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Forecasting of Pakistan's net electricity energy consumption on the basis of energy pathway scenarios

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Abstract

Power Sector pathways for Pakistan is developed in this paper to depict the future challenges & aspects associated with its forecasting and planning on basis of modeling tools. Major pathways will be taken for further study in predicting focus on energy source for power generation. Three scenarios (BAU, NC & GF) will be discussed over a 20 years period (2011 to 2030) and the results from these scenarios will highlight our focus on fossil fuels or either renewable for future endeavors. The result will provide the forecasting of power sector up to 2030 on basis of electric consumers growth, level of activities, final energy intensity, forecasted growth & other factors. Therefore, the overall result will indicate efficient factors for future evaluation of policies on energy planning. The result also provides the vision for other developing countries in the region to make strategy for renewable energy expansion on massive scale.

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Keywords: Energy Scenario; Energy Pathway; LEAP; Pakistan

1. Introduction

Electricity demand is mutually related with rise in GDP and improvement of life style especially in developing industrial countries. Todoc et al. (2005) stated that developing countries portray the true image for correlation and they mentioned that relationship exist between electricity usage, wealth and state of value added production activities [1]. In Pakistan, the electricity demand increased exceptionally due to stable 6% GDP growth per annum from 2002 to 2007 and with no proper planning in power sector, the

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country faced severe power cuts which resulted in 2.5% GDP loss, unemployment of 0.535 million industrial workers and loss of exports worth $1.3 billion [2]. To overcome this shortage, power supply systems with higher efficiency and lower operation cost should be constructed to overcome power cuts and circular debt in Pakistan's power sector.

Clearly, the future energy policy orientation is based on wide-ranging economics, environmental and political factors which impact the type of technology to be deployed to meet the future energy demand. In addition to the above factors, there are some issues in Pakistan regarding energy security and infrastructure up-gradation for reliable electricity supplies that will also affect the future energy policies.

In this paper, several long-term energy pathways have been appraised to show the diverse ways in which the energy demand can be reviewed. Three different long term energy scenarios are included i. Business As Usual (BAU), ii. New Coal (NC) and iii. Green Futures (GF). The scenarios evaluation starts in 2011 and concludes in 2030; meanwhile base year is taken as 2011. "The Long Range Energy Alternative Planning" (LEAP) software is employed to assess these different scenarios which is an accounting scenario-based energy modelling platform [3]. The starting segment of this paper illustrates the study method of scenario development for BAU, NC & GF options. The second section provides simulated result by using the energy modelling techniques to evaluate electric consumer growth, sector-wise forecasted demand and future growth of electricity consumption of the three scenarios from 2011 to 2030.

2. Power Sector Structure in Pakistan

The power sector in Pakistan is gravely focused on non renewable source. Fossil fuels provide huge chunk of power generation with 62% overall where as natural gas and furnace oil provides 31.5% & 30.5% respectively. Fossil fuels are followed by hydropower which is 33.5% of overall generation [4]. There are five electricity end users which include domestic, agriculture, industry, commercial and other services. Domestic sector make nearly 80% of electric consumers in Pakistan which makes the power supply system very complex and difficult to handle the load management at peak hours. Domestic and Industrial sector consumers are growing at average of 4.7% and 5.75% annually for last decade. Electric consumer growth for agriculture, commerce and other services are 5.3%, 5.86% and 5.32% respectively (Fig. 2) [5]. Moreover, futuristic Pakistan's economy will have to focus on industrial, trade and business sectors for progress and job opportunity. With forecasted sharp expansion in these sectors, the increase in electricity generation capacity will be required to satisfy the increasing demand for power.

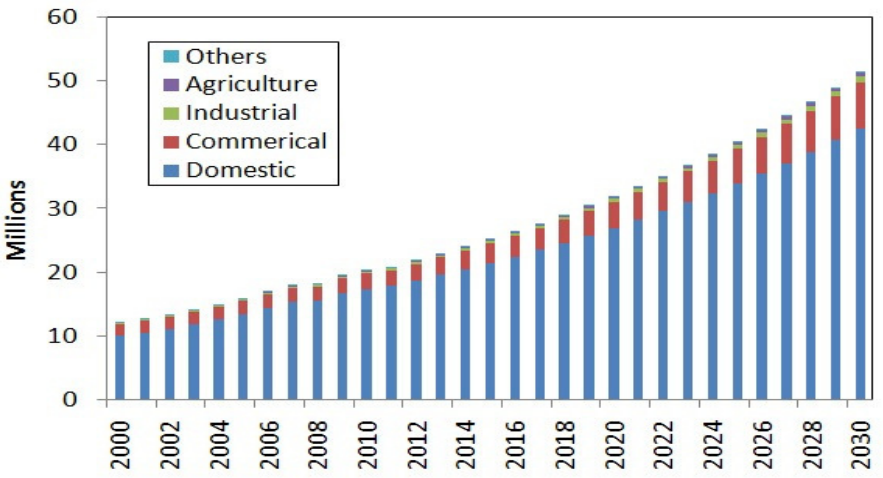

Fig. 2. Forecast of Electric Consumer Growth across five demand sectors in Pakistan

The organizational structure of Pakistan's electricity supply industry consists of four main organizations, which includes Water & Power Development Authority (WAPDA), Private Power & Infrastructure Board (PPIB), Pakistan Electric Power Company (PEPCO) and Karachi Electric Supply Company (KESC) which is privatized in 2005. However, WAPDA is liable for hydropower generation and PPIB deals with independent power producers (IPPs) which resulted due to the government policy launched in 1994 to attract private investment for thermal power generation. The other two electricity supply organizations are Pakistan Electric Power Company (PEPCO), consisting of four Generation Companies (GENCOs), nine Distribution Companies (DISCOs) and National Transmission and Dispatch Company (NTDC), and Karachi Electric Supply Company (KESC) is a vertical generated company involved in the generation and distribution of power supply to whole Karachi [6].

3. Study Method: Scenario Development

Scenario planning is a constructive technique to develop the long-term electricity infrastructures plan to deal with the unpredicted perspective requirement for power. "It permits the development of potentialities that are linked with diversity of policy and technological pathways with the intention of evaluating efficiently the doubts that lie forth in the energy, economic and environment segments" [7]. In energy research, long-term energy pathways therefore depict different narratives that propose a 'set of other possible situations for searching the future which may unfold in different ways' [8]. Impact of each pathway is rated and collated by using energy modelling techniques which are assessed.

In this paper, three energy scenarios, BAU, NC and GF options, are analyzed. Each scenario is assessed based on the supply side characteristics and assumptions according to the situation which resulted in the framing of particular energy policies.

3.1. BAU scenario

The BAU scenario portrays the energy scenario that is based on current trends by using government policy, plan & official forecasts which define the shape of the sector for next two decades. Factors considered are energy consumption in domestic, commercial, agriculture, industrial and other services, as well growth in electric consumers. Furthermore, the government of Pakistan has forecasted the elasticity index to be 1.5 by 2030 [9], simulating this pathway would be feasible to assess if the forecasting is indeed attainable under the present plans and vision of government.

In this scenario, Electricity Demand Forecast Report 2011 has been consulted for growth in demand of electricity by different sectors [9]. In general, three periods have been taken to determine the growth of electricity demand, which are 2011–2016, 2017–2022, and 2022–2027 (see Table 1). One of the common approaches, interpolation method, is used for Load forecasting.

3.2. NC scenario

Pakistan has huge quantity of retrievable coal reserves assessed to be about 185.5 billion tonnes, which it is not able to use in power generation and other energy demands. However, the discovered coal majorly composed of lignite with high sulphur content in Lakhra and low sulfur content with moisture in Thar which has a lower gross heating value. With growing electricity shortfall concerns, new power plants have to be built by 6th largest coal reserve country to overcome this mimic. Government has planned to convert oil fired plants worth 4200 MW to be converted to coal fired by using these excessive reserves and to overcome the circular deficit in this sector.

The NC scenario urges that Pakistan should move to a coal power generation to reduce its oil import bill and to overcome circular deficit in this sector which is worth 3 billion dollars. As indicated in Table 1, the NC scenario calls for decommissioning oil fired power plants which are to be substituted by coal fired plants in 2015.

3.3. GF scenario

This energy pathway is inspired by the Go Green initiative that will transform the policy towards injection of renewable energy in power generation. This pathway require better infrastructure for its advancement and acquisition of renewable energy technologies in the overall energy blend. With the country's heavy dependence on depleting natural gas and imported oil, reducing reliance on these becomes a key energy security solution.

Table 1. Assumptions used in different scenarios

	BAU	NC	GF
Driving Concept	Pursues repetitive directions in current technologies and policies. This policy supports responsive and continuous change rather than brisk and fundamental ones	Motivated by cheap technology fundamentals of coal and heighten oil prices with huge import bill	Supports Clean and environmental friendly energy policy
Demand side	Residential, commercial, agriculture, industrial and others sectors are included Demand side is divided into three periods: 2011-2016; 2017-2022; 2023-2028 For each sector, following input is required: Level of activity (No of consumers) & Final energy intensity (energy use per consumer) Average Growth in final energy intensity (2011-2030) – 6.1% annually Domestic Consumer growth (2011-2030) – 4.7% annually Agriculture – 5.3% annually Industry – 5.75% annually Commerce – 5.86% annually Others – 5.32% annually		
Supply side	System load factor (SLF) = 70%	SLF= 67% in 2030	
	T&D losses = 20.2%	T&D losses = 12.9% in 2030	
	Decommission 4200 MW oil-fired in 2015 & conversion of 4200MW oil-fired power plant to coal in 2015	New coal-fired power plants to be built	Decommission 5942 MW oil-fired plant upto 2030
	New coal-fired power plants in 2016, 2025 (Sahiwal, Faisalabad)	Total commissioning of 5300 MW coal-fired plant in 2020, 2025, 2028	Kohala Hydropower Project of 1100 MW in 2018
	Gaddani Coal Energy Park of 6600 MW	Convert 4200 MW oil-fired to coal	Tarbela expansion of 1400 MW in 2020
	New gas-fired power plants (2014, 2015, 2018 etc)	Gaddani Coal Energy Park of 6600 MW	Dasu dam of 4320 MW in 2028
	Import of 400 mmcfd LNG in 2014	New gas-fired power plants (2014, 2015, 2018 etc)	Neelum Jhelum & Large scale dam of 969 MW & 4500 MW respectively
	Neelum Jhelum Hydropower project of 969 MW in 2016	Import of 400 mmcfd LNG in 2014	New mini hydro 674 MW
	Large Scale Dam of 4500 MW in 2025	Neelum Jhelum Hydropower project of 969 MW in 2016	New nuclear & wind plants
	New nuclear plants of 2200 MW upto 2030		Enlarge composition of Hydropower for curtailment of gas and coal share to 35%

4. The Analytical Framework

The BAU scenario is an energy pathway focused on the current policy and plans by WAPDA, MOWP, PEPCO and NEPRA. The NC and GF pathways are more focused on the assumption based policies which consider worldwide sustainable and energy security philosophy.

In this methodology, the long-range energy alternative planning (LEAP) system is used as an energy modelling tool which will simulate the results of three energy pathways from 2011 to 2030. The LEAP model is a bottom-up model used to calculate the energy demand and supply in energy and non-energy sectors [10]. The year 2011 is used as the foundation year for all the energy pathways. In LEAP, calculation for electricity generation depends on the requirement of electricity usage by the each sector (Domestic, Industrial, Agriculture, Commercial and Others). In demand analysis, since the data required for the final energy intensity was not available for Pakistan, so the level of activities and total annual consumption by each sector was used to determine the final energy intensity. In this case, levels of activities stands for the amount of electric consumers, while the final energy intensity represents electricity consumed per electric consumer. Government has started the energy efficiency program by introducing energy savers and other energy saving appliances in 2011. This effect is assumed to be taken in NTDC Electricity Demand Forecast report 2011. The demand side consists of five demand sectors that include domestic, agriculture, commercial, industrial & others. In LEAP model, technologies are dispatched to meet the demand side based on each sector requirement.

The supply sector in Pakistan is modelled using a scope of power generation technology which include different types of gas turbines, combustion turbines, combined cycle cogeneration, hydroelectric (large and small-scale) and wind turbines. For each technology type, dispatch rule, process share, heat rate, process efficiency, historical production, exogenous capacity, endogenous capacity, maximum availability and fuel shares are required. Transmission and distribution losses are 20.2% at the current state but expected to be 12.9% by the 2030 [9]. In supply side of LEAP model, new and additional capacities are added exogenously or endogenously to the power sector infrastructure on the basis of planned additions to meet the demand sector requirement.

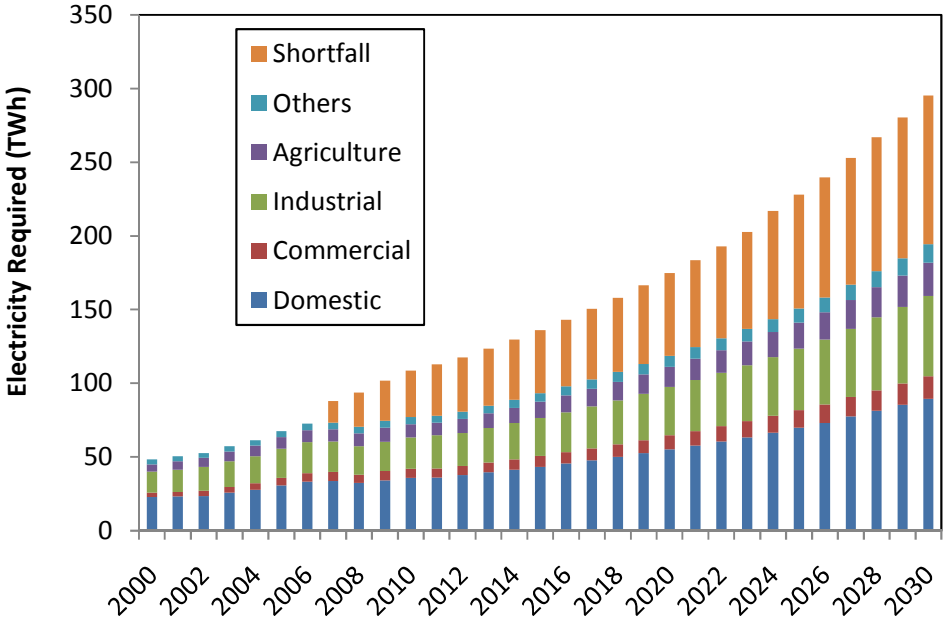

Fig. 3. Electricity requirement across the five demand sectors

5. Energy Consumption of Demand Sectors

Electricity demand is anticipated to increase with approximately 260% for next 20 years from existing 112 TWh in 2011 to 295 TWh in 2030 (Fig. 3). Major demand is driven by the domestic sector which is followed by industry, agriculture, commercial and others respectively. In 2011, domestic sector is a leading segment of electricity consumption as compared to the other sectors and in 2030, scenario remain the same which make the load management very complex. The major factor for rise in the domestic sector is due to increase in the energy use caused by the economic progress and other growth associated with it. Second most demandable sector is industrial and the country will have to focus on the industrial development which usually derives the positive role in economic development. Secondly, export oriented economy programme is also based on industrial sector progress, so the proper policy making is required to establish the electricity supply infrastructure to attain this goal.

6. Electricity Generation over 20 years

In 2011, over 62% of the electricity produced to power Pakistan's economy is generated from natural gas and oil. (Table 2). The remaining equilibrium came from nuclear, hydro and small portion from coal fired power stations. By 2030, the BAU pathway states that the composition of natural gas and oil has dropped to 19.81%, and 11.98% respectively. With the 6tth largest coal reservoirs in the world, coal increases from 0.1 to 14.1% which seems to become a valued subscription to the overall electricity generation. This is in line with the government's plan to decommission the oil fired pants and convert it to coal fired. Meanwhile, the renewable energy consists of 45.7% which include hydro, wind and solar.

Table 2. Composition (%) of Electricity Generation in scenarios

	2000	2011	BAU (2030)	NC (2030)	GF (2030)
Wind & Solar	---	---	1.95	1.12	5.46
Oil	39.5	30.5	11.98	2.34	2.18
Nuclear	2.9	4.4	8.38	6.97	9.76
Gas	32.0	31.5	19.81	23.51	29.45
Hydro	25.2	33.5	43.75	36.1	44.75
Coal	0.4	0.1	14.1	29.94	7.25
Bio mass	---	---	---	---	1.12

Furthermore, the study of BAU pathway trends shows that the enormous effort will be needed to meet the requirement. Fig. 4 shows that there is an increase of 305% in the supply between 2011 and 2030. Most remarkably, BAU scenario shows a three-fold increase by 2030 at the rate of 16.3% growth per annum in the hydropower generation, which would include large, micro and small scale hydroelectric power stations. This will require Pakistan to lure the global lenders, World Bank, International Monetary Fund (IMF) and Asian Development Bank (ADB), and foreign investors to built the hydropower stations supplementing to the power sector demand requirements. Additional increments are also anticipated for the coal power generation in the BAU scenario, which would result in 9.33% growth per annum depending on the utilization of Thar coal field and more it depend on the coal gasification technology success. From the prospect of 'energy security', coal used from the local reserves will be a strategic source of power generation for the future self reliance. Coal has many advantages but it causes the environmental problem which is the most crunch agenda of Environmental Investigation Agency (EIA)

and secondly with increase in the country's per capita consumption and the composition of electricity generation from coal, it is expected to cause increase in the carbon contents. This escalates a number of energy policy concerns regarding the energy dependence in Pakistan, whether to incorporate the local discoverable fossil reserves with environmental repercussions or to invest in the renewable energy sources.

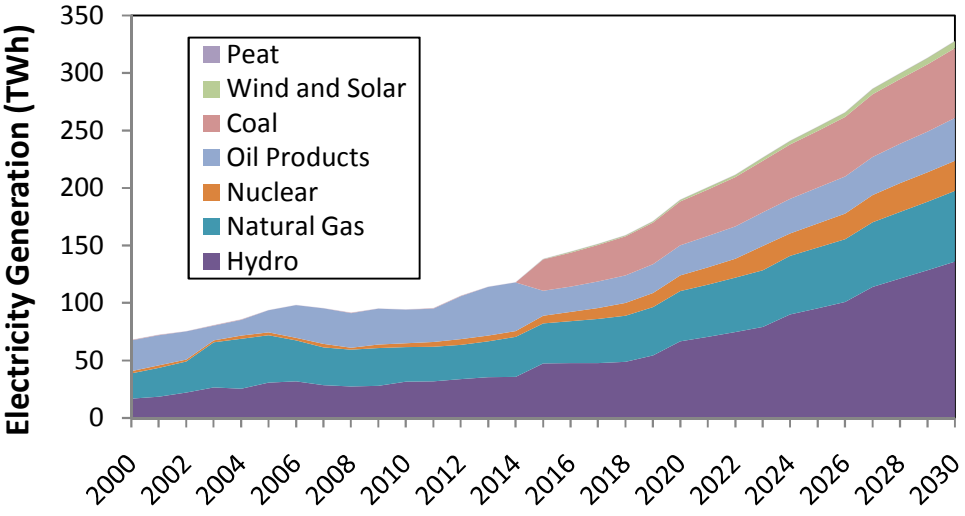

Fig. 4. Annual electricity generation in the BAU scenario from 2000 to 2030

The possible course of action between these two strategic energy options does not seem to be clear cut and there is no specific reason that why they should be mutually implemented. In BAU scenario, both options are appeared to be employed, i.e. increasing the coal composition to 14.1% and that of renewable energy sources to nearly 46% by 2030. In terms of renewable energy source (excluding hydropower), these technologies start to penetrate the energy market of Pakistan in 2015 with the average growth of 80% per annum up to 2030. Although, the share of renewables other than the hydropower still remains quite low in the country scheme of electricity generation, these figures are still noteworthy given that these technologies intervention in the system starts from the negligible base.

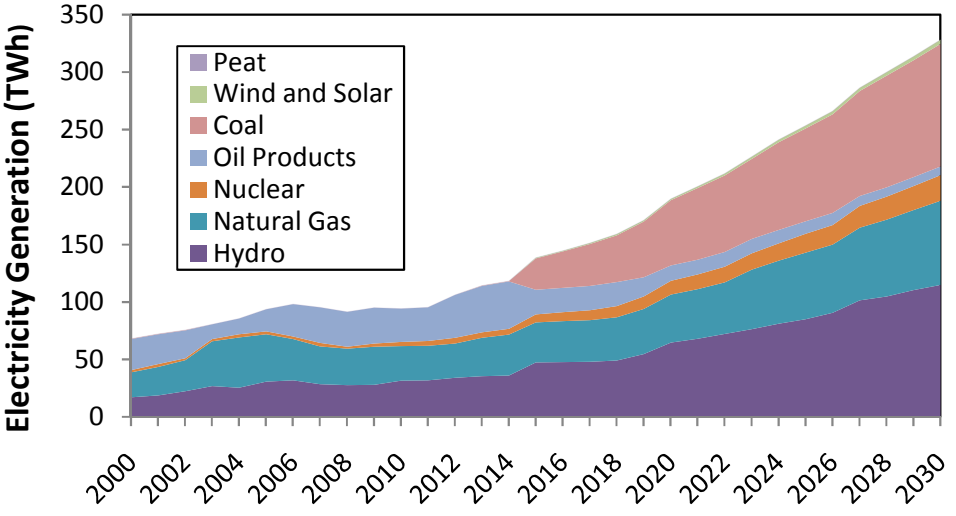

Fig. 5. Annual electricity generation in the NC scenario from 2000 to 2030

The other alternative scenarios have shown the different result from BAU pathway. In both pathways, New Coal and Green Future, share of the oil fired plants will decrease from 30.5% to nearly 2% which is supported by the policy of decommissioning the oil fired plants (Table 2), while the deficit resulted from oil plants decommissioning will be overcome by coal generation in the case of NC scenario (Fig. 5) and in GF scenario, hydropower will contribute the major chunk. Furthermore, NC pathway has demonstrated the different aspect in terms of the coal energy composition constituting 29.94% of the overall electricity generation in 2030 presenting a viable energy security prospect. Difference between these pathways can be gauged by Table 2 which states that NC scenario is more oriented towards the coal and GF pathway is more skewed toward hydro, wind & other renewables. Meanwhile in GF scenario, it has distinction of deploying the power generation from hydropower which is one of the cheapest source of electricity generation and lowest in O&M maintenance as shown in Fig. 6. The GF pathway is more of an aspiring approach for the perspective power generation that include biomass, hydro, solar and wind options, and it also help in diversifying the generation capacity to reduce the dependence on fossil fuels, slowing down the depletion of other fossil fuels and reducing the energy import bill. In addition to slowing down the depletion of natural gas reserves and avoiding the environmental controversies linked with the construction of coal power plants, the strong focus on the renewables results in the useful experience of these terminologies which will have far reaching impact on the future.

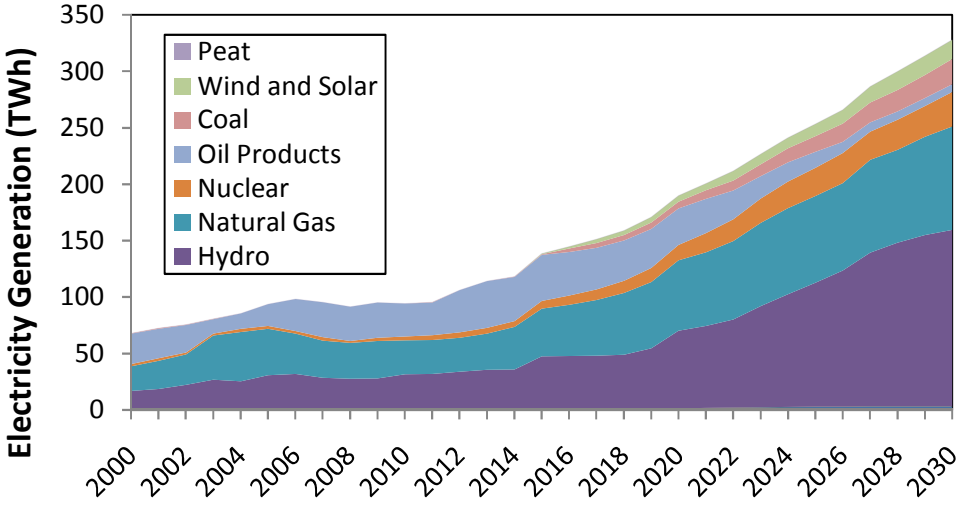

Fig. 6. Annual electricity generation in the GF scenario from 2000 to 2030

7. Conclusion

Energy security is one of the most important public policy issue that focus on the self dependable energy sources, reliability of futuristic supplies and how the energy market behaves. For developing country like Pakistan, security of energy supply can be achieved by expansion of supply in accordance with economic growth which comes from level of confidence for example, investment friendly energy policy, technology innovation, resource utilization locally, international agreements for supplies. For last so many years from 1990 onward, Pakistan is more towards increasing imported energy to meet demand and invested only in imported energy supply infrastructure to remain brisk with high economic growth. Consequence resulted in severe problems for Pakistan and it is now more of a energy starved country. This paper shows that Pakistan can still overcome energy security issues with proper planning and

direction. The scenario analysis in this paper presents different options of energy technologies ranging from current government policy to coal based or renewable pathway. This study is a source of way forward for Pakistan energy experts to find a viable solution for sustainable energy and energy security in future by implementing proper pathways according to future economic growth and political issues.

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