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MODELING AND FORECASTING OF ENERGY SCENARIO IN PAKISTAN WITH APPLICATION OF DECENTRALIZED ENERGY PLANNING

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ABSTRACT: The global energy demand has enlarged in recent years as a result of industrial development and population growth. This scenario has even intensified in Pakistan affecting industrial as well as domestic and agriculture sectors, causing 2-3% of GDP loss annually. According to Pakistan Energy Year Book 2012, Pakistan generation capacity being 95365GWh is far greater than the consumption 76,761GWh, indicating that these power-outages are not because of lack of generation capacity but improper energy management. The current pattern of centralized electricity based on costly imported oil, has resulted in inequities, debts and high transmission losses. Therefore, a change in overall energy mix has to be made considering requirements and regional availability of competent resources which can be possible by introducing Decentralized Energy Planning in power policy. In the present research work a comprehensive energy model for Pakistan has been created using LEAP, identifying the loop-holes in system and presenting possible remedies for the current energy crunch.

Key Words: Energy Outlook, Energy Modeling, Decentralized Energy Planning, LEAP

1. INTRODUCTION

The upswing in the worldwide energy crunch has questioned the security of energy and has shifted the attention towards divergence, production and effectual division. The possible solution is attaining an optimum energy blend using alternative fuels and endorsing energy productivity and interregional teamwork. Pakistan has also been a victim of this critical and persistent energy crisis. Even though the connected production capability far outstrips the highest energy demands in summer, overpriced generation makes electricity exorbitant for the native consumers and improvident for commercial and industrial end users. This hype in electricity is majorly an outcome of increased dependence on fossil fuels or the thermal sources.

Energy planning has always played a vital role for setting the structure in the energy sector. For refining the living standard and decreasing poverty in rural areas of developing countries, improved access to contemporary energy sources is essential. According to the world statistics, in 1996 more than 1.3 billion people residing in the rural areas had no electricity representing 80% of the world total population at that time, without the facility because of the poor transport setup [1, 2].

As an alternate method for rural electrification the decentralized transformation technologies are introduced employing resources locally available in the concerned regions. Decentralized systems can provide a more consistent electricity supply and produce revenue from the use of indigenous resources [2, 3]. For instance, the agricultural, domestic and forest wastes as well as other biomass resources can be used in electricity generation technologies, decreasing the reliance on imported fuel [3]. Different techniques have been investigated by the researchers to meet the energy crisis using decentralized energy planning. Decentralized energy models have been in practice for micro-level planning. An energy model for selection of technology for rural electrification and a Linear Programming based goal programming model had been established by Kanudia [4]. In the study, the energy model MARKAL (MARKet Allocation) had been used for various cost and tax scenarios for application of non-conventional energy technologies in the power production sector of India. Beeck projected a new method for regional planning, considering numerous constraints that include data expressed in monetary at least quantitative and its use in regional technology related problems, context -related concerns and focus on small scale renewable energy systems data accessibility [5]. Similarly, Tanatvanit et al. reviewed the energy consumption patterns in three economic areas; viz., industrial, transport and residential and predicted the energy demand growth and the resultant emissions for the year 2020 to these sectors, using a model based on the end-use methodology [6]. In the following sections, the

1.1 Energy Outlook: In the course of 2011-12, the power shut downs in Pakistan appeared to be the principal restraint in development of Pakistan. The unavailability of electricity and gas is regarded as the principal reason in limiting the production in most of the industries. Particularly, the industries that are highly energy driven (Iron, Steel, and Petroleum etc.) swept 0.2 % from actual GDP growth rate in the period 2010-12. Moreover, the assessed loss that this power crises has been causing to the economy is around 380 billion rupees per year [7], making up approximately 2% of GDP, whereas the subsidies cost that has granted by the treasury to the power sector, in the duration 2008-2012 amount to 2.5% of GDP that is 1100 billion rupees.

1.2 Installed Capacity in Pakistan: The total installed capacity of existing hydro and thermal generation units for Pakistan Electric Power Company (PEPCO) and Karachi Electric Supply Company (KESC) systems including the Independent Power Producers (IPPs) is about 22,797 MW as at the end of 2012 [10]. However, due to the seasonal variation of water inflows for hydro plants and the capacity de-rating of thermal units, the dependable capacity for the systems are estimated to be 15,254 during winter. The installed capacity of hydro plants accounts for about 31%, thermal capacity for 67%, and nuclear capacity less than 2%. The total installed capacity from IPPs is about 38% of the total installed capacity. Due to restrictions in availability of fuel and timely payments this production capacity also could not be operated at full. Even it is a claim that no substantial facility in the power sector was added during last ten years, exclusive of the 3,377 MW added since 2008- 09. In June 2012, the shortfall reached up to 8000MW. Surely, the huge shortfall was not mainly because of lack of generation capacity. [8]

1.3 Thermal Energy: Over and above 70% of total energy capacity of Pakistan is in the form of thermal energy having oil as major share-holder as described in the Table 1.

Table 1: Thermal Electricity Generation by Fuel [10]

Thermal Fuel	Electricity Generated(GWh)	Percent Of Thermal Electricity
Oil	33,562	54.74%
Gas	27,650	45.10%
Coal	96	0.16%
Total:	**61,308**	**100%**

Pakistan had been mainly using furnace oil for producing the thermal power [10]. Consequently, as the share of thermal power steadily amplified the electricity cost kept on growing. Electricity is generated highly expensively at 12 rupees per unit owing to larger dependency on the most uneconomical thermal sources HSD, furnace oil, and mixed that make up nearly 44% of Pakistan's total power generation, while the prices using ~~G~~gas and coal are reasonably low as approximately 4 rupees per unit.

1.4 Hydroelectricity: The enormous rise in prices of thermal fuels has necessitated the availability of the more cost effective hydro power. The current scenario of electricity generation illustrates that the potential of hydel sources has not been harnessed at its full. According to Pakistan energy yearbook 2012, the hydroelectricity generated comprised of 33.67% of total generation in the fiscal year 2012-13. There are twenty-three Water And Power Development Authority (WAPDA) hydro projects, totalling 37,057 MW, and eighteen IPP hydro projects, totalling 5,519 MW, that have been identified and proposed on the future project list provided by National Transmission and Despatch Company NTDC. Additionally, the hydro projects of Kalabagh 2,776 MW and Doyian 490 MW are not on the WAPDA list but the feasibility studies have been completed in 1987 and 2004, respectively. Hence, the total capacity of future hydro potential is 43,676 MW. However, the hydro prospectives traced in the northern areas of Pakistan entail extensive transmission lines to transport electricity to the utility points. Further, the cost of generation of hydro electricity is the least amongst all of the alternatives, but is highly susceptible to seasonal variations and other effects as well.

1.5 Nuclear Energy: In 2011-12 the share of generation from nuclear sources was 4.9% of Pakistan's total electricity production. Currently there are three operational nuclear power genration units: Karachi Nuclear Power Plant having a capacity of 137 MWs at Karachi, C-1 & C-2, capable of generating 325 MWs each, respectively operating at Chashma. At the same site two more nuclear power units C-3 & C-4 are under construction with generation capacity of 340 MWs each. The Energy Security Plan prepared by the Pakistan government predicted the erection of 8800MW nuclear energy based power production units till the year 2030. The objective has further been elevated up to over and above 30,000 MW by 2050 to fulfill the power needs of Pakistan. [17]

1.6 Renewable Energy: In 2003 there was no concept of renewable energy utilization in Pakistan[18]. Therefore, Alternative Energy Development Board (AEDB) was founded to synchronize, expedite and encourage renewable or alternative energy technologies and to raise share of power production from renewable energy resources to 5% by the year 2030 . The board formulated Alternative and Renewable Energy (ARE) Policy in 2012 that included all alternative energy technologies together with hydro, solar, wind, geothermal, waste-to- energy, cogeneration and bagasse offering tremendously attractive monetary and economic benefits to both native and overseas stockholders. Pakistan is heavily dependent upon renewables states that the population in rural areas encounters over and above 95% of their household energy requirements through biofuels [12, 13]. The energy scenarios that can be accomplished by utilizing the renewable sources are summarized in the Table 2 but, this huge energy potential is still unused in Pakistan with only a negligible amount of these resources being harnessed.

Table 2: Renewable potentials for Pakistan [14]

Energy type	Estimate (MW)
Wind	340,000
Solar	2.9 Million
Hydro (mini)	2000
Hydro (small)	3000
Hydro (large)	50,000
Bagasse Cogeneration	1800
Waste-to-power	500
Geothermal	550

2. METHODS AND MATERIALS

For the energy modeling and forecasting, LEAP has been used that is extensively used software for the analysis of energy policy and assessment of climate variation alleviation established at Stockholm Environment Institute. LEAP does not represent the model of a certain energy system, rather is a device utilized to construct models of diverse energy systems, each requiring its exclusive data arrangements. It is proposed for a medium to long-term energy modeling. Scenario usually contain both a historic era known as *Current Accounts,* in which the model is run to check its capability to imitate identified statistics, as well as multiple advanced situations. Normally, most readings use a prediction period of amid twenty to fifty years. The major advantage of LEAP is that lower data is required initially.

2.1 Modeling on LEAP: The bottom up LEAP-based energy system model has been used of as a logical framework to analyze the energy security in case of Pakistan. It simulates the energy flows in an economy, from the primary energy supply source, conversion into secondary useful energy, and consequently the provision of its different forms to the point of utility. These energy flows are explained in the model with the help of thorough demonstration of technologies being provided to an end use mandate. The energy system model of Pakistan comprises of four modules; primary energy resource, conversion methodologies, utilization technologies and need for energy services. Primary supplies are crude oil, hydro, natural gas, nuclear, imports of oil, solar wind etc. whereas transformation methodologies module entails power production and distribution systems, natural gas processing and distribution systems and oil refineries. Service energy consumption is divided into five categories that include households, commercial, transportation, agriculture and industry. Energy Modeling for Pakistan has been done here using considering two cases.

2.1.1 Base Case: In this case, GDP of Pakistan is assumed to grow at an annual rate of 3.6%, for GNP 6% growth rate was considered and the population was estimated at an annual growth rate of 3.5% based on the GDP and population data for the period of 20-2013 [15, 16]. Further the supply of electricity is forecasted on the basis of current rate of development of the installed capacity utilizing the sources being used presently.

2.1.2. Modified Case: The modified case considers the same key assumptions as used for the base case. Table 3 shows that how the incorporation of decentralized energy can affect the future of the country. A change in the current energy mix of Pakistan is proposed, as the disastrous effects of the current energy blend have already been discussed in the previous sections, so the installed power generation capacity is assumed giving more attention towards the more efficient and reasonable resources viz. coal, hydel, nuclear and some renewable sources (wind, solar and biogas). These assumptions are actually based on the future goals already been set in the long term energy policy of Pakistan.

Table 3: Modified case assumptions

Resources	Assumed Installed Capacity in 2040
Small hydel projects	1500 MW
Larger hydel projects	2500 MW
Coal-fired	6000 MW
Nuclear	20000 MW
Wind	5000 MW
Solar	2000 MW
Biogas	1000MW

3. RESULTS AND DISCUSSION

Energy model has been developed on the basis of different steps which include: Key assumptions, demand analysis, transformation and resources.

3.1 Key Assumptions: Key Assumptions are used as a place to put data that affects the energy forecasting but not handled anywhere else in the demand, transformation or resource analyses of LEAP. The key assumptions for Pakistan used in this model are:

- GDP: 336.50 billion US$
- GDP growth rate: 3.6%
- GNP and growth rate: 105.5 billion US$, 6%
- Population: 184.3 Million persons
- Population growth rate: 3.5%

3.2 **Demand Analysis:** Demand analysis is a fragmented, consumption based methodology for modeling the final energy consumption. The demographic, economic and end-use information are put in to create scenario that observe how total consumption of final energy grow over time in all the demand sectors. Energy demand analysis can also be considered as the foundation shepherding towards the incorporated energy analysis, since all resource and transformation calculations are determined by the intensities of ultimate demand evaluated in the demand analysis. Figure 1 and 2 showing the results for overall demand structure for Pakistan, which consists of sectors including: households, commerce, industry, agriculture, and transport. Each of these is divided into diverse sub-sectors, fuels and end-uses.

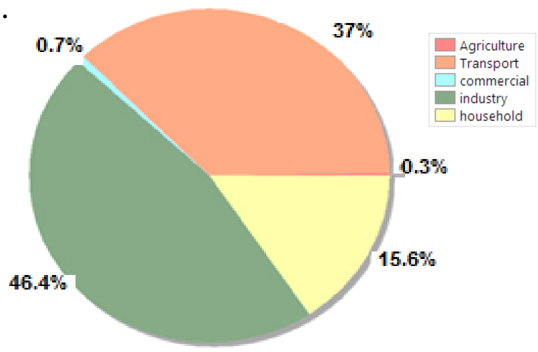

Fig.1: Sectorial Distribution of Energy Demand

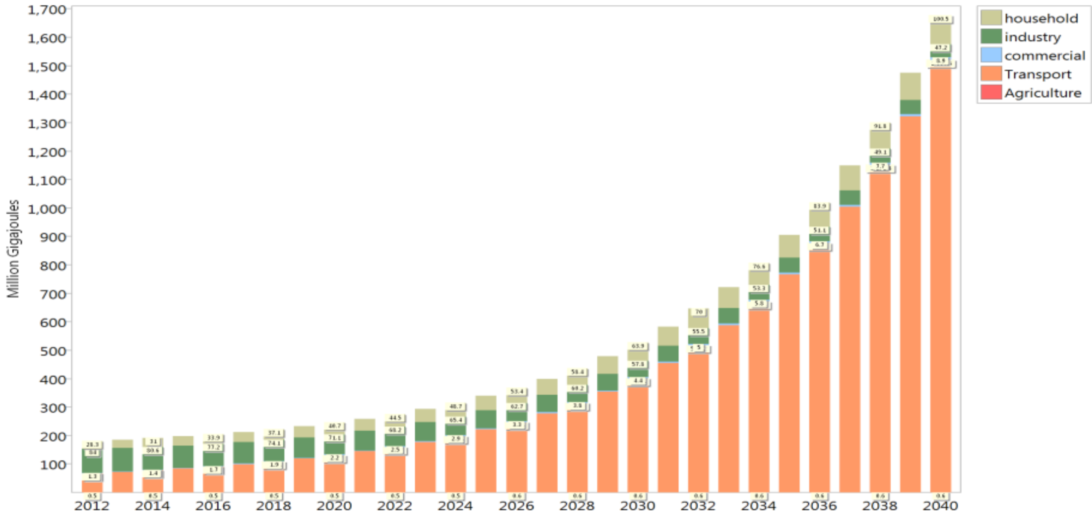

Fig. 2: Forecasted Distributions

A rapid and marked increase in transport sector can be seen here owing to the increasing population and burdening on the road transportation.

3.2.1 Household

The demand of energy in households varies for the urban and rural parts of the country and further for their electrified and un-electrified regions. Therefore, a complete data set had to be compiled for each type concluding into the demand tree shown in Figure 3. The current percentage of urban population in Pakistan is 37.9% while the remainder is rural population. This graph shows the pattern of forecasted energy demand by rural and urban domestic population, from the graph it is observed that currently the proportion of energy consumption by the rural population is higher than the energy pattern forecasted in the year 2040 whereas the growth rate is much faster for the urban population. This shift of energy demand trend is owing to the increasing urbanization in Pakistan.

Electrified Urban Households:

The figure 4 shows the share of power utilities in electrified urban regions. According to the rough estimates, 100% of electrified urban households use electricity for lighting purposes and almost same is the percentage for the households using natural gas for domestic cooking and heating purposes. While the percentage of households using electricity for refrigeration and air conditioning purposes is 60% which is predicted to rise gradually till the year 2040. Whereas, the energy demands in the non-electrified urban households is particularly based on natural gas needed for cooking and lighting puposes, while in some households other fuels has also been used as in LPG, kerosene oil and biomass, however, their percent share is almost negligible.

Electrified Rural Households:

Major part of the Pakistan population resides in the rural regions and this makes almost 64% of the total population, presently, however only a little fraction of this population have access to electricity. Figure 5 shows that almost all the electrified households use electricity and natural gas for lighting and cooking or heating purposes, respectively. On the other hand, the energy demands in the non-electrified rural households is particularly based on natural gas needed for cooking and lighting puposes, while in some households other fuels has also been used as in LPG, kerosene oil and biomass, however, their percent share is not much appreciable.

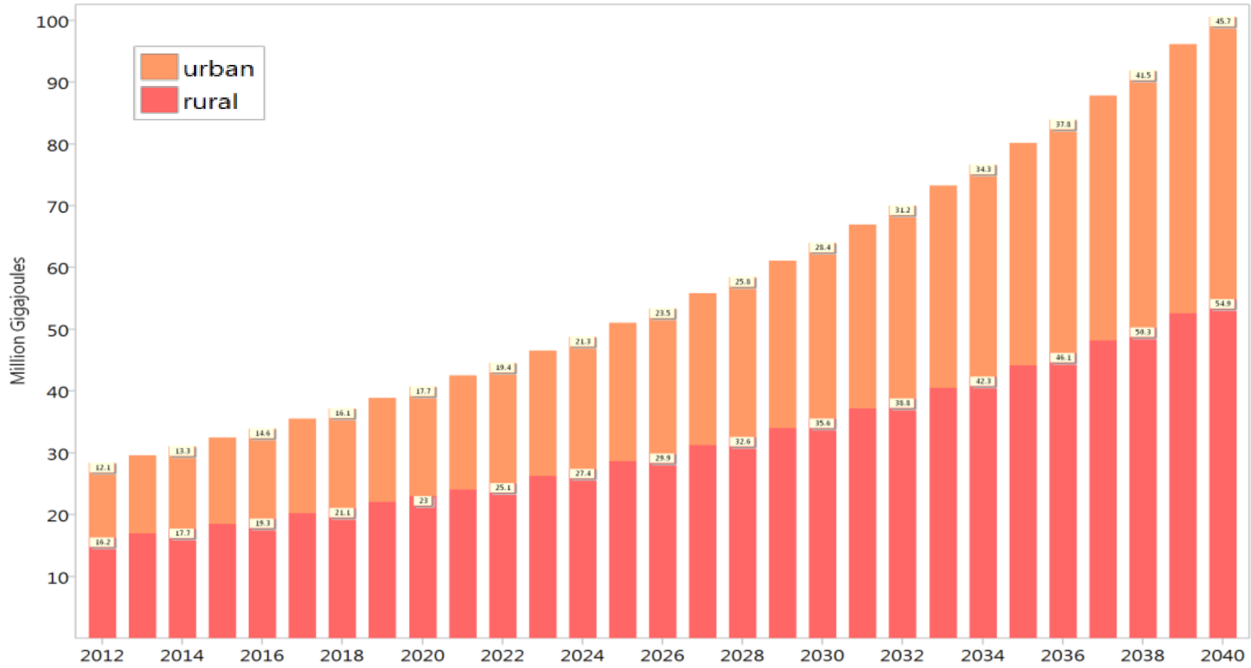

Fig. 3: Forecasted energy demands by overall urban and rural regions

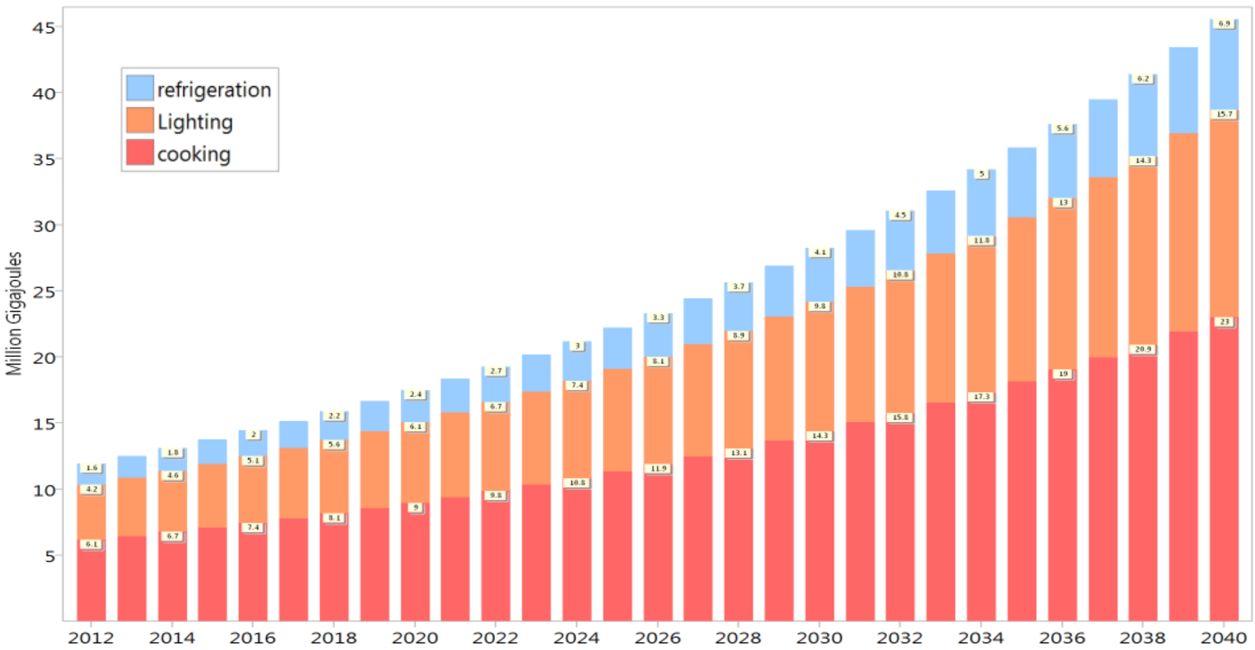

Fig. 4: Energy demand for Electrified Urban population

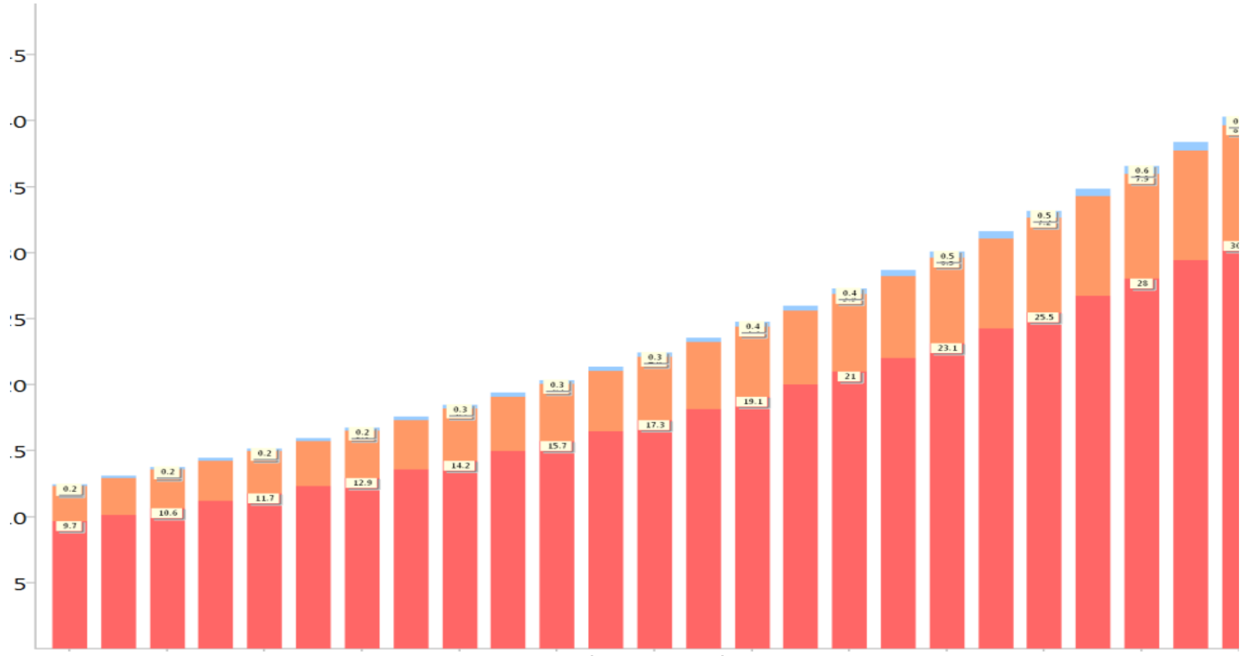

Fig.5: Energy Demand for Electrified Rural Population

3.2.2 Transportation: The Figure 6 depicts the picture of the consumption of different fuels being used in transportation sector. The category diesel also includes the High Speed Diesel (HSD), Light Diesel Oil (LDO) and the Furnace Oil, further it accounts for the diesel consumed by tractors for agricultural purposes as well. The non-energy fuels contain the gasoline, High Octane Blending Component (HOBC) and aviation fuel. The growth rate of the consumption of these fuels is expected to be the fastest. Another fuel having fast growing consumption is Compressed Natural Gas (CNG) having annual compound growth rate of 16%, which dictates an alarming situation as this increasing demand in transport sector is depriving the power sector of natural gas resources.

However, to lessen the consumption of CNG, government has limited the supply of CNG to few days in a week only, in some parts of the country.

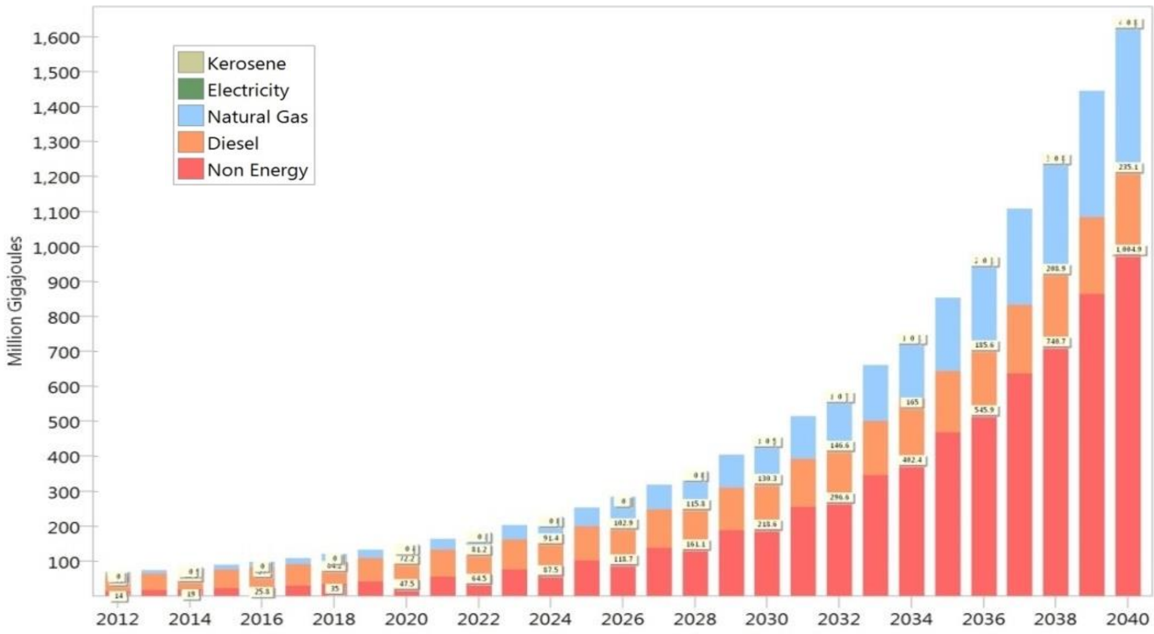

Fig. 6 Energy Demand by Transportation Sector

3.2.3 Industrial Sector

Industrial sector in Pakistan has been facing severe crisis due to lack of required resources, since 2006, particularly since natural gas had been supplied to the transport sector, as most of the industries in Pakistan has been based on ~~N~~natural gas. Therefore, most of the investors were compelled to shut down their industries and hence a drop in energy consumption has occurred. If this current negative growth rate remains, a marked reduction in energy demand in industrial sector is anticipated, which obviously will endanger the economy of Pakistan. The energy demand by industry is shown in Figure 7.

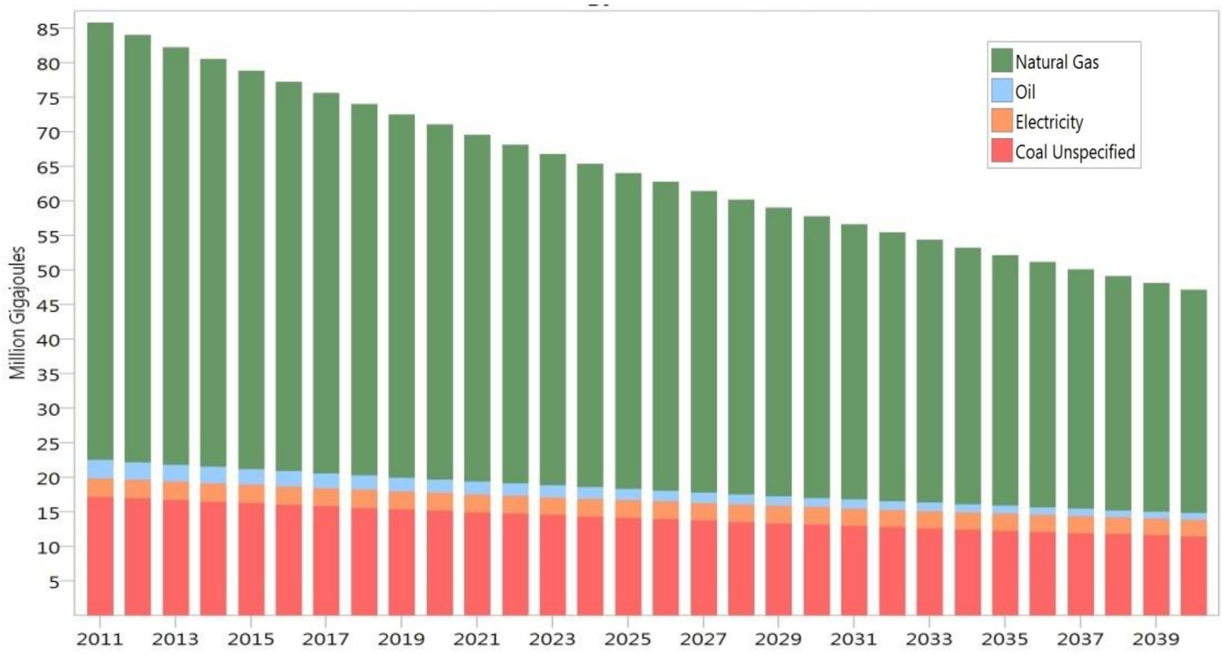

Fig. 7 Energy Demand by Industry

3.2.4 Commercial

The commercial sector in Pakistan is also majorly based on natural gas, while electricity and LPG are employed as well, to meet the energy needs in commercial sector. The overall annual compound growth rate of energy demand is currently 2.9% with natural gas consumption growing at a rate of 4.8% while for electricity and LPG the ACGR being 1.4 % and -1.7% respectively. The energy demand by commercial sector is shown in Figure 8.

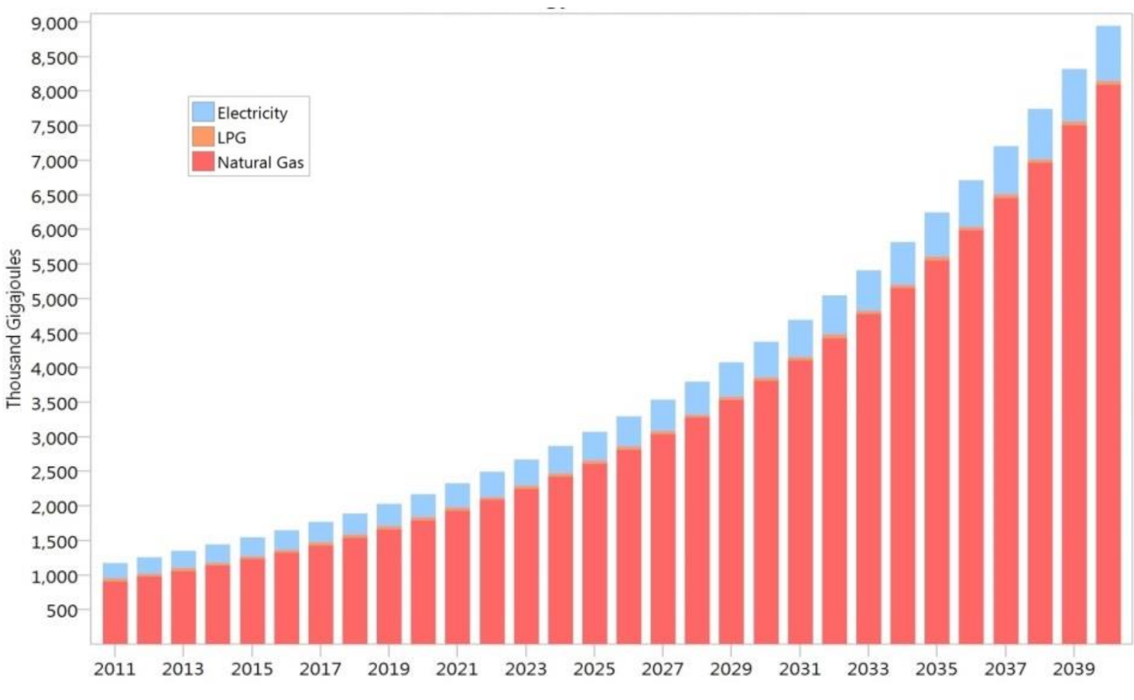

Fig.8 Energy Demand by Commercial Sector

3.2.5 Agriculture

The agriculture sector in Pakistan mainly needs electricity and to a minor extent diesel or other oils. The diesel consumed in tractors has been already considered in the transport sector that is why it is not included here. The utilization of electricity is for operation of tube wells etc. however, this amount is still insignificant as compared to other sectors. The annual compound growth rate for electricity consumption is 0.9%. The energy demand by agricultural sector is shown in Figure 9.

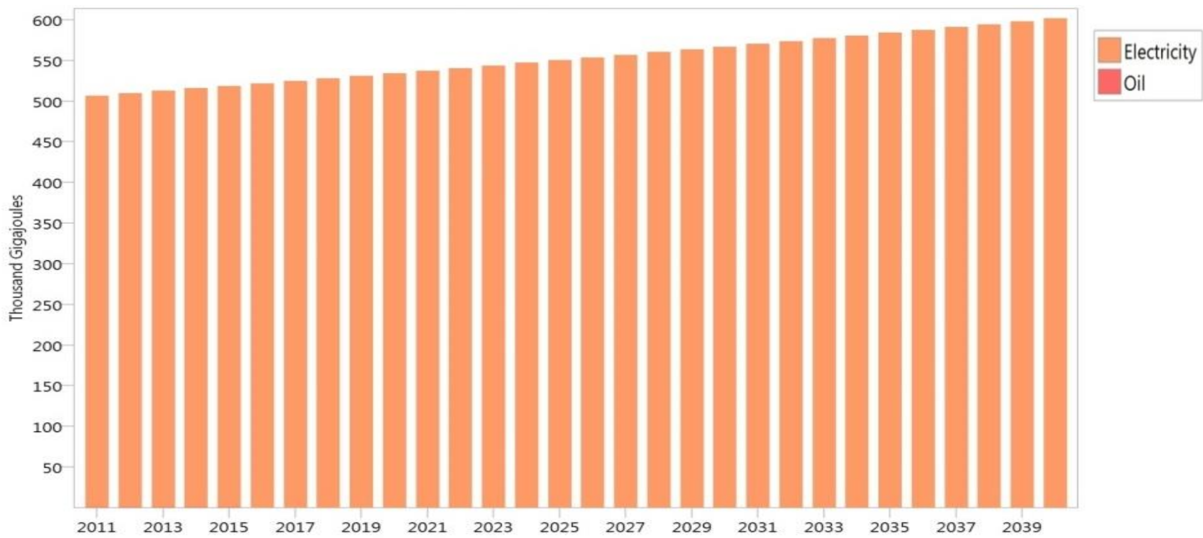

Fig. 9: Energy Demand by Agriculture Sector

3.3 Energy Transformation: Base Case

For the base case, considering the current capacity utilization and energy mix, the transformed energy into electricity can be optimistically forecasted to be 48.2 Million Gigajoule in the year 2040 as shown in Figure 10. This scenario considers that the hydel power plants being under construction right now shall be operational by 2040 and a negative growth for oil based electricity has been considered. The consumption of Natural gas is considered to grow on the current rate 3% while that for coal the rate is 0.8%.

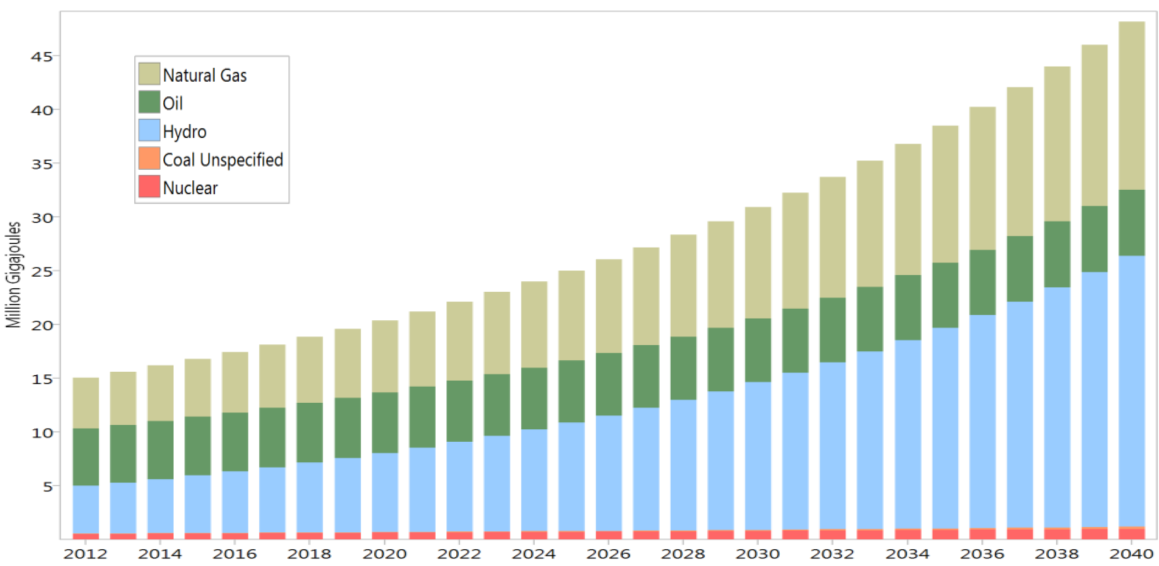

Fig. 10: Transformed Energy Base case

3.4 Resources

Taking into account the energy resources reserves in Pakistan as shown in Figure 11, the greatest reserves are present for that of coal amounting to *186 billion tonnes* making up almost 5500 billion gigajoules of energy if being harnessed effectively .Whereas the reserves of natural gas and oil in comparison with that of coal, are next to nothing.

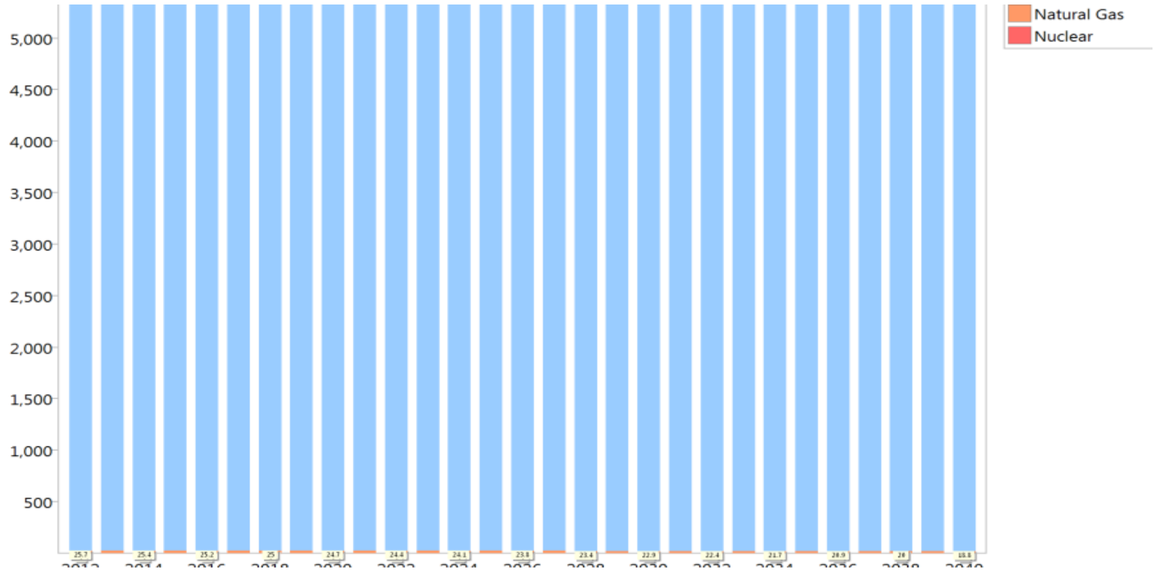

Fig.11Primary Energy Resources Reserves

3.5 Energy Transformation: Modified Case

Figure 12 represents the modified case.it has been worked out to bring about a reformation in the energy mix of Pakistan utilizing the decentralized energy planning, shifting the concentration from thermal electricity to hydel, natural gas and nuclear energy and introduction of some renewable resources such as wind, biogas and solar as well. A comparison of Base case and modified case is also shown in Figure 13.

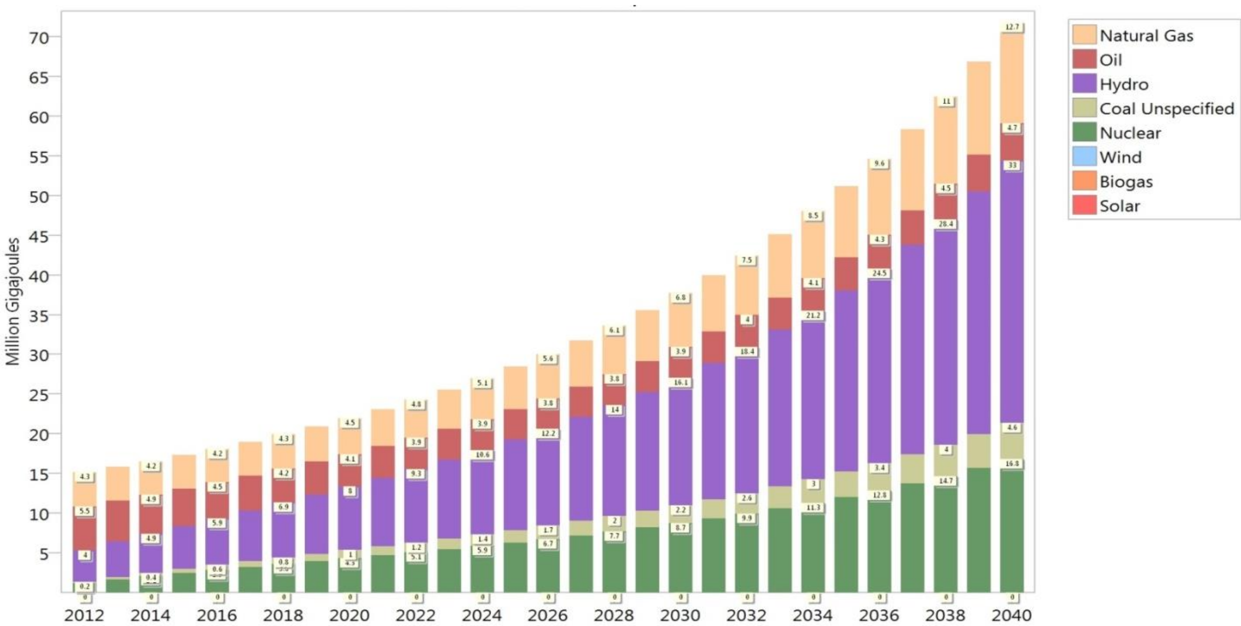

Fig. 12: Modified case Electricity Generation

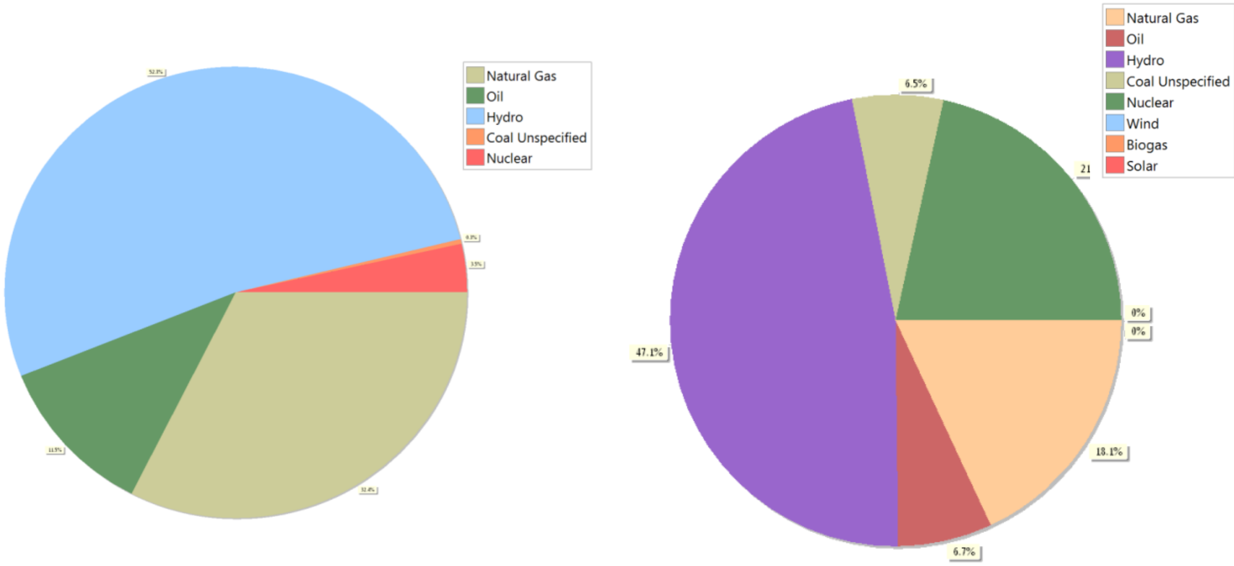

Fig. 13 Comparison of Base case and Modified (Decentralized Energy) case

4. CONCLUSION

Today, the high electricity costs are majorly an outcome of higher dependency on centralized systems operating mainly on conventional resources and necessitate giant investments to establish national distribution grids that can power remote regions as well. A deliberate policy alteration has to be undergone to rectify the mix of energy by switching from the current oil-centered power generation to hydro, nuclear and using renewable energy resources and this can only be undergone by implementation of decentralized energy planning that employs the alternative/renewable resources conveniently. The forecasted results based on the current energy scenario estimated the total electricity generation to be 48.2 Million GJ in 2040 while employing decentralized energy the same is forecasted to be 71.8 Million GJ in the year 2040.

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