US.-Pakistan Centre for Advance Studies – Energy
National University of Sciences and Technology
Sector H-12 Islamabad

Quantification of Various Impacts due to Climate Change on the Electrical Power System of Pakistan

Project PI: Dr. Syed Ali Abbas Kazmi
Assistant Professor

Research Assistants: Mahad Malik, Hamza Nasir

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Chapter 1 INTRODUCTION

The world is getting heated up and humans are to be blamed for. The increase in global temperature and the change in climate has a massive impact on the environment as well as humans. The carbon emissions from different sources are the major reason why the global temperature is increasing, and global warming has reached to its threshold value. The world is reaching to the phase where it is important for every country to contribute positively towards this major issue. As soon as the countries are getting aware related to the condition of climate and ozone layer and how much has it affected the environment and the people, there are eager to contribute towards saving the environment.

Global warming is not a phenomenon which is discovered recently. The time has come now where this issue is going out of hands and quick and instant measures if not taken may lead to severe climatic issues, increased global warming and health issues as well. The major cause for the global warming is the greenhouse gas emission which is incontrollable. The major share in greenhouse gases is of CO_2 and majority of it is produced by burning the fossil fuels.

The major and the most important thing the world can do is to reduce the carbon emissions as much as possible because they are the heart of the climatic destruction. The carbon emissions per capita increases with the increase in population. The population is increasing with a rapid rate and so will the carbon emissions. So, the need of the moment is to make some strategy, or some agreement and the whole world agrees on such efforts. This is not just the problem of a specific country, this is a global problem, and everyone must contribute in this regard. Certain climatic varying targets were set by the European union in EC 2014 which stated that by the year 2030, the greenhouse gases emissions must reduce 40% and the renewables energy target much reach 27% rather than utilizing and relying on the fossil fuels which is the biggest source of greenhouse gas emission [1].

Different countries have proposed their own different targets of reducing the harmful gases emission and certain targets were set by them. The US set their targets of emission reduction from 26% to 28% till 2030. Likewise, the European union aimed at the greenhouse gases reduction of 35%. Japan set their ambition of 26% reduction in greenhouse gases till 2030 as compared to 2005 level. Finally, South Korea set their targets and proposed a reduction of 37% in comparison to business as usual levels till 2030 [2].

The Chinese government came up with a suitable solution for this kind of situation. They contributed to the situation with a plan that the coal-fired power plants must be replaced as early as possible and the power to be generated must be generated in such a way that low carbon emissions are emitted. The renewable energy which is the core strategy of the Chinese energy system reforms contributed to such a plan. This is not as easy as it looks like. Renewable energy having the stability issues and the instability issues regarding the utilization of power are the two major concerns to be resolved [3].

The Alternative energy development plan (AEDB) was made for the year 2012-2021. The ministry of energy came up with this plan and it stated that a policy should be made regarding the deployment of renewable energy. The main idea behind this plan was that by the year 2021, the share of renewable energy must increase to 25% in the total power consumption of the country [4].

Pakistan, a country most likely to be seriously affected due to global warming and has taken its measures regarding the protection of environment. Pakistan has a vast potential of clean energy. The renewables once deployed in the country can help resolving the energy shortfall as well as the economy will boost up to quite an extent [5]. The oil import from foreign is the major strain to the economy of the country. Renewable energy once deployed in the country may lead to reduction in the greenhouses gases and not only it is saving the environment, but the renewable energy will then become cost-effective in the country which will further result in the better energy security.

So, the need of the time and aim of this research was to quantify the impact of climate change on electrical power grid of Pakistan with respect to CO_2 emissions, generation, installed capacity and energy mix from different resources for different years. This report aims at benefitting the country from environment perspective and leads towards reduction of respective electricity crisis. Quantification of climate change on power system of Pakistan is vital towards reducing the fossil fuel and CO_2 emission impacts complemented with renewable generation. Many policies have been made on the renewable energy utilization, however none of them was implemented with full spirits.

The world-wide efforts on the quantification of various impacts due to climate change has seen the limelight. The major motivation for this study was that many of the countries have considered the impacts of climate change quantitatively. Though, quantifying things makes it easier for the policy makers to come up with a policy. Our target is quite the same. Quantifying the impacts due to climate change will help the policy makers to come up with a suitable policy for the country which will help the country in not only saving the environment but will also help in the longer run.

In the context of Pakistan, the limitations in the quantification is that it is not properly addressed anywhere. No such efforts are done for the quantification with respect to the climate change. So, there was a need for this as it has an indirect impact on the power grid of Pakistan. Once, quantification is done, the impacts can be considered separately which would help in achieving better efficiency of the power system and its components.

The power requirement of the country is increasing with a rapid rate. The major portion of the generation is done with the help of fossil fuels which is harmful for the environment. The motivation of the research is to come up with such a strategy that the energy shortfall can be minimized, and the carbon emission can be reduced to the required percentage. The quantification of the energy mix required power generation and the carbon emission once done could be very useful in not only resolving the energy shortfall of the country, but it will also be helpful in reduction of the carbon emission which is the cause of destruction of the environment.

Chapter 2 LITERATURE REVIEW

2.1 Policies on Energy in Pakistan

Pakistan is a country yet to be familiarized with the concept of quantification. If we see from the perspective of the world, there is a lot of work done on the quantification of the impacts due to the climate change. Most prominently, the Grasiosa Island-Azores have done the quantification of different impacts due to the climate change. They have done the quantification of every harmful gas like SOx, NOx, CO_2 etc. With the help of this, it is easier to understand the impacts of different emissions on different systems of the islands. The goal was to assess the environmental impacts on the electrical grid of Grasiosa island [6].

Table 2.1 ***Policies on the Energy and Power Sector of Pakistan***

Year	Policy	Important points	Lacking points	Environmental issues	Prospects
1967	Liefticnk Report	New thermal power plants	Renewable integration	Nil	N/A
2005-2030	Energy Security Action Plan	Security of energy supplies	Instability and pricing	Nil	N/A
2025	Vision 2025	Increase share of indigenous resources	Energy security concerns	Considered	Environmentally suitable options
2011-2030	^NPSEP	Technical and environmental issues	Environment briefly considered	Considered	Renewable Generation
2005-2030	National Energy Security Plan	Expanding of indigenous resources	Fossil fuel based energy generation	Clean fossil fuel generation	Increase in renewable % from 20 to 36
2010-2030	Pak-IEM	Advance Pakistan's energy system	Environment	Nil	N/A

*IEM=Integrated Energy Management; ^NPSEP= National Power System Expansion Plan

There are many efforts being done in this field at the organizational and governmental level in Pakistan for the betterment of power sector and appropriate planning and development of the resources for the core purpose of better energy utilization and development. Many policies were made by the government in this regard. The very first of the energy planning effort which took place in Pakistan was Pakistan integrated energy model (Pak-IEM). It provided the Pakistan energy system plan that how Pakistan can advance in energy sector over the next 20 years.

The limitation of the Pak-IEM was that it has not seen the power sector with respect to the environment. Further other energy plans include Vision 2025, NESP plan, National Power System Expansion Plan (NPSEP). Many power policies were made in the power sector as well. Some of them include power generation policy, hydro power policy, policy for new

IPP's and policy for power genration 2002. Policy for development of renewable energy generation in 2006 was made. This policy was made to boost up the generation of clean energy from renewables like wind, hydo, and solar etc [7].

Table 2.1 shows the glimpse of major energy and power policies of Pakistan. The policies which we have used in our research are Vision 2025 and NESP plan. The main cause of considering these two policies were solely on the basis of increased renewable generation and their focus towards saving the environment. The increase in the renewable generation not only fills up the power requirement of the country, in addition it is ideal for the environment as well. The increase of renewables in energy mix and the increase in share of indigenous resources are the core things which are now required in a policy and the practical implementation of this needs to be done as soon as possible.

2.2 Reasons for the failure of Energy and Power Policies of Pakistan

The trend of power and energy policies in Paksitan arose sharply in 1994. There was a need of those policies because the country was in unstable condition. The weakness in the institutions of Pakistan and limtations in the required skill set of the concerned persons was one of the major cause of failures. The persons with required professional capabilities and expertise in the relevant fields available also faced limiations in beaurucratic/technocratic setup, complimented with the absence of required resources makes the policies inefficient. The energy planning approach put less focus on the manpower. The policies were made, however they were not so successful as they lacked integrated planning of power and energy. The followed policies became just like old wine in the new bottle. These were major reasons why the policies were never successful. The issues regarding the ministries and lack of co-ordination among the persons did not let a single energy policy document to the success [7].

The making of policies on the energy and power sector of Pakistan started in 1994 and majority of those policies were about cost effective production of energy and the utilization of primary energy resources. In the making of policies, no environment related objectives from the perspective of power sector of Pakistan were considered and few proper studies were conducted for the national policy making. Due to the lack in policy making the outcome was never up to the mark and that is the major reason why these policies results in achievement of less benefits than the aimed ones.

Chapter 3 CURRENT STATISTICS

3.1 Current Electricity Generation Profile of Pakistan

The Table 3.1 shows that analysis is done on the previous data of the electricity generation extracted from Pakistan Energy Yearbook for each resource. The resouces includes Hydro, Thermal, Nuclear and Renewables. The total installed capacity of the previous five years are also calculated and the production of each resource out of the total installed capacity is shown in the table. It shows that the deployment of renewables in the national power energy mix started in the year 2014 and onwards with a rapid increase till 2016-17. The generation from thermal is increased approximately 4500MW from 2012-13 to 2016-17. The total installed capcaity is increased rom 22812 MW to 29944 MW from 2012-13 to 2016-17 [8].

Table 3.1 ***Total installed capacities of different energy resources (2012-2017)***

Year	Total installed capacity (MW)	Production from Hydro (MW)	Production from Thermal (MW)	Production from Nuclear (MW)	Production from Renewables (MW)
2012-13	22812	6773	15289	750	0
2013-14	23530	6893	15887	750	0
2014-15	23759	7030	15541	750	438
2015-16	25889	7122	17115	750	902
2016-17	29944	7129	20488	1090	1237

The Figure 3.1 illustrates the total generation profile of Paksitan from 2000 to 2025. The generation has increased from 16000MW to 35000MW approximately for the year 2000-2025 [8]. However, Our generation curve however lacks the consumption if this typical generation process is followed and lack of investment in overhauling and expansion of transmission and distribution systems has observed.

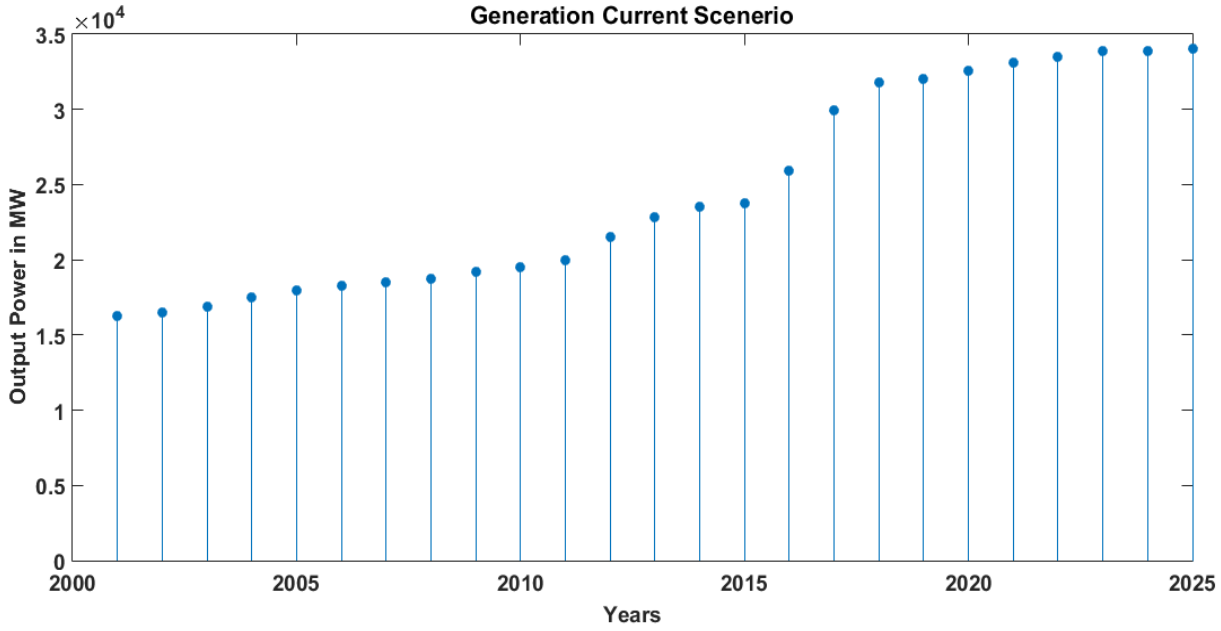

Figure 3.1 ***Total power generation in Pakistan in MW (2001-2025)***

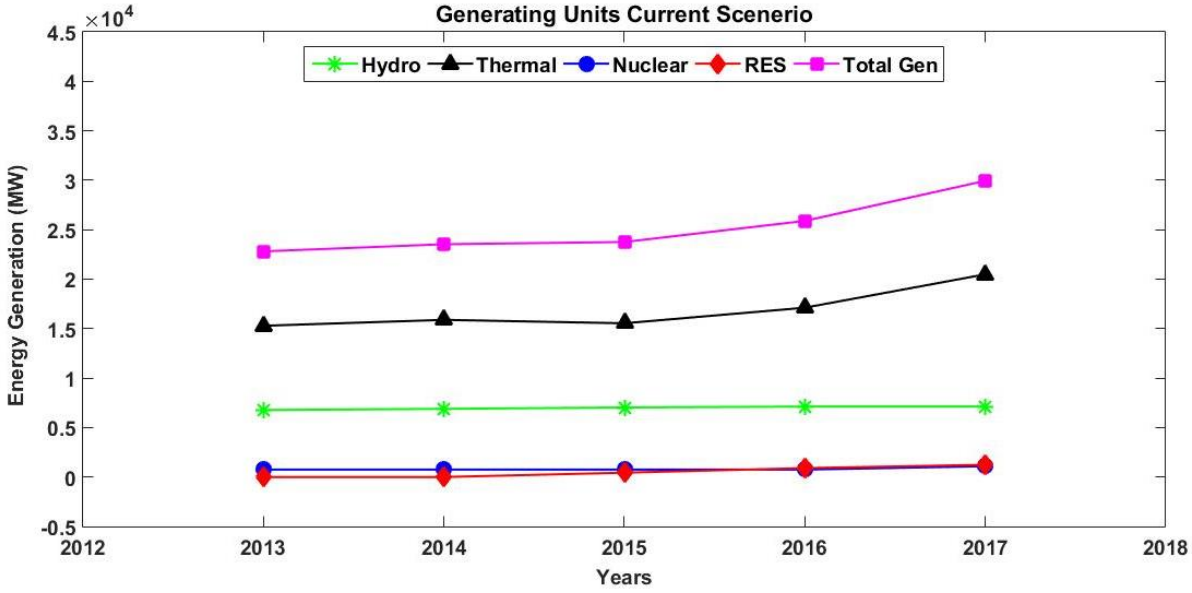

Figure 3.2 ***Generation of energy from different resources in Watt-hour (2013-2017)***

The Figure 3.2 shows the generating units current scenerio of Pakistan. It is observed that the total generation is increasing with a rapid rate from 22000MW to 30000MW from 2013 to 2017. The total required generation is increasing promptly. Likewise the generation from thermal is also increasing with a rapid rate and keeping in mind, thermal is the key source of carbon dioxide emissions. The change in hydro from 2013 to 2017 has not seen quite a lot of change as a hydro project atleast takes 5-7 years in completion. The slight increase can be seen in the nuclear and renewables as the deployment of renewables has begun from 2014 and onwards [8].

Table 3.2 ***Total installed capacity including differnt resources in Pakistan in % (2012-1017)***

Year	% Hydro (MW)	% Thermal (MW)	% Nuclear (MW)	% Renewables (MW)
2012-2013	29.69	67.02	3.28	0
2013-2014	29.29	67.51	3.18	0
2014-2015	29.58	65.41	3.15	1.84
2015-2016	29.50	66.10	2.89	3.48
2016-2017	23.80	68.42	3.64	4.13

The Table 3.2 illustrates the percentage of different resources in the total power generation of Pakistan. The percentage generation from hydro has reduced from 29.69% to 23.80% from the year 2012-13 to 2016-17. The percentage of renewables has increased significantly to a noteable figure. In year 2012-13 and 2013-14, there was no renewable generation observed, however it showed its presence in next 3 years and has increased upto 4.13%. Slight increase in the percentage of thermal and nuclear can be seen from 2012-13 to 2016-17 [9-10].

3.2 Emissions From The Resources for Electricity Generation

Table 3.3 ***Different emissions of gases in Kilo-tons/year (2005-2030)***

Year	NO_X	CO_2	SO_2	PM 10	PM 2,5	TSP
2005	640	136631	954	733	581	1111
2010	854	161395	1381	863	655	1403
2015	1278	320010	2360	1064	766	1861
2020	1794	390200	3687	1313	924	2344
2025	2353	478150	5281	1629	1126	2924
2030	2957	530000	8255	2213	1477	4040

The Table 3.3 illustrates the differnt emissions of gases in kilo-tons per year. It is observed that Nox has increaed in a huge amount from 2005 to 2015 and is expected to increase with a rapid rate till 2030 in the BAU scenerio. Similar scenerio can be observed in the case of SOx. It is expected to increase upto 8255 kilo tons per year. Particulate matter 10 and Particulate matter 2,5 case is not different than this. Increasing with such a rapid rate. Total suspended particles (TSP) is also has also expected to increase with a rapid rate from 2005-2030 [9-11].

Table 3.4 ***Different emissions of harmful gases in Giga-grams Gg (2008-2012)***

Year	NO_X	SO_2	N_2O	CO	NH_3	CH_4
2008	223.62	743.97	0.327	62.71	1.15	1.13
2009	251.25	861.92	0.370	67.13	1.34	1.17
2010	269.47	944.65	0.311	69.65	1.47	1.07
2011	N/A	N/A	0.316	N/A	N/A	1.05
2012	N/A	N/A	0.316	N/A	N/A	1.05

The table 3.4 encapsulates the different emissions of harmful gases in giga grams from the time period of 2008-2012. It is shown that the NOx and Sox have increased from 2008 to 2010. While N_2O and CH_4 has reduced. N2O hasreduced from 0.327 to 0.316 Gg from 2008-2012 and CH_4 has reducede from 1.13Gg to 1.05Gg from 2008-2012. The carbon monoxide (CO) has also increased repidly from 2008-2010 [9-11].

3.3 Policy Impact and Limitations of Core Data

Problems in energy and power policies: Where is Pakistan lacking?

There were certain factors in which Pakistan lacked in the policy making. Many policies regarding the power and energy system of Pakistan were made, however they lacked the proper integrated planning approach encapsulating power sector of Pakistan. The policies are to be planned according to the needs of the country, which must be aligned with best international practices and suitable for Pakistan's environment and requirements. Pakistan being a unique country can never use the complete policy or the energy model of any other country.

The policies made faced a lot of issues regarding the consistent behaviour and implementation. Due to these reasons the country not only faced the energy crisis and electricity shortfall, but the economy of the country was also affected to quite an extent. The energy modelling tools were never implemented with full spirits and country had to bear the loss for that. Pakistan has always lacked in the policy making or the formulation phase of the policy which is the major part in building up a policy.

Chapter 4 METHODOLOGY

4.1 Analysis of Power System Polices to date

4.1.1 Case 1-National Energy Security Plan (NESP 2005-2030)

A comprehensive strategy made by the government of Pakistan consists of various objectives. Some of them were objectives so they fall under the category of short term and similarly the medium term and the long term objectives. The core purpose of NESP was to replace the inefficeint energy sources with the efficient ones. This could be done by increasing the share of less volatile and cheaper resources. Also, the increase in share of renewables would be as efficient as anything. As this plan was from the time period of 2005-2030, so it was decided that the share of alterantive enrgy and renewables must increase from 20% to 36% by the end of 2030 [12].

4.1.1.1 NESP Salient Features

The important features of the NESP plan includes that the energy mix of the country must be expanded in such a way that greater share of hydro, coal, nuclear and renewables must be initiated. In other words, the diversification of indigenous resources was needed to be done. The initialization of the large-scale hydro power projects and some major programmes needs to be done for the better and efficient utilization of hydro which is a major contributor in the clean energy of Pakistan. Run of river projects were also encouraged. With the help of more utilization of hydro power, not only the energy shortfall in the country would be minimized and also the water could then be used for irrigation aiming at agriculture purposes. The target for nuclear set and the power generation from this resource was aimed at 8.8GW by the end of 2030 [10]. For the achievement of this target, intensive measures were taken to explore and mine uranium which is the basic element to produce nuclear energy.

4.1.2 Case 2-Vision 2025

For an effort to make Pakistan to become a leading economy Asian country, Vision 2025 came into being. This consisted of goals having seven elements which would ensure the sustainable development of the country. A major pillar in those seven elements included the energy security by the end of 2025. The aim of vision 2025 was to eliminate the shortfall of electricity from the country by doubling the generation capacity to 45000MW so that the people can get uninterrupted and affordable access to the electricity. This would not only fulfil the energy needs of the country but 90% of the population of the country can get the access to electricity.

This plan not only aimed at eliminating the shortfall of the electricity and also focused on the cheaper power generation by increasing the role of indigenous sources to 50%. Food and water being the key concerns for the future development, the vision included energy security in that regard too. However, many problems were faced by the country which includes unstable law and order, the vast increase in population, inefficient and inconsistent policies and lack of skilled manpower. Solving all these problems would ensure the success of the plan and that was not an easy task to get through [13].

4.1.2.1 Goals of Vision 2025:

This plan endeavour to achieve the future generation of 25000 MW by the end of year 2025. This would abolish the load shedding from the country by the year 2018. The major thing to do was to perform the optimization of the energy mix by utilizing all the resources of power generation like oil, coal, gas, PV, nuclear, hydro and biomass and preferring the indigenous resources which would boost up the economy of the country. The unique concept of environmentally sustainable options needed to be considered. The accomplishment of two large hydropower projects and the utilization of Thar coal was the important goal of the Vision 2025.

The clean energy utilization as a replacement for the fossil fuels to meet the electricity demand was a major part in the vision 2025. The nuclear power projects need to be completed by the end of 2025 [13]. The saving of energy by reducing the transmission and distribution losses and accurate use of controls. Furthermore, the use of energy efficient devices and demand side management was also one of the important aspects of this plan. Providing incentives to the people for reducing the peak curve and using energy efficient appliances. Last but not the least, the strengthening of the regulatory reforms and institutional framework to improve the overall efficiency was one of the goals of the plan.

4.1.3 Case 3-National Power System Expansion Plan (NPSEP 2011-2030)

The National power system expansion plan was undertaken by NTDC to meet the growing demands of the country and to reduce the demand and supply gap. NTDC made a contract with consultants SNC-Lavalin to come up with a plan which would not only consider the technical and economic aspects, and also the environmental aspects as well for the periods of 2011-12 to 2029-30.the focus was to devise such a plan in which hydro must be utilized as much as possible along with the inception of other energy resources such as nuclear, thermal and renewables to meet the growing demand of the country and fulfil the demand and supply gap.

The NPSEP was envisaged in the context of utilization of new generation facilities, focusing on the transmission and distribution requirements to meet the future demand of the country. This plan was not just a short-term plan with short term goals, and it consisted of long-term goals. The short-term goals consist of the elimination of load shedding and long-term goals comprised of expansion of electricity sector. Tharparker coal needs to be utilized as much as possible with support from international organizations offering higher taxes for the embryonic development of additional plants.

The NPSEP also endorsed to check the feasibility of hydropower in the country. Furthermore, it also identified the reason for the natural gas shortages and how it can be minimized by exploration of the natural gas in the country. A plan needs to be implemented to minimize the shortfall of the natural gas [13].

Chapter 5 RESULTS AND DISCUSSIONS

5.1 Our plan with respect to NESP 2005-2030

The NESP, an alternative energy perspective, was a Government designed strategy which consists of short term, long term and medium term objectives. The important features of the NESP plan includes that the energy mix of the country must be expanded in such a way that greater share of hydro, coal, nuclear and renewables must be initiated.

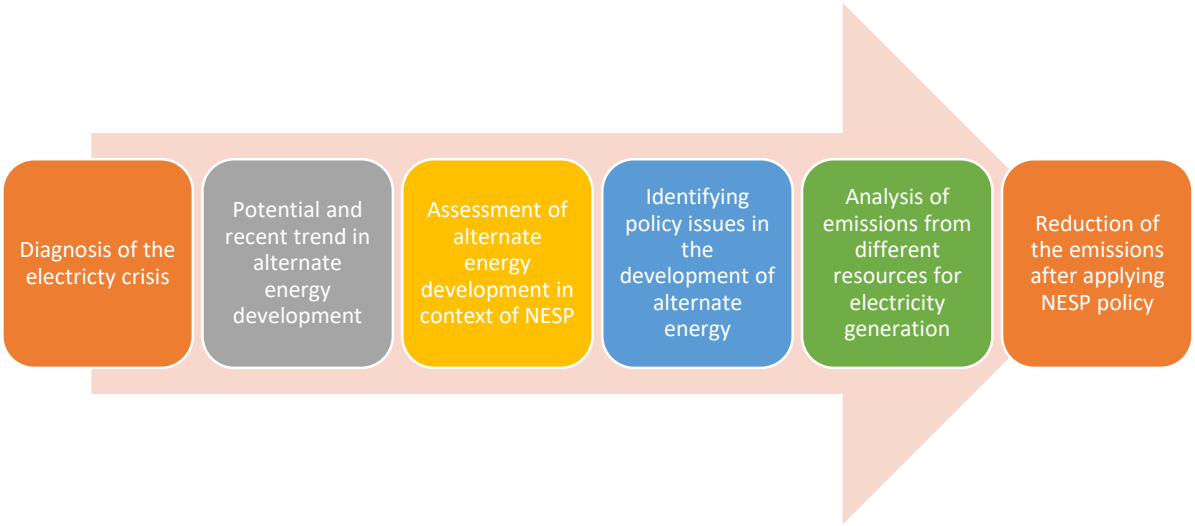

Figure 5.1 ***Our plan with respect to NESP in a flow diagram***

Our methodology (shown in Figure 5.1) is basically to perform the successful utilization of NESP plan and its salient features with an addition of an important factor i.e. how the energy mix of the country will affect the environment and what can we do to save the environment. We will work to analyze the different harmful emissions from different resources of electricity generation. We will calculate per kilowatt value of the harmful emissions and check how much of the energy resource is affecting the environment. Furthermore we will work to make a strategy of what measures we can take to reduce these emissions and save the environment [14].

Our country has become 104th memeber to sign the Paris agreement in Nov, 2016. The members of the agreement are obliged to keep the global warming temperature well below 2 degrees centigrade. So, we intend to include the aim of Paris agreement in our research and think of measures and strategies to reduce the harmful emission which in the long run is saving our environment by keeping the global temperature in the required limits as set in the Paris agreement.

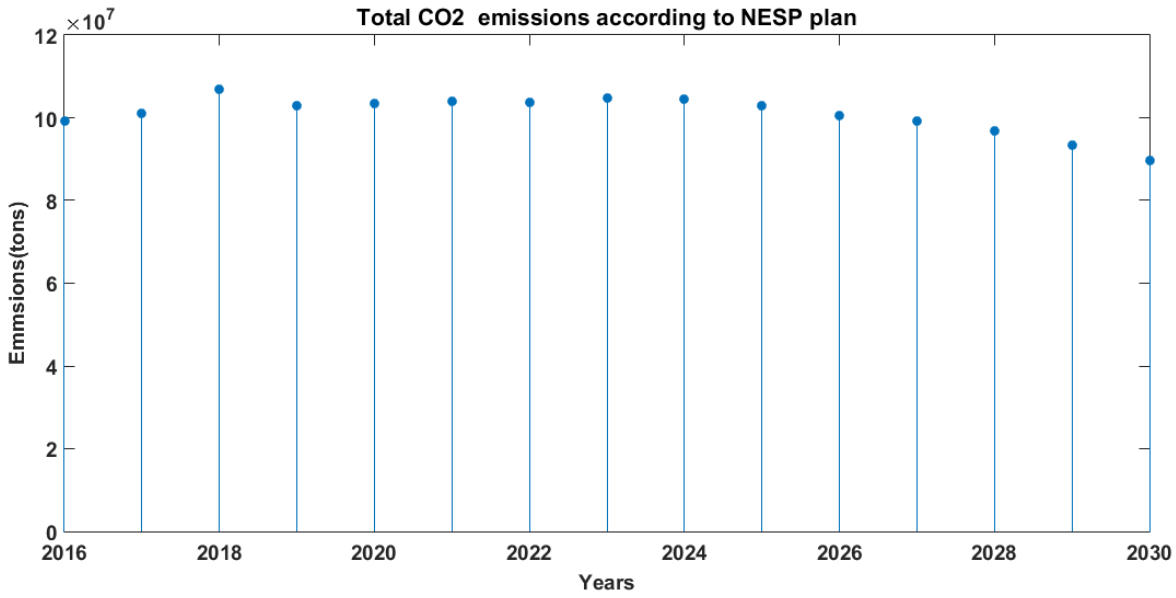

Figure 5.2 ***Carbon dioxide emissions by power generation in tonnes according to NESP plan (2016-2030)***

The above shown Figure 5.2 embellishes our plan with respect to the NESP plan. The amendments done in NESP plan are shown in this figure with one perspective which is the carbon dioxide emissions. The carbon dioxide emissions by power sector i.e. 26% of total emissions in tons are shown in the figure. The carbon dioxide emissions are decreasing sharply from 2024-2030. This is due to the deployment of renewables and the clean energy. Hydro plants will be running, and clean energy will be generated which will reduce the carbon emissions and save the environment [15-16].

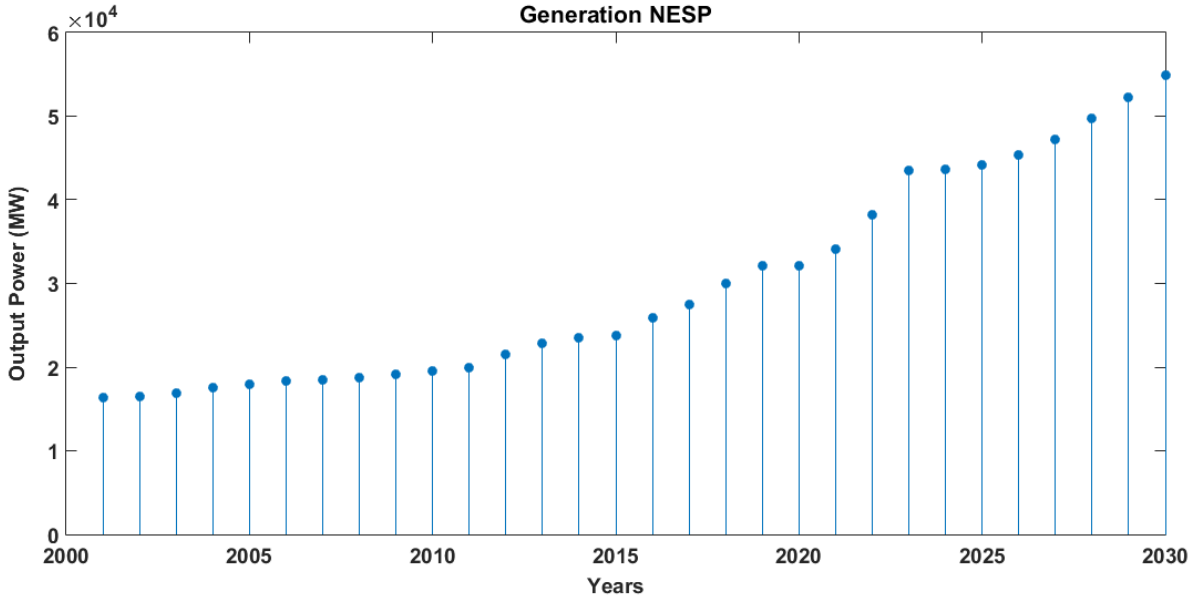

Figure 5.3 ***Generation of power in Pakistan with respect to NESP plan in MW (2001-2030)***

Hence, the total CO_2 emission from overall country emissions ranges from 35524 kilo-tons/years out of 136631 kilo-tons/years in 2005 to an estimated value of 124319 kilo-

tons/years (out of 478150 kilo-tons/years) in 2025, and 137800 kilo-tons/years (out of 530000 kilo-tons/years) in year 2030, in case of business as usual, respectively [10, 15]. Kindly refer to Table 3.3 for reference base values.

The Figure 5.3 adorns the increase in generation with respect to the NESP plan. It is visible that the generation is increasing with a rapid rate from 2000 to 2030 that can balance our consumption. In 2000 the generation capacity is 17000MW and in the year 2020 it will increase up to 32000MW and finally in 2030 it will be 54000MW. The generation capacity will increase as per the NESP plan to follow the predicted consumption scenario [14].

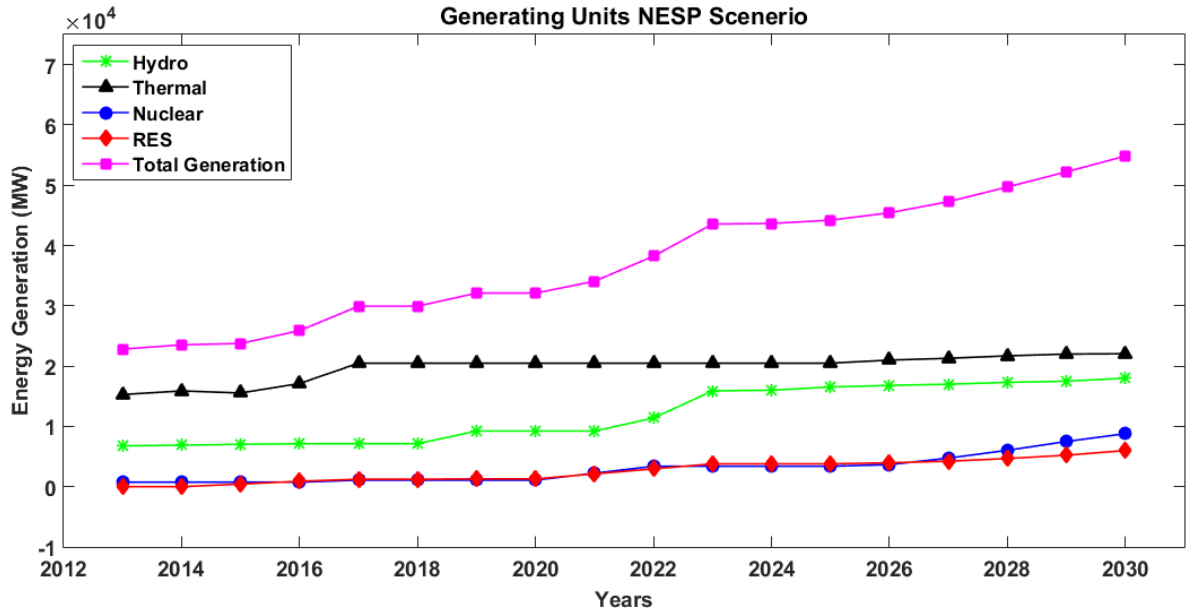

Figure 5.4 ***Energy generation with different resources (2013-2030)***

The Figure 5.4 illustrates the generating units of each resource in the NESP scenario. The total required generation is increasing with a rapid rate of 5% approximately. In 2013 it was 22000MW and by the end of 2030 it is predicted to be around 50000MW. The thermal generation was increasing previously so by the deployment of clean energy and renewables the thermal generation is kept constant which will not only reduce carbon emissions and also help in saving the environment. Hydro power projects are being implemented which has increased their respective share in the generation mix. Similarly, the trend of alternative energy that is utilized, and renewables deployment across horizon till 2030 can be illustrated in figure 5.4.

5.2 Our Plan with respect to Vision 2025

In our proposed plan, as shown in Figure 5.5, we have come up with is not only beneficial in resolving the electricity crisis of Pakistan but also it is beneficial for the safety of environment. As Pakistan has signed an agreement i.e. Paris Agreement so this plan is also favouring the Paris Agreement as well. The plan focuses on the total generation of electricity. We have increased the generation of RES from 0.3% to 12%. With the addition of Diamer Basha dam and Dasu dam, 8820 MW of clean energy will be produced. The energy production from hydro is increased from 23.7% to 35.4% [17]. This will be useful in saving

the environment as well as lowering the demand and supply gap. The production from nuclear needs to increase rapidly for the purpose of running base loads.

Figure 5.5 ***Our plan with respect to Vision 2025 in a flow diagram***

Previously the production from nuclear in total electricity generation was 4.12% and now in our plan it has increased till 7.86%. Practically if we consider the emissions from thermal, we know that we cannot decrease the production from thermal but what we can do is we can lower the production and make it constant. So, the thermal production has been kept constant so that the emission produced by thermal may not increase further, effecting the ozone layer and the environment.

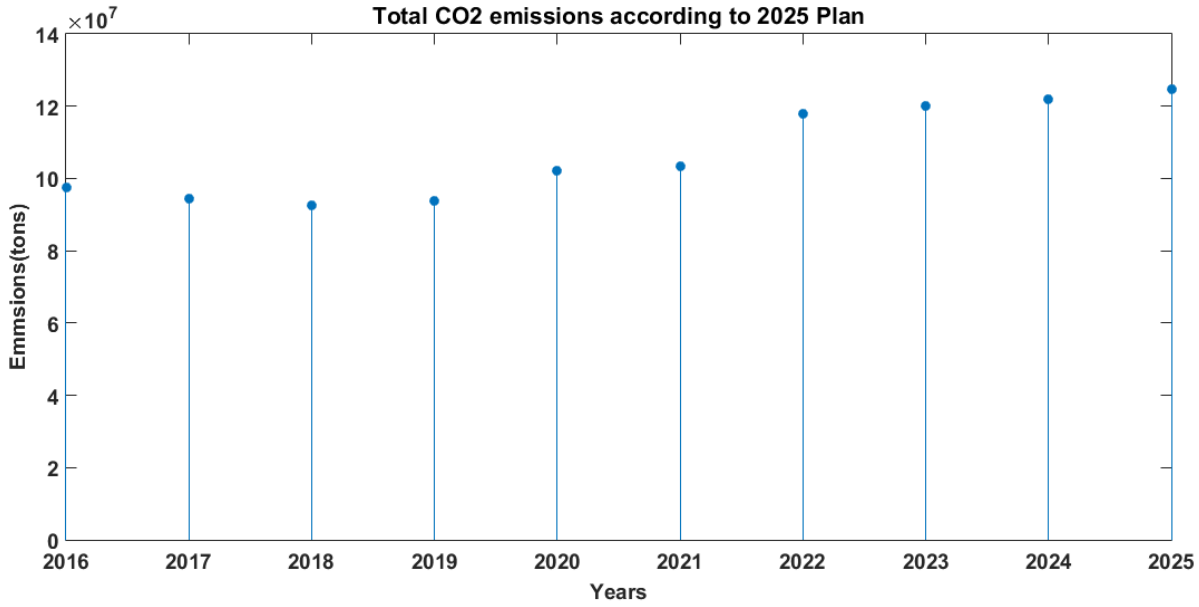

Figure 5.6 ***CO_2 emissions by power generation in tonnes according to Vision 2025 plan (2017-2025)***

The Figure 5.6 visualizes the carbon dioxide emissions in tons according to the Vision 2025 plan. The emissions have increased from 2018 to 2025 from 9 tons to 13 tons approximately. Since indigenous resources were utilized along with economically feasible options, which were undertaken in Vision 2025, reason-being renewable plants were in process of being deployed. Thus, the emissions have increased in power sector up to a certain extent during stated period.

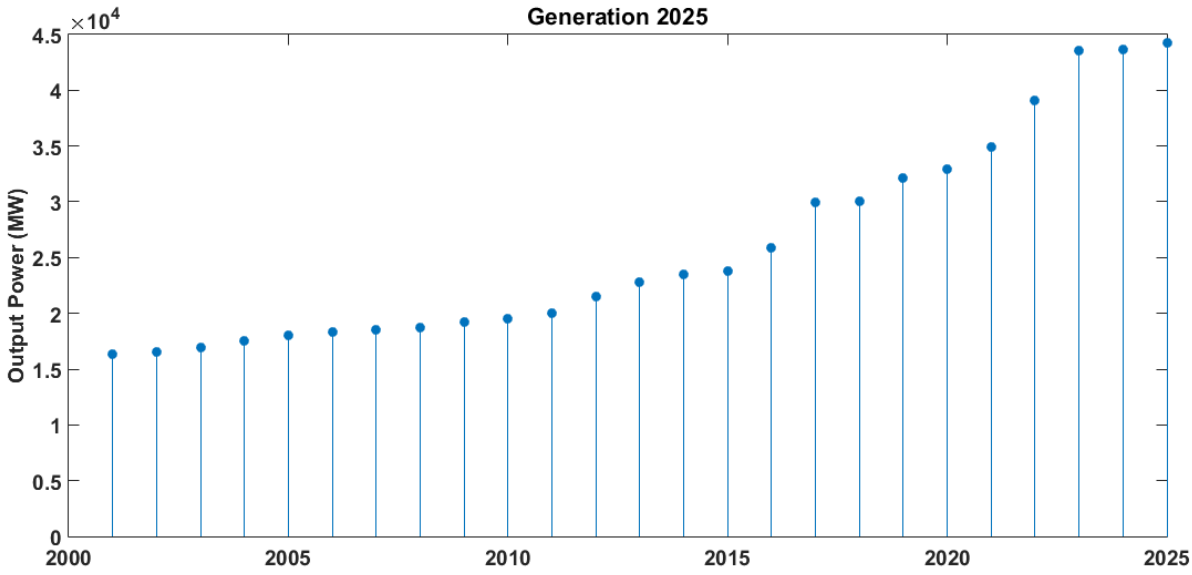

Figure 5.7 Generation of power in Pakistan with respect to Vision 2025 plan in MW (2001-2025)

The Figure 5.7 illustrates the generation of power generation sector in Pakistan with respect to the Vision 2025 plan. The generation has increased from 16000MW to 44000MW from 2000 to 2025, respectively. Since load is expected to increase drastically due to factors such as population and core economic projects like CPEC. Thus, energy requirement per capita would increase significantly across coming years. In figure 5.7, we have considered time horizon projection across year 2025 in accordance with VISION 2025. This is the reason why the generation capacity will have to increase at a fast rate to match up with countries future requirements.

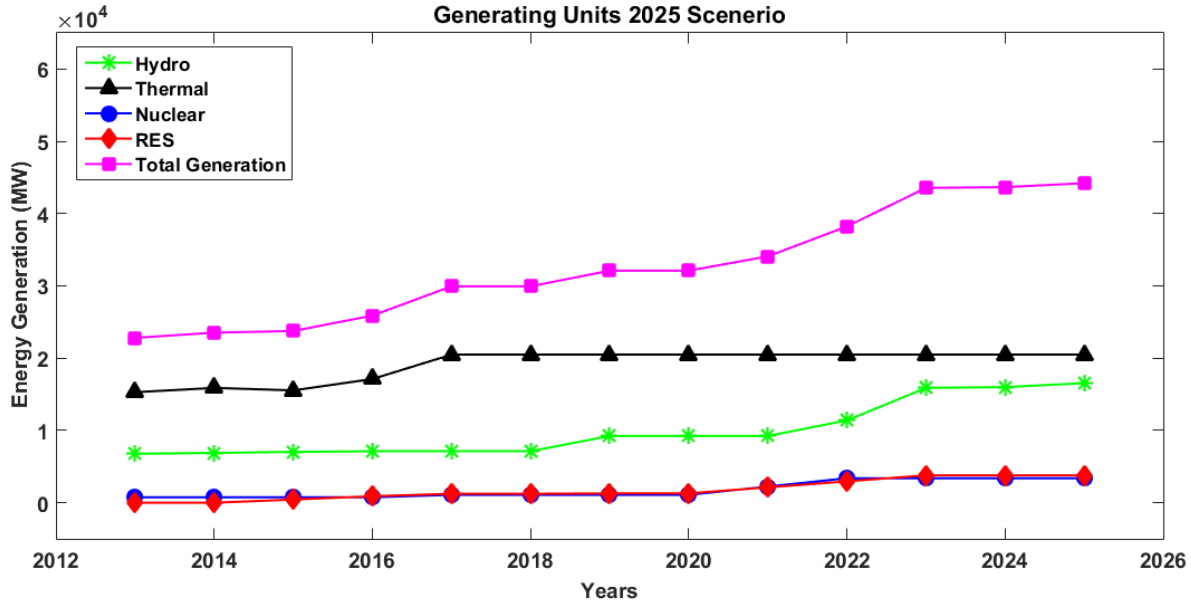

Figure 5.8 Energy generation with different resources (2013-2025)

The Figure 5.8 demonstrates the energy generation from different resources. The share of each resource in the total generation can be seen. The total required generation is increasing rapidly from 2017 to 2023 and after that there is a slight increase in the generation till 2025. The thermal generation is constant as no more new thermal plants were constructed and the renewable deployment was under process. The generation from hydro is increasing as new hydro projects were under assembly. The renewables were deployed, and nuclear plants were also commissioned. This is the reason why there is a slight increase in these respective resources.

In our plan for the vision 2025, per home consumption was also observed. If we introduce energy efficient devices like energy saver, energy saver fans, lights and LEDs, we can clearly see that per home consumption is reduced. This will not only help in saving the energy, but it will also save the transmission line from overloading, resulting in better efficiency. The energy consumption will reduce to quite an extent if the houses of the whole country are considered. The consumption gap will reduce as well. It can be seen from figure that if average house consumption of each house in Pakistan is reduced from 0.1 KWh to 0.7 KWh with the utilization of energy efficient devices, it will significantly reduce the overall consumption on domestic side (Being largest load consumer), as shown in Figure 5.9. In addition, these efforts also encourage the local industry to make energy efficient devices and open more business opportunities in Pakistan. Furthermore, the but it will also decrease the emissions as less generation will be needed which will result in less emissions.

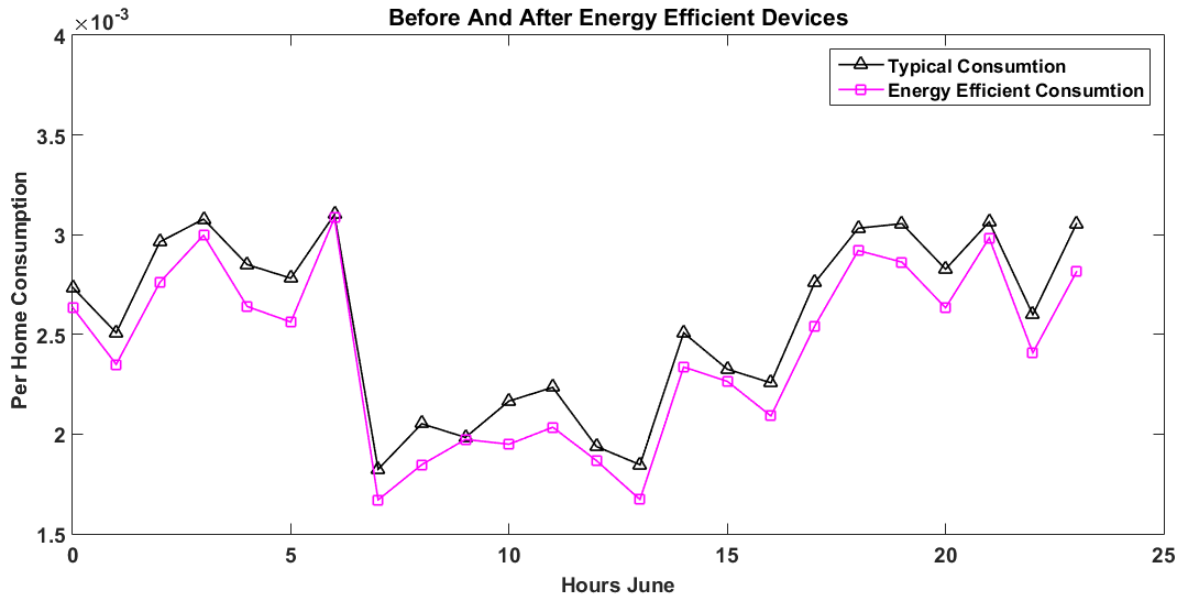

Figure 5.9 ***Before and after introducing the energy efficient devices (Per home)***

5.3 Our plan with respect to NPSEP (2011-2030)

Our methodology with respect to this energy policy is quite contrasting in such a way that this policy aims to mitigate the power shortages keeping in mind the environmental safety and what we intend to do is just the reflection of what they are aiming at. Also, they aim to

utilize the renewables and our methodology is again trying to save the environment and renewables is so far the best option of generating electricity which helps in saving the environment as well.

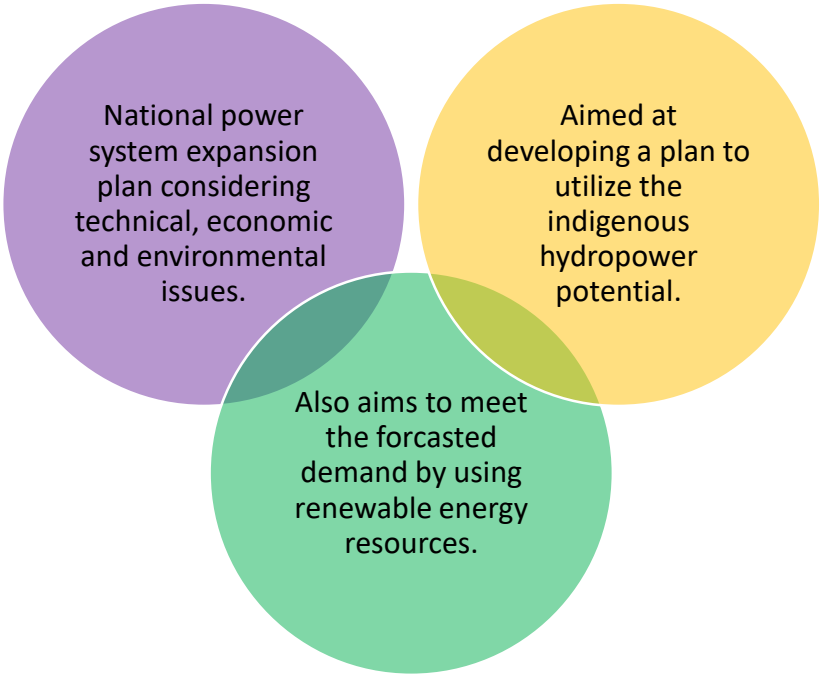

Figure 5.10 ***Our plan with respect to NPSEP (2011-2030)***

The Figure 5.10 shows that the NPSEP plan consisted of the technical, economic as well as environmental aspects. The mitigation of energy shortfall by introducing new plants was the major plan but this plan also considered the environmental aspects as well. Clean energy generation was encouraged. The hydro power potential is outstanding in the country so if it can be utilized, it will not only mitigate the load shedding but also help in saving the environment [16-17].

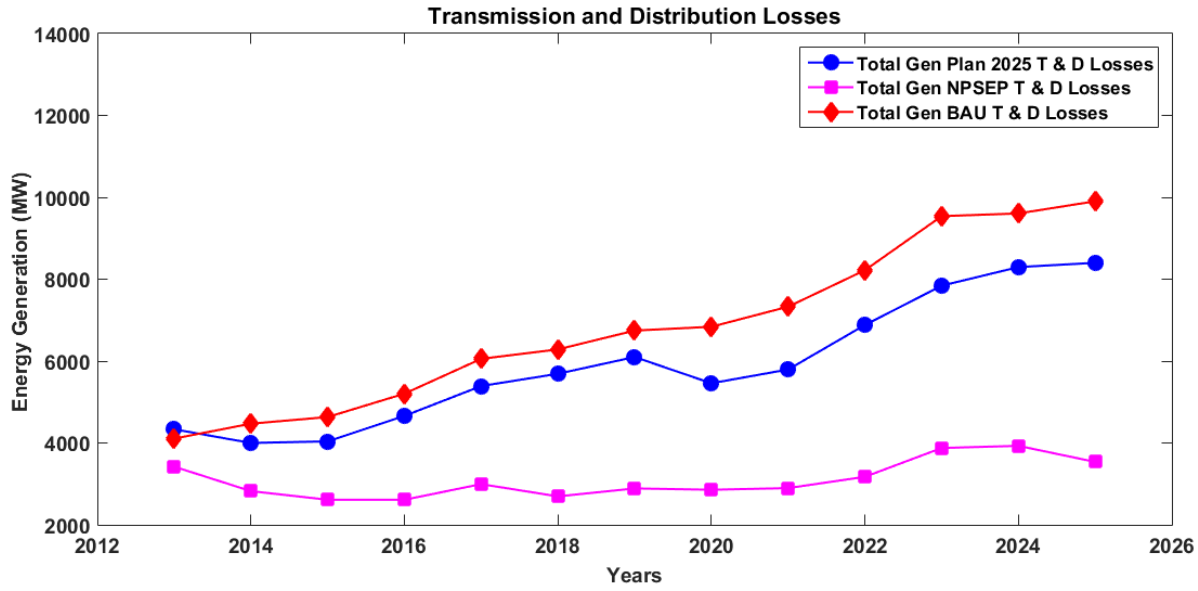

Figure 5.11 ***Transmission and distribution losses for 3 case scenerios (2013-2025)***

The NPSEP plan fouses on the transmission and distribution losses and aims to minimize them. The other two plans which have been discussed above that is Vision 2025 and NESP plan donot specifically talks about the trnasmission and distribution losses. NPESP plan at some point focuses a lot on the mitigation of T&D losses, as shown in Figure 5.11. So, according to the plans and BAU (business-as-usual) scenerio, the transmission and distribution losses are discussed in this regard.

5.4 Our Plan with respect to Paris Agreement

An agreement which took place in december 2015 visions for the greenhouse gas emissions mitigation and adaptation which begins in the year 2020. All the countries who have signed the agreement have to keep their global warming temperature well below 2 degrees celcius. This agreement aims to strengthen the countries in controlling the impacts of climate change and come up with a low carbon and low GHG emission plans. Every member of the Paris agreement must be able to find a way to keep the temperature well below the stated limit and make a GHG emission free pathway towards the future [18].

While keeping in view that Pakistan is a member of this Paris agreement, it needs to keep the global warming temperature increase below 2 degrees celcius. So, the most basic thing to achieve this target is by minimizing the carbon emissions. To minimize the carbon emissions, the NESP plan and Vision 2025 plan can play a vital role. Three scenerios have been made to observe the carbon emissions increase. The figure below discusses the three scenerios.

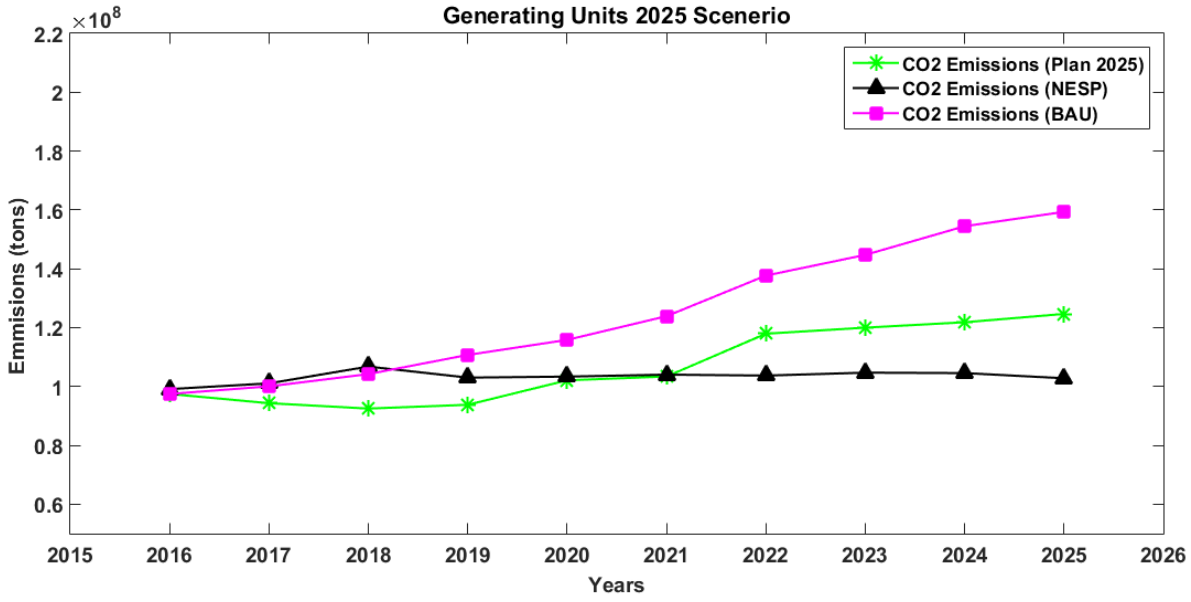

Figure 5.12 ***Carbon emissions plan for differnet case scenerios from the year 2016-2025***

The Figure 5.12 shows the carbon emissions plan under 3 different case scnerios. Firstly, in the BAU (Business-as-usual), the carbon dioxide emissions are increasing with a rapid rate typically. If the situation keeps on going like this, the carbon emissions will incresae to a dangerous level. Secondly, if we consider our plan of Vision 2025, we can see that carbon emissions will increase but not as much as in BAU scenerio. The increase is slight in this case due to contionuous increase in population. This is due to the fact that renewable deployment

will be done which will negate the effects of carbondioxide emissions. Last but not the least, the NESP case is seen on the graph with a black line and it clearly states a stable line for the carbon dioxide emissions. This is due to the energy efficient devices as well as renewable deployment and the production from hydro increases with a rapid rate. No new thermal plants to be built and clean energy genertaion will result in such a line [19].

Another important thing to keep in view is that what are the different impacts which can occur due to that 2 degrees change in temperature. The efficiency of transformers are also affected by the increase in temperature. The genreation redcuces when the transformer is not working on its ambient temperature or the ideal temperature. The ambient temperature is directly affected by the change in climate. The figure 5.13 shows the loss in generation with respect to three scenerios.

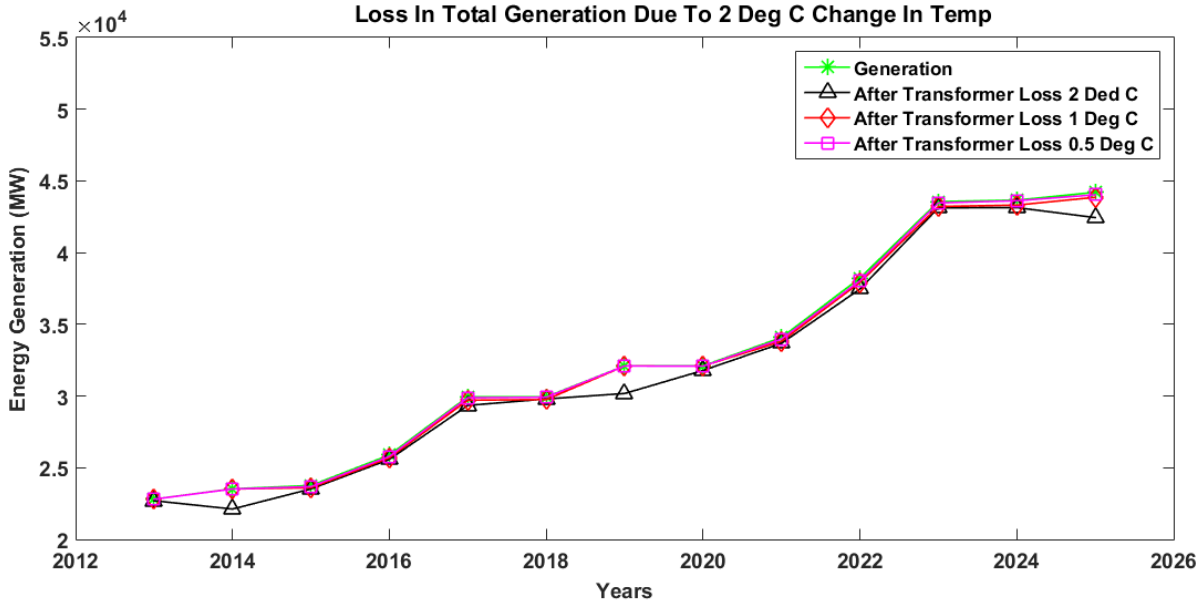

Figure 5.13 ***Loss in total generation due to 2 degrees celcius change in tempearture (2013-2026)***

The above Figure 5.13 shows the loss in total generation upto 2 degrees change in temperature. The first scenerio is when 0.5 degree celcius temperture is increased, the loss in generation is slight. This is due to the reason that the transformer is not working on its ambient temperature where it produces the best efficiency. The second scenerio is for 1 degree celcius change in the ambient temperature. It can be seen that the loss in generation is more than the one for 0.5 degrees. Finally, the third scenerio is change in temperature of 2 degrees. The loss in generation is quite evident in this case scenerio. The more there will be increase in the ambient temperature, the lower will be the efficiency [20].

The Figure 5.14 illustrates the thermal plant behaviour with respect to ambient temperature for three different scenerios. The ambient temperature for a thermal plant to work in ideal scenerio is 15 degrees celcius. And in Pakistan, the average temperature is 20.1 degrees. Now considering the three scenerios i.e if according to Paris Agreeement, temperature increases up to 0.5 degree celcius, the efficiency of thermal power plant will decrease as average outdoor temperature is already 5 degrees above the ambient temperture [21].

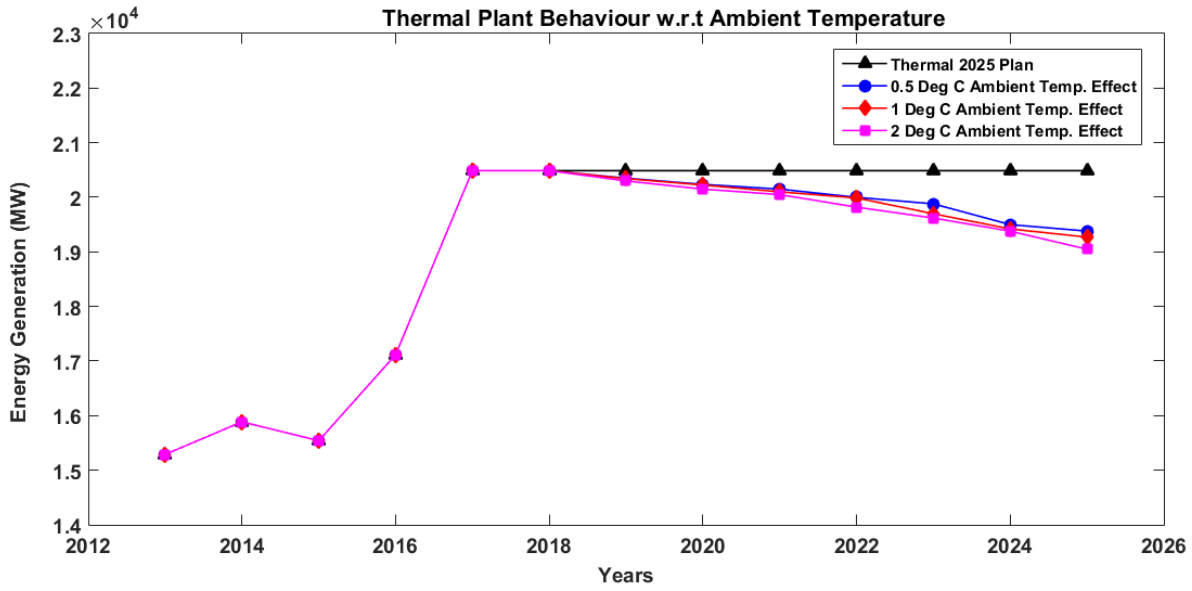

Figure 5.14 ***Thermal plant behaviour with respect to ambient temperature for differnt case scenerios (2013-2025)***

The energy generation will certainly drop if the temperature increases 0.5 degrees celcius. In the second scenerio, if we increase the temperature up to 1 degrees celcius, efficiency of the plant will decrease that will result in lowered generation. Finally if the temperature increases till 2 degrees, the efficiency will drop further more. The conclusion is that according to Paris agreement the global warming temperature can not increase more than 2 degrees. If the temperature will increased more than 2 degrees, the thermal power plant will also keep on losing its efficiency of generating electricity and as a matter of fact approximately 67 % of the total electricity generation of Pakistan to date is contributed by the thermal power plants.

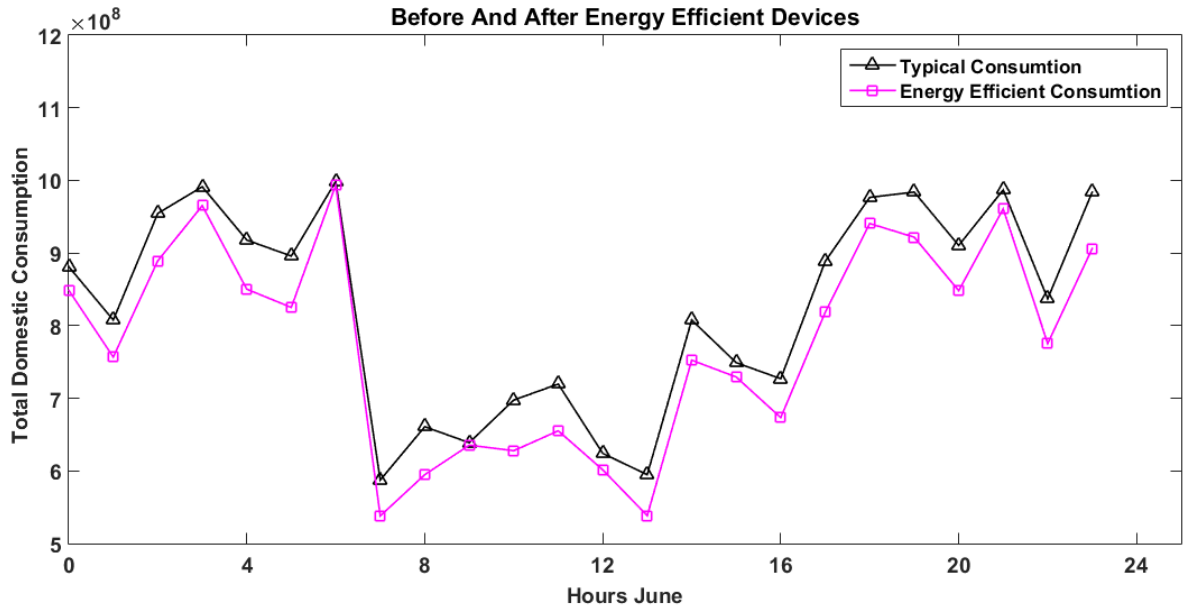

Figure 5.15 ***Total domestic consumption of Pakistan before and after energy efficient devices***

The Figure 5.15 shows the total domestic consumption of Pakistan for a typical day of June. The idea was to calculate how energy efficient devices play their part in lowering the energy consumption and the difference is quite lucid. In different times of a whole day the consumption varies. Certain fluctuations are clearly seen in the graph due to different loads requirements at different times. Undoubtedly just for a day, the difference is quite clear and if we consider it yearly, the difference will be greater and energy consumption can be greatly decreased with the help of energy efficient devices. We have divided loads in three different categories i.e. time flexible loads, time inflexible loads and power flexible loads. All have their own properties in lowering the consumption graph. Implementation of such devices would result in considerable decreased consumption. It is evident from the results that a substantial consumption is decreased with efficient devices from maximum average load value of 9370 MW to 8120 MW, respectively. Hence, a significant amount of electricity can be saved, which is rather supplied by generation predominated by thermal contingent. Moreover, the resulting emissions out of most predominant domestic load across can be decreased by a significant amount with notable savings in electricity (1200-1300MW). The total load requirement of Pakistan to date is approximately around 27000 MW and out of which 9380 MW is load of residential sector. Since, approximately 26% of emissions are generated by overall power sector of Pakistan and residential sector constitutes 34.74%-46.51% (40.5% on average) of total load [22]. Hence, overall reduction in emissions from respective sector with reduction of load pattern (1200-1300MW) that constitutes around 1.2512-1.582% (1.42% on average) of overall emissions produced by electrical sector of Pakistan.

Chapter 6 CONCLUSIONS

The following conclusions have observed in this report.

1. It is observed that a lack of dedicated planning has observed from environmental perspective in the electrical power sector of Pakistan.
2. There have been no previous studies aimed at quantification of environmental impacts of electrical power sector of Pakistan, which can not only vital for combating degradation to the environment, and also pivitol for the achievement aimed objectives of respective dedicated policies at country level.
3. It has also observed that although the generation to date has increased significantly; however, overhaul, modernization and comissioning of transmission and distribution systems have not addressed accordingly, resulting in more system losses. These losses are covered with more generation, a major portion of which comes through thermal plants.
4. The proposed methodology encapsulates three cases of policies with a cerntain contigent of environmental quantification as a base case namely NESP, Vision 2025 and NPSEP.
5. Our first part of methodology (case 1) aims at optimal utilization of NESP plan and its salient features with an addition of an important factor i.e. how the energy mix of the country will affect the environment and what can we do to save the environment. The work conducted analyze the different harmful emissions from different resources of electricity generation suchas per kilowatt value of the harmful emissions and their impact on affecting the environment. The result is provided with quantified CO_2 emissions per capita, overall generation trend till 2030 and generation via various resources in the energy mix.
6. The second part of our methodology aiming at vision 2025 (case 2) provides results of quantifications of abovementioned case 1. In addition, it provides the impact of KWH reduction in per hold of Pakistan from 2.5 KWh (average) to 2.1 KWh with efficient devices. The utilization of energy efficient devices, it will significantly reduce the overall consumption on domestic side (being largest load consumer). Moreover, it will also encourage the local industry.
7. The case 3 of methodology aiming at NPSEP provides quantification of losses minimization projection of various other plans in comparasion with bussiness as usual scenarios across the time horizon of 2016-2025.
8. The final plan in this study gives the quantification in accordance with Paris accord. The quantifications of CO_2 emissions, transformer losses and thermal power plants have evaluated across ambient temperature increase of 0.5˚C, 1˚C and 2˚C, respectively. The increase of 2˚C ambient temperature results in significant CO_2 emissions in bussiness asusual and result in decrease in transformer efficiency and significant thermal power plant efficiency, respectively.
9. As a matter of fact approximately 67 % of total electricity generation of Pakistan is contributed by the thermal power plants. The thermal generation needs to keep constant and the increase of renewable generation has to increase to keep the ambient temperature withn limits in accordance with Paris accord agreement.
10. The use of smart devices on country scale results in overall reduction of load pattern (1200-1300MW) that constitutes around 1.2512%-1.58% (1.42% on average) of overall emissions produced by electrical sector of Pakistan.

Chapter 7 FUTURE WORKS

The following future works may give a guideline to a way forward towards combating impact of climatic change focusing power sector of Pakistan.

1. Effective integrated power policy needs to be carried out, aiming at reducing environmental /climatic impact on electrical power sector of Pakistan.
2. Modification of existing infrastructure and new extensions must be back compatible with existing infrastructure and aimed at reducing system losses. Indigenous R&D option must be exploited for increase of renewable energy options in energy mix.
3. More focus must be put on improving transmission and distribution system, since loss minimization is directly linked with generation, a major portion of which comes from thermal contingent (67%).
4. New planning tools are required for modification of existing electrical grid that makes itself compatible with sustainable and low emission based generations.
5. Clean development mechanism must encorporate new mechanisms and protocols to give incentives to all stakeholders from the perspective of environmently friendly option in terms of carbon credits and tax incentives.
6. Renewable technology must be indigenized to reduce the cost and tax credits must be improved to encourage maximum participation of stake holders.
7. Efficient DSM must be implemented on consumer side and limits on net metering must be increased as per technical specifications for maximum renewable energy source integration, aiming at increase of renewable generation.
8. Energy efficient devices must be encouraged at consumer level and manufactured locally to reduce additional electricity intake, reflected mostly on domestic load side and environmentally impact generation side (mostly thermal) to cover the deficit.
9. The cap on net metering have to be increased from current 1 MW to high value for the encouragement of other stakeholders in investing towards the renewable technology.

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