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Is it wise to compromise renewable energy future for the sake of expediency? An analysis of Pakistan's long-term electricity generation pathways

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A B S T R A C T

Pakistan's acute energy crisis has critically affected its already fragile economy, costing in recent years up to 4% it's of Gross Domestic Product. Political expediency in the wake of the current power crisis in Pakistan together with the current high investment costs of renewable energy technologies have shifted focus of the policy to thermal power plants in the short run to meet the deficit. This paper presents a long-term view of the current power policy and forecasts electricity demand in Pakistan in the long run congruent with anticipated strong economic growth, as envisaged in 'Pakistan Vision 2025', its medium-term development framework. Using Long Range Energy Alternatives Planning (LEAP), a bottom-up scenario modelling framework, different electricity generation scenarios are developed to meet an estimated annual requirement of 303.7 terawatt-hours (TWh) by 2035. Government policy (GP) scenario models the current economic and power policy, while Renewable Energy (REN) and Demand Side Management (DSM) scenarios provide alternative power generation pathways. These scenarios are compared based on net present cost (NPC) at different discount rates (5%, 7% and 10%). Interestingly, the REN scenario with a 35% share of solar PV and wind power turns out to be economically more viable than GP and DSM scenarios saving $26 billion and $17 billion in NPC respectively, due to sizeable savings on imported fuels. Greenhouse gas (GHG) emissions associated with all three scenarios over the study period are also estimated, whereby the RE scenario appears to save over 221 MtCO2 and 159 MtCO2 more emissions compared to GP and DSM scenarios. The results of the least cost scenario are also analysed to depict falling investment and installation costs of renewable energy technologies making them more profitable as a long run energy security option for Pakistan. Policy implications in the light of the study are discussed.

1. Introduction

In recent years, Pakistan's acute energy crisis has critically affected its already fragile economy. Electricity shortfall reaches as high as 7000 Megawatts (MW) during the peak demand period in summer, causing 8–10 h of power cuts per day. This situation has not just had a crippling effect on social life but also resulted in the closure of small scale industries and lay-offs of workers. Power shortages also took a toll on the country's overall Gross Domestic Product (GDP) which was cut by 2% in 2013 [1]. If the crisis persists, it is likely to impede Pakistan's future economic growth prospects. In 2014, the Planning Commission [2] put forward its Pakistan Vision 2025 which aims at high economic growth in the next decade and outlines the plan for socioeconomic development. The plan emphasizes the need for around 7% sustained growth to employ the youth bulge and meet sustainable development goals [3]. If the growth targets materialized, there would be high demand for energy in general and electricity in particular [4]. The economy has witnessed 9.5% growth in electricity demand in the past during a period of high economic growth averaging 6.6% from 2004 to 2008.[1] Increase in electricity demand ensuing from high economic growth was not anticipated and electricity generation capability remained almost stagnant.

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[1] Source: Ministry of Finance, Pakistan and National Electric Power Regulatory Authority (NEPRA).

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Wide-ranging structural problems notwithstanding, the roots of the crisis could be traced back to the power policy of 1994 which significantly altered the electricity mix in subsequent years by providing incentives to oil based thermal power plants [5]. In the 1980s, hydroelectricity contributed 60% of total power generation which gradually dropped to 34% by the year 2015, while the share of fossil fuel based thermal power generation rose to 61% [6,7]. The oil price boom of 2007–08 rendered Pakistan's power mix unaffordable for the populace. Successive governments did not pass on the high cost of electricity to consumers and provided the differential as subsidies, which in 2014 amounted to $2.9 billion [8]. Tariff and subsidy related issues and poor revenue collection by power distribution companies disrupted cash flow in the supply chain and piled up debt between various entities, including generation and distribution companies, fuel suppliers and refineries referred to as 'Circular debt' [9]. The liquidity constraints forced power generation companies to operate below capacity, thus exacerbating the power cuts inflicted by the already inadequate installed capacity. Although circular debt is a governance problem, excessive reliance on imported fuel with high price volatility lead to a worsening of the problem in the existing subsidy regime. Despite payment of circular debt amounting to $4.8 billion in 2013 by the Ministry of Finance [10], it rose again to around $3 billion due to persistence of structural bottlenecks and a high cost power mix [11]. The task of meeting the current deficits and future needs of the economy is indeed daunting. Policy inaction on planning capacity expansion and diversification of the power mix would take a heavy toll on the economy. The electricity demand forecast based on Vision 2025 which aims at diversified, cost effective and sustainable future power supply scenarios is thus critical from academic and policy perspectives.

This study is aimed at analyzing the long-term electricity demand for Pakistan's economy as envisaged in Pakistan Vision 2025 fomented by high economic growth. The disaggregated electricity demand at sector and subsector level is forecast using the Long Range Energy Alternatives Planning modelling (LEAP) tool [12]. LEAP has been widely used for scenario based modelling due to its flexibility in determination of the level of detail in energy system analysis and data requirements. Its ability to use existing energy system data to develop long-term scenarios using an energy forecast system allows the comparison of outcomes that different policy pathways entail [13]. It has been applied in the power sector for planning capacity expansion and assessing the outcome of different development pathways. For example, Aliyu et al. [14] analyzed the power generation expansion plan and its impact assessment for Nigeria, Bautista [15] and Park et al. [16] compared government policy with sustainable energy alternative scenarios for Venezuelan and Korean power sectors respectively, Kale and Pohekar [17] compare various scenarios of electricity demand supply for Maharashtra (India) and McPherson and Karney for Panama's power sector. The LEAP framework has also been used for CO2 mitigation and environmental impact assessment by comparing baseline and mitigation policy scenarios [18,19].

Not just confined to power sector, LEAP modelling has also been used to develop long-term scenarios of transport energy demand and resulting vehicular emissions impact [20,21]. The model is also capable of analyzing the dynamics of an entire energy system that includes transformation of primary energy supplies to secondary fuels, including electricity and all demand sectors consuming natural resources or secondary fuels. For example, a whole energy system has been modelled to forecast long-term energy demand and supply by Takase and Suzuki [22] for Japan, Kalashnikov et al. [23] for Russia's Far East, Roinioti et al. [24] for Greece and Yophy et al. [13] for Taiwan.

Among various energy system models LEAP is particularly suited to the needs of developing countries due to its application at various geographic levels and flexibility with data requirement and scope [25]. Earlier studies analyzing Pakistan's electricity sector demand and generation expansion planning e.g. Refs. [26,27] fell short of analyzing bottom up energy detail in household and industrial sub-sectors and end uses. Unlike previous studies that use standard cost and plant characteristics, this study relies on country specific investment, operation and maintenance (O&M) costs and process efficiencies for electricity generation technologies which vary greatly with geography and depending on country specific financial policies viz. interest rates, tax structure and quality of fuel input [28–30]. Capital and O&M costs of 71 power plants with diverse technologies and their actual heat rates in base years 2014 have been used to calculate the power dispatched based on running costs to present realistic cost and benefit analysis. This also incorporates fuel and investment cost projections of the World Bank, International Energy Agency (IEA) and International Renewable Energy Agency (IRENA) [31–34]. In this study, electricity demand is forecast for four major electricity consuming sectors, sub-sectors and end uses for households. Three different electricity generation pathways for the period 2014–2035 are developed and are analyzed in terms of their economic and environmental impact.

1.1. The structure of Pakistan's power sector

Pakistan's power sector comprises four major entities i.e. Water and Power Development Authority (WAPDA), Pakistan Electric Power Company (PEPCO), K-Electric and Pakistan Atomic energy commission (PAEC) (Fig. 1). WAPDA is responsible for hydropower development while PEPCO, through its five thermal power generation companies (GENCOs) National Transmission and Dispatch Company (NTDC) and its nine electricity distribution companies (DISCOs) oversees thermal power generation, transmission, distribution and billing. K-Electric is a vertically integrated power company with its own generation, transmission and distribution system for Karachi, the biggest city in Pakistan. PEPCO and K-Electric also purchases electricity generated by Independent Power Producers (IPPs). To regulate the power market and determine electricity tariffs for different power producers, there is a statutory body, the National Electric Power Regulatory Authority (NEPRA). It ensures the protection of consumers' and investors' interests and enables a competitive environment in the market based on fair commercial principles. In 2015, the total installed generation capacity in the country was 24,906 MW, of which PEPCO system contributed 22666MW while K-electric has an installed capacity of 2240 MW [6].

1.1.1. Electricity demand

There are four major sectors contributing to total electricity demand in the country, these being households, industry, commerce and agriculture. The household sector, with more than 20 million consumers is the largest demand sector and in 2015 consumed 38.7 TWh of electricity followed by industry, agriculture and commerce with 24.1 TWh, 8.3 TWh and 6.3 TWh respectively.[2] Over the last two decades, electricity consumption by households has posted average annual growth of 4.3% while total consumption has increased at an annual growth rate of 3.8% [6]. Growth in electricity consumption in all productive sectors of the economy could be attributed mainly to rapid urbanization, improvement in living standards, electrification and an increase in the population.

[2] Industrial electricity consumption of 24.1 tWh only includes demand met through national grid and does not include demand met by captive power plants in industries.