included in the analysis. Energy demand is forecast based on previous annual compound growth rate (ACGR 2006–12). In electricity supply analysis, four scenarios; i.e., business as usual (BAU), green Pakistan (GP), nuclear and optimization scenarios have been developed to assess the validity of different parameters of cost, environment and generation.

3. Energy demand and demand forecast

The main energy consumption sectors of the country include domestic, industrial, agricultural, transport, commercial, thermal power generation and other government services. Natural gas is utilized in fertilizer manufacturing industries in two ways which are termed as 'energy' and 'non-energy' use. The formation of ammonia (NH₃) and urea (NH₂)₂CO is categorized as non-energy use and natural gas as a fuel in fertilizer manufacturing process is known as energy use. The energy and non-energy use of natural gas was noted as 0.817 MTOE and 3.157 MTOE respectively during 2011–12. Oil, natural gas, electricity and LPG have traditionally been used in domestic sector of Pakistan. Out of 28.19 million households where country's 180.7 million people reside, nearly one third were electrified by the end of 2011–12 [37]. Electricity is used in domestic sector for lighting, refrigeration and cooking. Oil, gas, electricity and coal have been traditional fuels used in industrial sector in the country. Brick kilns use 39% and cement manufacturing industry consumes 60% of coal. The road, rail, air and marine constitute country's transport network and the fuels used in these sectors during 2011–12 were aviation fuel, motor spirit, HOBC, E10, kerosene oil, high speed diesel, light diesel oil, furnace oil, electricity and natural gas. The agricultural sector consumes high speed diesel oil in tractors for which distinct data are not available but are included in overall transport sector. Light diesel oil and electricity are also in use in agriculture sector. Energy demand forecast is developed on the bases of annual compound growth rate (ACGR) which is calculated from 2006 to 2012. Use of oil and LPG in domestic sector is continuously decreasing due to an increase in use of natural gas and electricity. The other reason of this decrease is that the non-electrified households are being converted to electrified ones. In commercial sector, use of LPG is gradually decreasing whereas there is an upward trend in natural gas and electricity consumption. Fossil fuels used in thermal power generation have shown mixed trends. The use of oil in this sector is gradually increasing while natural gas and coal have shown negative consumption growth indicating their use is continuously decreasing. Table 1 provides data on energy consumed and annual compound growth rate (ACGR) of different fuels and sectors of the country.

4. Energy supply

4.1. Electricity supply

Electricity is mainly generated in Pakistan through thermal, hydel and nuclear resources. Pakistan atomic energy commission (PAEC), water and power development authority (WAPDA), independent power producers (hydel and thermal), generation companies (GENCOs) and K-Electric limited are electricity suppliers of Pakistan [38]. Most of the country supply come from thermal resources which include natural gas,

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