The long-term Electricity Planning for Sindh Province (Pakistan): An Application of Long-range Energy Alternatives Planning

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Abstract

Electricity has become very important commodity of today's human life. The demand of electricity is increasing day by day due to rapid increase in population and development in industries in the world so its generation needs to be managed appropriately. Long term planning of electricity supply is important which calls to ensure sustainable electricity for a developing country like Pakistan. Sindh is the key province of Pakistan with its population living in both urban and rural areas. Electricity demand of Sindh province is increasing rapidly due to rapid increase in its population and economic development. In this study LEAP (Long-range Energy Alternative Planning) model has been used to forecast electricity demand for the year 2035 for the province Sindh. Subsequently, three supply side scenarios has been developed which includes Business As Usual (BAU), Renewable Rich (RR) and Thar Coal (TC) scenarios over the study period 2014-2035 to meet the forecasted energy demand of the province. In the targeted year 2035 the projected electricity demand for the province is grown by 116.93 % over the base year 2014.

Keywords: Electricity demand forecasting; Electricity generation; LEAP

1. Introduction

Electricity is the most extensively consumed energy resource among natural gas, liquid fuels and coal in all consumers' categories except transport sector, so long term planning of electricity is vital for the operation and expansion of power system in order to cope up with the fast growing electricity demand. Sindh province is the 2nd largest populated and 3rd largest in area [1]. The gross state domestic product for Sindh province in the year 2014 was estimated to be 240 billion rupees. The electricity consumption for the province in 2014 was 20,800 GWh [2]. The province started facing the scarcity of power since 2007 and currently it is facing a short fall of 1,543 MW and is expected to increase in future if current trend continues. Currently province is facing 8 to 10 hours load shedding in residential, commercial and in industrial areas on daily basis [3]. Several consumers uses backup generators during these blackouts. However demand of electricity is increasing due to development in every aspect of life, so keeping in view along with demand and supply side management load forecasting is necessary to cope up with this increasing demand. An extensive work is needed in the power generation planning and modeling to decide areas of future investment with precise things.

There are number of energy modeling tools created worldwide through computer software tools, some of these are Homer, Energy plan, RET screen, LEAP, MESSAGE and Markel [3]. In this study LEAP model is used for the forecasting of electricity. LEAP is widely used energy-environment modeling tool to generate energy scenarios. These scenarios are based on accounting of how energy is produced and consumed in particular region under price, available technology, available resources, economic and social development [4]. In this study using LEAP model three scenarios are generated which includes Business as Usual (BAU), Renewable Rich (RR) and Thar coal (TC).

2. Methodology

2.1 Sindh's LEAP model framework

On the basis of Pakistan's electricity system three scenarios are developed considering 2014 as base year and 2035 as targeted year. The first scenarios is Business as Usual which is developed according to government power policies and other two scenarios includes Renewable Rich and Thar Coal which are developed according to new strategies.

In this methodology long-range energy alternatives planning (LEAP) system is used as energy accounting modeling tool which matches demand and supply side electricity generation technologies [5]. It has various modules such as key assumptions, demand, transformation, resources etc.

In the key assumption module, data such as total population, households, GDP and similar data has been used [4]. Demand analysis is used for modelling the requirements for final energy consumption. In the demand module, broad sectors such as domestic sector, industrial sector, commercial sector, agriculture sector and railways are created using the sectoral electricity consumption as given in Table 2. The electricity consumption values for the base year 2014 have been used for forecasting electricity demand and supply.

In a transformation module, simulation of energy conversion and transportation of energy from the source of primary energy to the final fuel consumption is done. In the transformation module, data related to electricity generation power plants such as installed capacity in MW, historical production in million kWh, process efficiency, maximum availability, capacity credit. The assumptions made in the LEAP model are listed in Table 1. The electricity transmission and distribution losses of KESC are 23%, HESCO 26% and SEPCO 39% in 2013-14 [7, 9, 10]. The first simulation year is set as 2015.

Table 1
Assumption used in LEAP model

	Natural gas	Nuclear	Oil	Coal	New coal	New wind	Solar	Wind	Thar coal
Process efficiency %	56	33	51	42	42	100	100	100	42
Historical Production (GWh) in 2013	15,318	328	6553	155	0	0	0	0	0
Exogenous capacity (MW)	3,422	137	2,372	150	3,960	2200	109	50	236
Life Time (Years)	30	30	30	30	30	20	25	20	30

Fig. 1. Shows the electricity module framework developed for Sindh LEAP model, that consist of various energy resources, electricity generation, transmission and distribution and the demand.

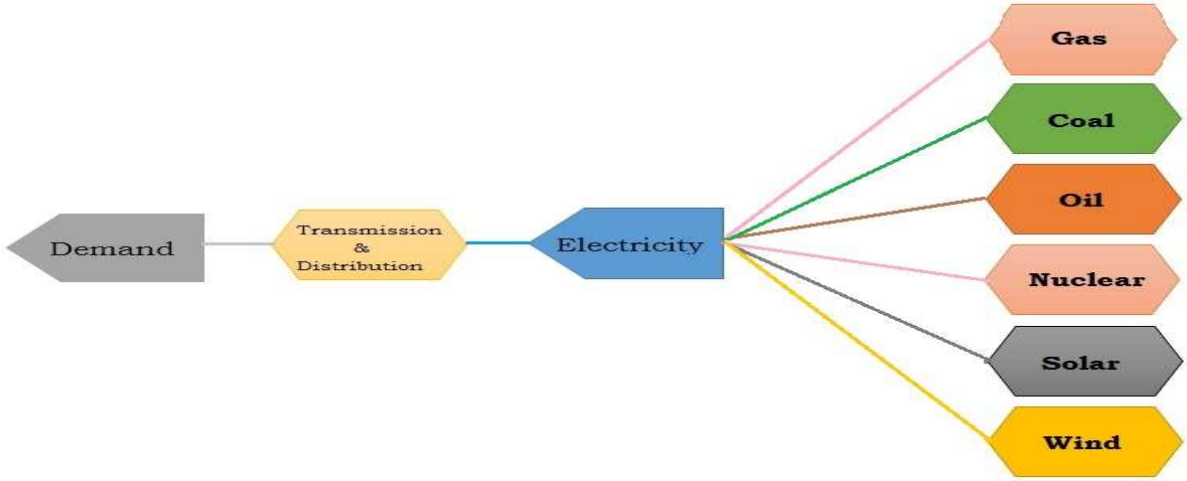


Fig. 1. Electricity module framework for Sindh LEAP model

3. Analysis of electricity demand

The electricity consumers in the province are categorised as domestic, commercial, industrial, agriculture and other services. The major portion of electricity generated is being consumed by domestic sectors, followed by industries.

Table 2 shows the historical sector wise electricity consumption for Sindh province for above mentioned sectors from 2008-09 to the year 2013-14 [2, 8]. In the year 2013-14 electricity consumption for the domestic sector was 9,213 GWh. The consumption of electricity by the commercial sector in the year 2013-14 was 1,938 GWh. The electricity consumption for the industrial sector in the year 2013-14 was 4,938 GWh. The consumption of electricity for the sector of agriculture in the year 2013-14 was 849 GWh. In the same way the consumption of electricity by the other government sector in the year 2013-14 was 902 GWh. The total consumption of electricity grew from 14,518 GWh in the year 2008-09 to 17,839 GWh in the year 2013-14, a growth of 81.38% [2, 8].

Table 2
Sectoral electricity consumption for the province Sindh (2008-14) in GWh

Year	Domestic	Commercial	Industrial	Agriculture	Others	Total
2008-09	7,505	1,575	4,012	690	736	14,518
2009-10	7,902	1,659	4,229	726	777	15,293
2010-11	8,211	1,722	4,387	750	806	15,876
2011-12	8,442	1,773	4,511	772	827	16,325
2012-13	8,687	1,911	4,804	858	932	17,193
2013-14	9,213	1,938	4,938	849	902	17,839

4. Analysis of electricity supply

Electricity supply for Sindh is relying on non-renewable resources with negligible share of renewable resources. Fossil fuels are providing full part in power generation-almost 100% of which natural gas and oil provide 70% and 28% respectively [3], while coal and nuclear has combine share of 2% in generation as shown in figure 2 (a). [2]

The shortage of electricity can be quantified by analysing the pattern of electricity demand and supply. Fig.2 (b) shows the electricity demand and the generation for the period from 2010-11 to 2013-14 [7, 9, 10]. The load shedding is carried out by the national transmission and dispatch company (NTDC) when the supply does not meet the electricity demand. The demand increased from 3,880 MW in 2010-11 to 4,368 MW in 2013-14, whereas the generation is 2,690 MW in 2010-11 to 2,825 MW in 2013-14[18].

a

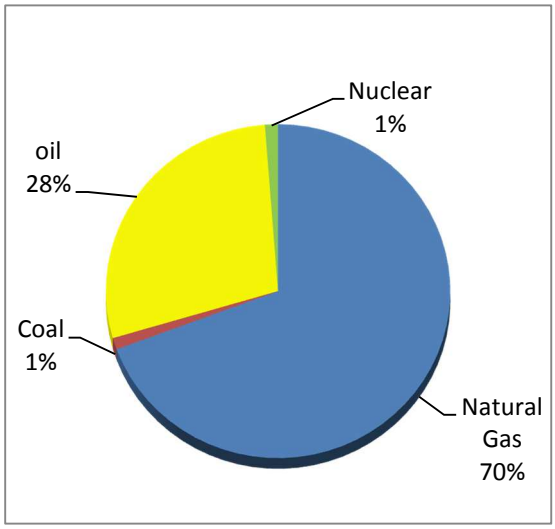


Fig. 2 (a) Fuel used for power generation

b

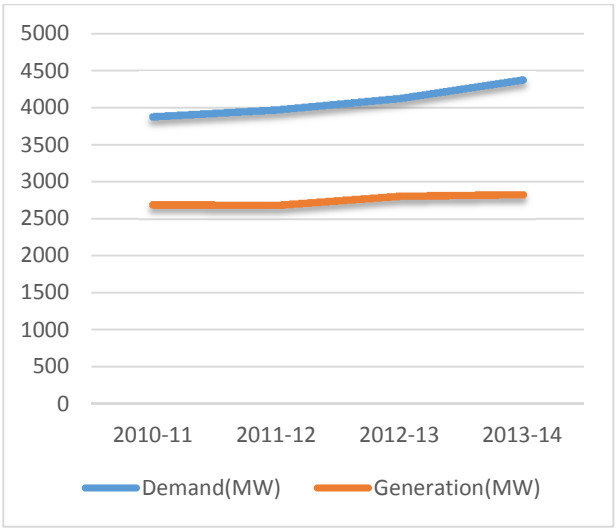
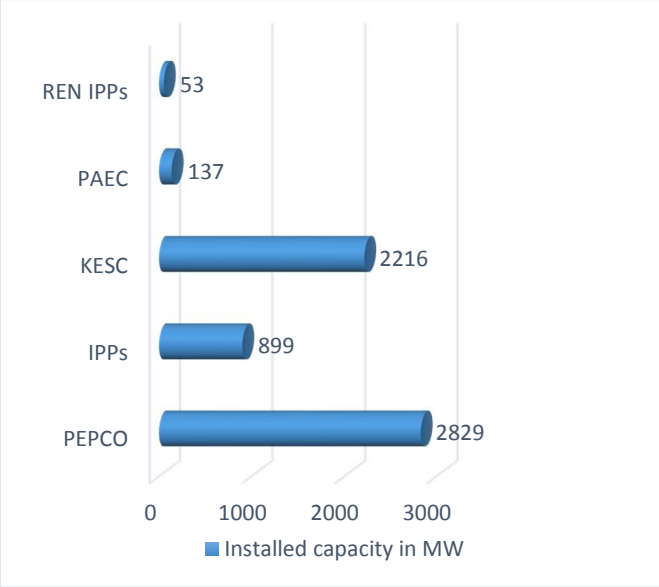


Fig. 2 (b) Electricity demand vs generation

Electricity supply of Sindh province is from federal government entities that are PEPCO, IPPs, KESC, PAEC and Renewable IPPs. Figure 3 (a & b) show the installed capacity of electricity supply of these entities in Sindh. PEPCO has maximum share of installed capacity of 2829 MW in Sindh followed by KESC which is 2216 MW. PEPCO mainly consist of gas and oil power plant and KESC consist of oil and gas power plant. IPPs are having installed capacity 899 MW which includes Engro energy with installed capacity of 217 MW, Foundation power of 185 MW, TNB liberty power plant 235 MW, Gul Ahmed with 136 MW and Tapal with 126 MW first three are based on gas fuel and rest are based on oil fuel. PAEC only deals with nuclear power generation having installed capacity of 137 MW. AEDB consist of wind power plant with installed capacity 53 MW [2]. Figure 3 b shows that natural gas has maximum share in installed capacity followed by oil. Coal has negligible share as compared to its potential. Wind also is sharing less part and solar zero instead of the fact that potential of these renewable resources along with coal is considerably large enough to lead oil and gas based installation. At present time the share of gas based power plants in Sindh is 56% followed by

39% of oil based power plants. The installation of nuclear, coal and wind based power plants is 2%, 2% and 1% respectively.

a **b**



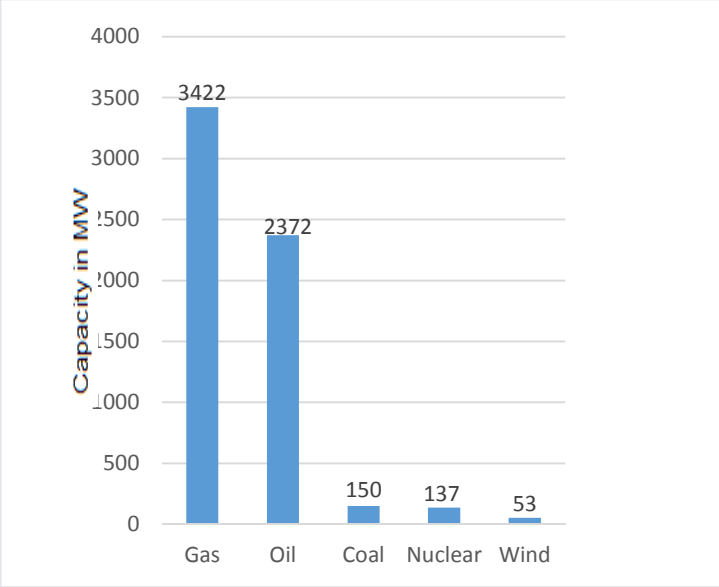


Fig. 3 (a). Installed capacity of electricity by supply entities.

Fig. 3 (b) Installed capacity of electricity by source.

5. Development of Scenarios

Scenario is a planning which is technically constructed to provide the future long term electricity framework and it deals with the unpredicted perspective need for power. In the research of energy long term energy headways hence provide a different narratives that advice a set of other possible situations for searching the future which may unfold in different way [6]. Each scenario is analysed and checked on the supply side characteristics and assumptions as per particular philosophy which resulted in development of specific energy planning.

Three supply side scenarios has been developed which includes Business As Usual (BAU), Renewable Rich (RR) and Thar Coal (TC) scenario over the study period 2014-2035.

5.1 Business as Usual (BAU) Scenario

BAU scenario portrays the electricity situation based on current trend and policies of government. In this scenario it has been assumed that development in the future will follow the same trend as in the past and no change will be made in the policies. All variables and parameters of power system will remain same including generation technology, efficiency, losses of distribution and transmission lines, and percentage share in the generation of electricity, the fuel, and installation of the plants, growth rate of electricity utilization and of economic growth [11]. The scenario will be dominated by natural gas followed by oil based generation technology. All current power installation will be generating at its full capacity. The installation will be increased according to government plans. Renewable energy contribution will remain weak [12]. Most power plants will be using existing technologies. The contribution of fuels used by power plants will be indigenous.

5.2 Renewable Rich (RR)

Currently the electricity generation is based on expensive imported oil and natural gas of Pakistan. Oil import bill has weakened the economy and major share of gas in power sector has caused gas shortage in other sectors mainly domestic [13]. As a solution to these problems this scenario has been generated to make the exploitation of untapped renewable resources that are wind and solar having huge potential [14]. In this scenario the reduction in share of gas and oil in power generation has been proposed. Addition of renewable plants is suggested the target is to replace expensive and depleting non-renewable resources share in power generation by green resources. The financial side for renewable energy should be looked into to understand. This energy scenario will require financial support to make sure the tapping of renewable resources.

5.3 Thar Coal (TC)

In the generation of Sindh's electricity the share of coal is negligible as compared to expensively imported oil and indigenous natural gas instead of the fact that coal has highest potential. Considering this situation an alternative scenario for the Sindh's electricity has been generated which is dominated by the coal from coal deposits in Thar Desert [15]. This scenario focus to direct electricity sector towards least cost coal generation technology and emphasis shifting thermal mix towards coal. It suggests government move to coal production so as to decrease its oil import bill and overcome the circular deficits. In this sector Sindh has a huge quantity of coal reserves estimated to be 175 billion tons only from Thar, which is not utilised yet. In order to curtail power shortage new power plants will have to be installed by the province. In this regards government has planned to move 4200 MW oil plants towards coal fire plants by using this huge reserve [16].

6. Results and Analysis

6.1 Demand projections

The forecast of electricity demand for three scenarios developed viz. BAU, RR and TC is shown below in figure 4. The demand is forecasted up to the year 2035 considering 2014 as base year. The LEAP's forecasted demand for all three scenarios is same that is 24.8 thousand Gigawatt-hour in the base year and 53.8 thousand Gigawatt-hour in the end year, with the growth of 116.93 % over the base year.

The sector wise electricity demand for BAU, RR and TC is found to be same as shown in figure 5. The percentage growth of consumption for the domestic sector in 2035 over the base year is 152 %. The percentage growth of consumption for the commercial sector in 2035 over the base year is 152 %. The percentage growth of consumption for the agriculture sector in 2035 over the base year is 75 %. The percentage growth of consumption for the industrial sector in 2035 over the base year is 141 %. The percentage growth of consumption for the other government sector in 2035 over the base year is 144 %.

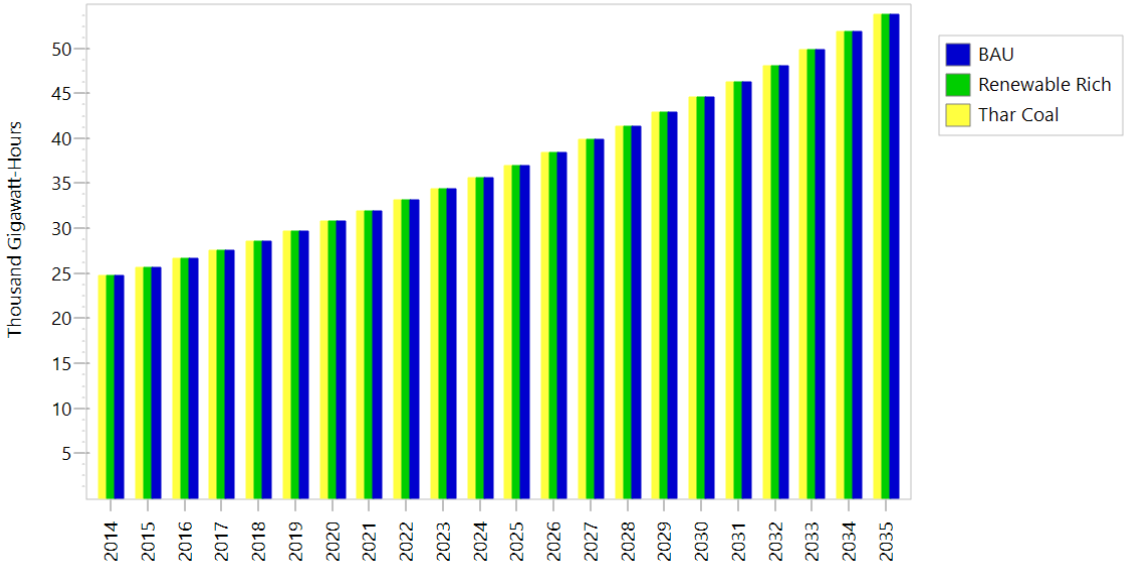


Fig. 4 Electricity demand for various scenarios.

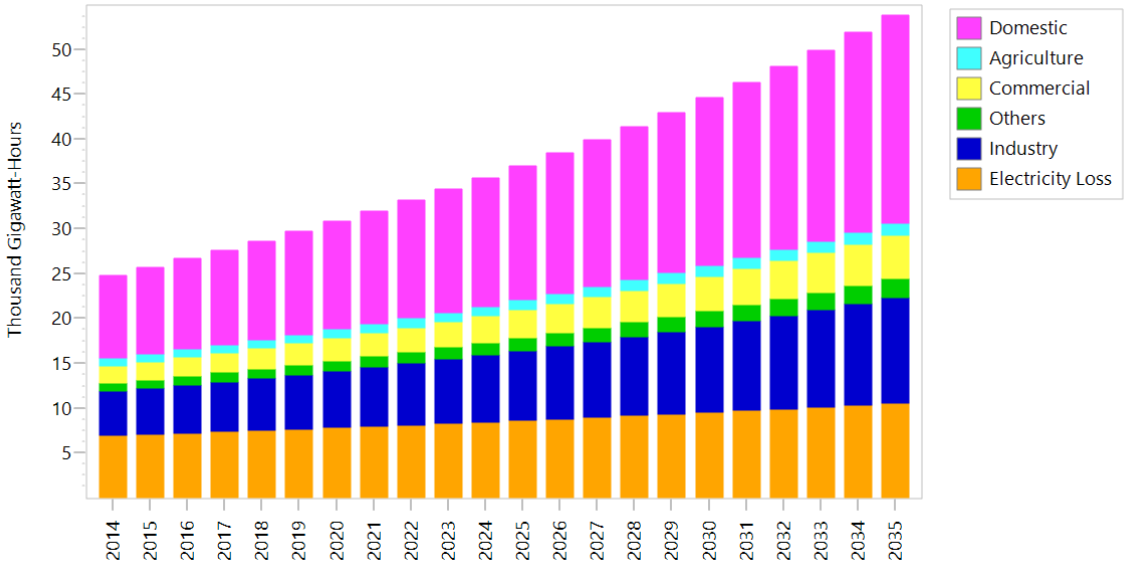
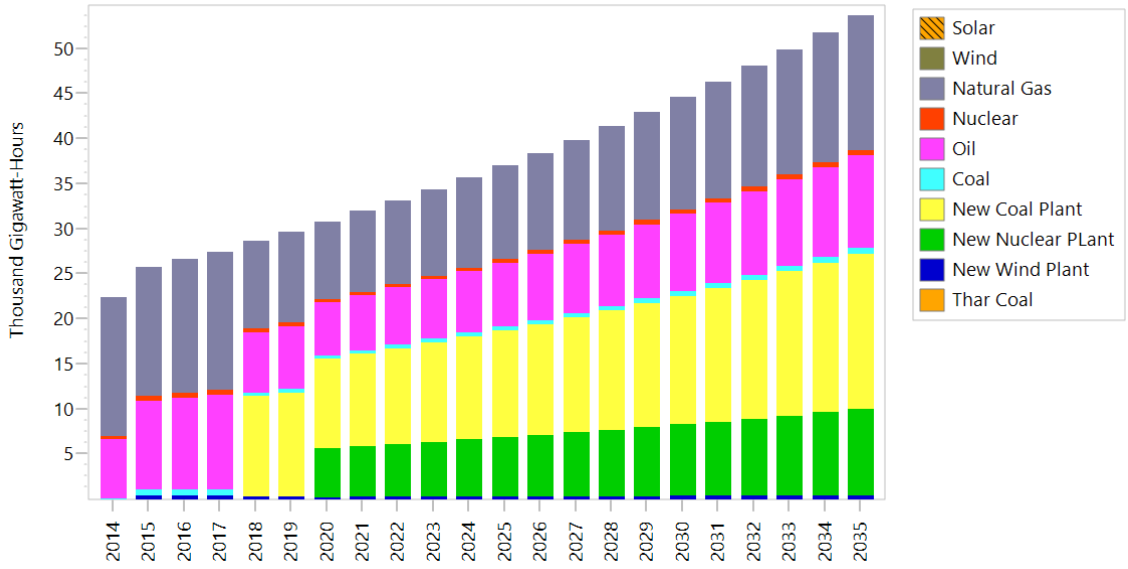


Fig. 5 Sectoral electricity consumption for BAU

6.2 Comparison of electricity generation by various scenarios

The figure 6a-c indicates the generation of electricity for three scenarios viz. business as Usual (BAU), Renewable Rich (RR) and Thar Coal (TC). The electricity production by all scenarios in the base year is 22.4 thousand Gigawatt-hour and the projected electricity generation in the targeted year by the RR and TC is 53.8 thousand Gigawatt-hour and by BAU is 53.7 thousand Gigawatt-hour. The percentage growth of electricity generation is 140.18 % in the end year over the base year by all three scenarios. In the comparison of BAU and RR the electricity generation from natural gas is reduced by 10.4 thousand Gigawatt-hour in RR, in the same way the electricity generation by oil is reduced by 7.2 thousand Gigawatt-hour. Similarly in comparison of TC and BAU the electricity generation from natural gas is reduced by 8.9 thousand Gigawatt-hour in TC and the electricity generation from oil is reduced to 6.2 thousand Gigawatt-hour in TC.

a



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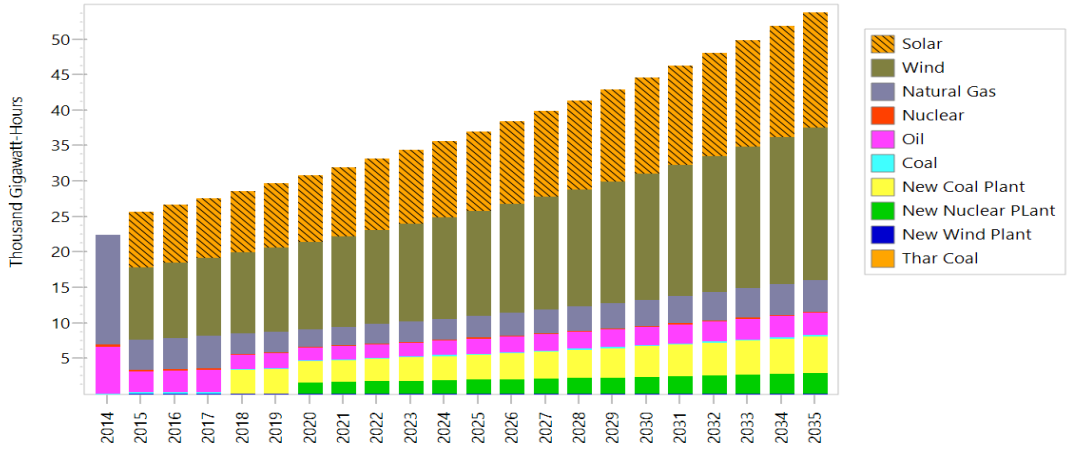

c

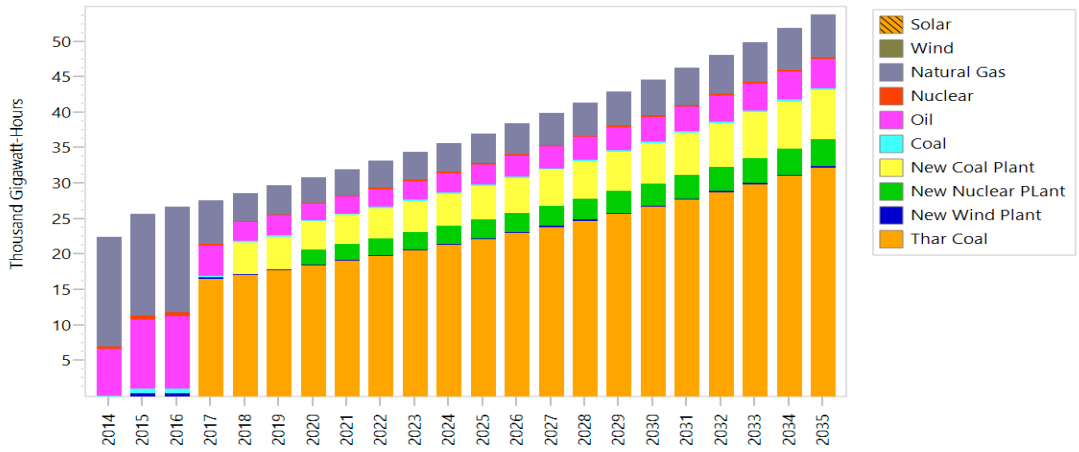

Fig. 6 (a) Electricity generation in BAU, (b) Electricity generation in RR (c) Electricity generation in TC

7 Discussion

In this analyses the current electricity situation in the province Sindh has been presented. Electricity demand and supply data for the last 6 years has been collected. Based on available data three supply side scenarios are developed for the year 2014-35 which includes BAU, RR and TC, considering 2014 as base year. Province's demand for various sector is also forecasted for the targeted year. The comparison study of all three scenarios indicates that RR scenario is environmental friendly and it decrease the share of electricity generation from oil and natural gas which cause very expensive electricity generation. The TC scenario gives an idea of diverting from existing source to the coal majorly Thar coal as its potential is not exploited yet. In the base year 2014 the total electricity production was 22.4 thousand GWh. The forecasted values of electricity production for the targeted year 2035 for various scenarios are: BAU 53.7 thousand GWh, RR 53.8 thousand GWh and TC 53.8 thousand GWh. The electricity generation share for base year by natural gas was 68.5 %, oil 29.3 %, nuclear 1.5 % and coal 0.7 % in BAU scenario. In the end year 2035, electricity production by natural gas decreased to 27.7 % in BAU and 8.3 % in RR and 11.1 % in TC. Electricity generation by oil reduces to 19.2 % in BAU and 5.8 % in RR and 7.7 % in TC. The electricity generation by coal in BAU is increased by 33.3 % and in RR it reduces to 10 % and TC it increases by 73.3 %. Renewable resource has negligible share in the BAU, while in RR it has the combine share of 70 %.

8 Conclusion and Recommendations

In this paper the current electricity demand and supply has been studied based on the available data and assumptions electricity demand of the Sindh province for various sectors is calculated and it found that the demand will increase by 116.93 % over the base year 2014. This study has successfully modelled BAU scenario and two alternative electricity generation scenarios using LEAP model for period from 2014 to 2035. Results shows that alternative scenarios are better than BAU from environmental impacts and cost analysis. The alternative scenarios give an alternate path to overcome the ongoing electricity crisis in the province, by

reducing the high import bill of imported resources and diverting towards indigenous resources. RR scenario has described enough potential of renewable resources that are solar and wind with the combine potential of more than 100,000 MW [17]. TC scenario is another option to move towards our own resource instead of importing the coal at high rates. The estimated potential of Thar coal reserves is found to be more than 100,000 MW. This huge untapped potential of coal can be the best solution available for the policy makers to overcome electricity crisis.

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