ACADEMIA International Journal for Social Sciences
Volume 4, Issue 2, 2025 ISSN-L (Online): 3006-6638

Historical Nexus of the Development of Power Sector in Parallel to Population and Household Growth in Pakistan from 1947 to 2018

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Received: 09-03-2025 **Revised:** 10-04-2025 **Accepted:** 07-05-2025 **Published:** 31-05-2025

ABSTRACT

The energy and power crisis has been evident in the last decades in Pakistan due to many reasons. In this current research, we have tried to find out the historic nexus among the population, housing and power sector development of Pakistan. To understand where in the history of Pakistan things went wrong. Why has this power crisis arisen in the last few decades? This research highlights the nexus among these three variables and the severity caused by any of them. The broader research covers the situation in the whole of Pakistan with special emphasis on the province of Punjab. The different growth factors of population and housing are outlined. It is believed that Pakistan needs 0.7M new houses every year to meet the demand. The domestic sector consumes 24.5% of the total available energy in Pakistan and 47% of the total electricity produced. According to one estimate, the power demand of Pakistan would go up to 101 GW. We have also identified the reasons for power crises of Pakistan as technical, non-technical and general issues. Pakistan started with a generation capacity of 0.06GW for 31M people, which rose to 22.5GW in 2018 for 209 M, having 32.2M houses. It is estimated that by 2050, the domestic sector will have 50.8M households with an average occupancy of 6.1. The Punjab had 21.8M population which has now grown to 110M (17.3M houses) in 2018 and is predicted to be 177M (28.6M houses) by 2050.The power generation capacity of Pakistan is around 22.5GW, and the current demand is 17GW, but it is not producing enough power to meet the current demand, and there is a shortage of 5GW. Considering all future projects, Pakistan would be able to produce 43.3GW by the year 2030, and its demand would be 54.4GW. The domestic sector is the largest consumer of power, having 84% of consumers in the entire country. Punjab consumes 62% of the total electricity produced in the country, and out of this, 85.6% is consumed by the domestic sector of Punjab. In total domestic sector of Punjab consumes 53% of the power consumed in Pakistan.

***Key words**: Housing, power crisis, growth rate, technical issues, shortage*

INTRODUCTION

A consistent approach to the development of Pakistan's power sector is missing. It seems as it developed independently, having no coherence with the growing population's need for it, due to increased demand, by different sectors of the country, especially the domestic sector, which has been facing severe power cuts of 12- 16 hours in the rural area and 6-8 hrs in the urban areas. Pakistan consists of four provinces,

each province is divided into Districts (103), which are further divided into Union councils (6022) [1] Punjab is the largest province (36 districts) in terms of its GDP (60%), population (53%), development, industry, and agriculture. Hence, its importance is evident, so the smooth progress of its different sectors is essential for the country's growth. Its population is growing rapidly [2] . Punjab accommodated 5.3 million migrants during the time of partition [3]. Punjab's population growth rate is 2% per year [4], and according to the 1998 census, the average household size having one room is 5.3, two rooms is 6.9, which is very high [4] [5]. It has 127.7M inhabitant, out of total 241M population of entire country, as a result its domestic sector requires more power.

Pakistan is among those developing countries of the world that are struggling to meet the needs of the citizens in every walk of life. This power shortage has not arisen all sudden, it has been accumulating over the history of Pakistan. The present population density of Pakistan (255p/km^2) is expanding at the rate of nearly 7% every 5 years; by 2050, it would be 402p/km^2, which is 58% higher than its present value. Punjab is the densest province with a current density of 535p/km^2 and would have 861p/km^2 by the year 2050, so power usage per km^2 would also surge at a rapid pace.

Attempts made by different governments to overcome power shortages in the history of Pakistan have been ineffective. One possible reason, among others, is the inability of authorities to forecast actual power demand and take effective measures.

In this research paper different factors responsible for the increase in the power demand are discussed w.r.t population growth and the growth of households, answering the current research question, which states as, what would be the demand of power in GW for the proper functioning of domestic sector of Punjab with no power-cuts in future till 2050? Firstly, this paper examines how population and housing sector growth have increased the power demand in the country, with the Punjab in focus, and the measures taken by the different political governments in their time to produce power to date. Secondly, this paper estimates the future demand of power by the housing sector, based on several factors as per the usual business of living standards and different categories of householders. This paper is an attempt to understand the relationship among population, households and power sectors forecast based on certain factors largely ignored by previous researchers.

LITERATURE REVIEW

The literature is reviewed in three main areas, covering population growth trends, housing sector growth and power sector development as seen by different researchers, generally in the context of Pakistan and particularly in Punjab.

Population Growth Causes & Trends

The impact of unmatched population growth is multifaceted. Its effects can be seen in different walks of life. The rapid addition of individuals to the population is causing many socio-economic and managerial problems, which require prompt solutions. Otherwise, it would be too late to control the adverse impacts of rapid population growth. The world population has been increasing at a varying rate throughout history. By the year 1830, it reached one billion. since then, it has been doubling at different trends, like it took 100 years to add another billion, and the next third billion was added in just 30 years. The fourth billion was added in 15 years, and it took only 12 years to add the fifth billion. Currently, the world's population is about 8.2 billion, it will reach 9.7 billion by the year 2050 [6] [7] . It is also estimated that a 97% increase in the world population (yearly-75M) would be from less developed countries, Pakistan is one of them [8].

The primary cause of population growth in the developing countries is bourgeoning birth rates as compared to the death rate per year [8] [9]. Developing countries have 30% of people under 15 years of

age, while developed countries have only 17% in the same age range. More young and old people increasing the dependency ratio in developed countries [8] Figure 1

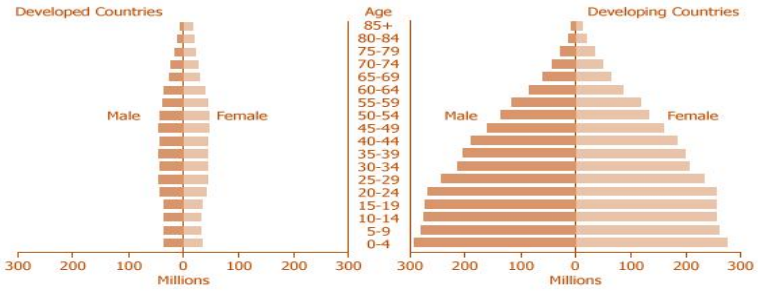


Figure 1 United Nations Population Division, World Population Prospects: The 2010 Revision, medium variant (2011).

Robert Malthus gave apocalyptic views in the late 18th century about population growth and starvation, [10] emphasising birth control. According to him rapid increase in population would put pressure on the food supply, and the people will be forced to live at a bare subsistence level. Poor nations would never be able to rise above this level [9]. If left unchecked the nature will take its course and the death rate will increase. Apparently, food supply will encourage people to have larger families and change in lifestyle. Eventually, as Malthus would argue that there would be more people and less food for them, identify it as a 'trap' and people will be forced to live again in miserable conditions.

Simon and Kahn gave opposite concepts, supporting population growth rather than insisting on birth control. According to them, every individual will create many more resources than they will consume in their lifespan. A larger number of people would be creating more resources, and per capita production would increase. As a result of this, the coming generations would have less pollution, more food, and be less vulnerable to resource-supply imbalance, as explained by Daly (2013 [11]. The relationship between population growth with economic growth has been the topic of discussion throughout history. According to pessimists, Malthus (1798) & Ehrlich (1968) argued that population increase will cause the scarcity of food supply and ultimate starvation. On the other hand the optimists: Kuznets(1967), Simon(1981-87) and Boserup(1981), believed that increase in population would help in economic growth, as more individual would produce more than their requirement, the third group of people, the Neutralists: Kelly(1995), boom and Freeman (1986), denied any relationship exist between population growth and economic growth, and suggested that lack of education, restricted trade and institutional barriers are main causes of less economic growth and should be the main concerns [10].

The average increase in the number of individuals in any population, taking into account the births, deaths, immigrants and emigrants, which happens over a year, is known as *population growth* [2]**.** The number of individuals keeps on changing in the population, and its number is positive, which it would be called population growth. *Population growth rate* (PGR) can be defined as the change in population over the identified period [2].

PGR= (population at the end of the period-Population at the start of period/ Population at the start of the period) *100

*PGR = (No. of Births + No. of Immigrants) – (No. of Deaths + No. of Emigrants) of any Population***.**

Population growth is generally written as Growth Ratio, which is the change in population as the percentage of the population at the start of any period, so *Growth Ratio: PGR *100%* [2].
The population in Pakistan is unevenly distributed, Punjab have 26% of the land area and consists of 56% of the total population. KPK have 13% of land area with 16% of population, Sindh have 18% of land area having 23% of population, and Baluchistan, being the largest province 44% land area have just 5% of the country's population [12]. At the creation of Pakistan, its population was 13th in the world, having 32.5M people. It remained in 13th position till 1996 with a population of 140 M. In the year 2009, it became the 6th most populated country in the world, having 162M inhabitants. In the year 2018, it is ranked in the 5th position, and according to one estimate based on the decline in infertility rate assumption, it would be the fourth populous country in the world having 2050 with 305M inhabitants. (Figure 2)

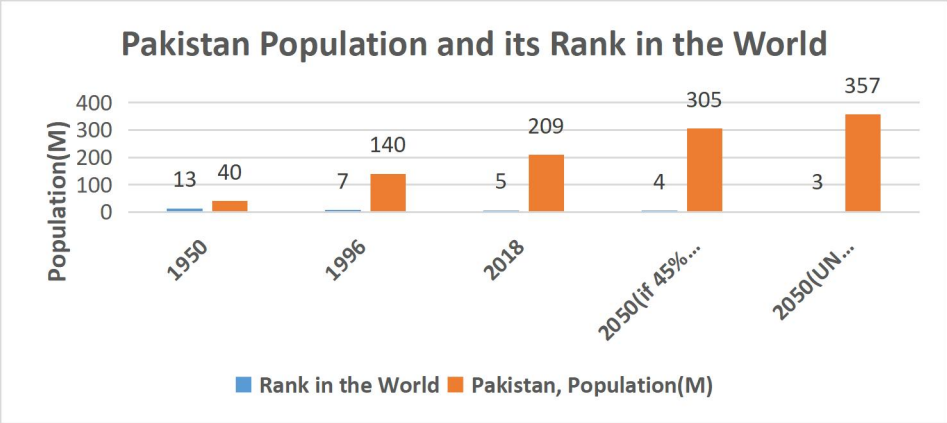


Figure 2 Pakistan's population increase and its ranking in the world

In 1947, roughly 1M people were added in a year, but today 1M is being added every three months, with such a growth rate, it would be difficult to sustain the demand of infrastructure, houses, energy, education and health, etc. The historic population analysis of Pakistan shows that there were younger age people and fewer old, but with time, there is a shift in the age percentage of citizens. As shown in Figure 3 there would be more or less equal numbers of people in the different age groups, which will increase the dependency ratio in the country as mostly the middle aged people are the bread earned of the family and younger and older people are mainly dependent on middle age people (25-60).

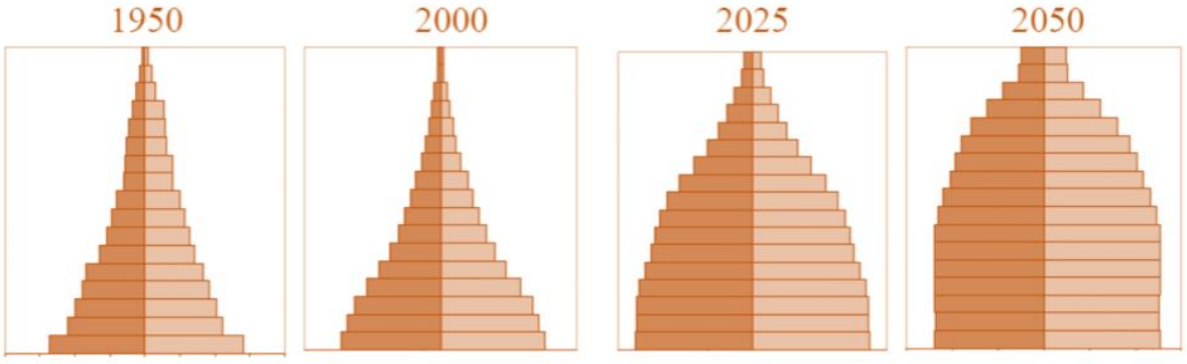


Figure 3 Population growth rate [6] based on the median variant of fertility, Pakistan

According to the planning Minister, Pakistan has 9 cities with a population above 1M, as compared to the time of independence, with only two cities having a population of 0.5 M. It is estimated that by 2030, the

urban and rural population will be the same. (Ahsan Iqbal) [12].The natural growth rate is 2% per year in Pakistan [13] [14] , any area having populations of 1000 people per square mile is classified as 'Ruralopolises', estimated that 60-65 % of Pakistan areas in this category (Qadeer). [13], average growth rate of Pakistan from 1947 -1990 was 3%, it was highest in the 1980s at 3.5%. After the 1990's it started to decline, primarily due to the efforts of the family planning department of Pakistan [14]. Pakistan had plans to reduce its growth rate from 1.9 to 1.3% by 2020, [15].

Causes of Population Growth in Pakistan: *Independence of Sub-Continent*; Pakistan came into existence in 1947, and around 4.7M Sikhs and Hindus left for India. Approximately 6.5M Muslims migrated from India to Pakistan. According to the 1951 Census, 48% of the urban population of Pakistan was migrants from India. There was a massive increase in the urban population of Punjab and Sindh, while massive de-urbanisation in the Provinces of KPK and Baluchistan [1].

Afghan Migration: There was a huge migration from Afghanistan to Pakistan (1981-1994), approximately 3.7M Afghan refugees took asylum in Pakistan.

Urbanization: According to the 1951 census, around 6.5M took shelter in Pakistan, which came from a rural parts of India, and 4.5M people went to India from Pakistan, as a result, there was a net increase of 1.8M people, who mainly settled in urban Pakistan [12] . The rapid increase in urbanisation exerts immense pressure on the housing, services, job market and many other sectors [16] [17]. Its effects on the rising land prices, construction costs make it very difficult to afford a house in urban settlements. Among other causes of urbanisation in Pakistan, migration of Muslims from India during the wars of 1965 and 1971 took place, other migrations were from Afghanistan in the 1980s. (As anti-Soviet insurgency raged in Afghanistan) [18] [13] (Wilson Centre Pakistan Scholar Program).

Another driving factor of urbanisation is economic necessity, as there are more employment opportunities in cities than in villages in Pakistan. People from the rural areas start coming to cities, and when they get a job and some savings, they start living in the urban areas [18]. War against terrorism, which took place in 2007-8, caused many people (3M) from the tribal areas to take shelter in the urban areas of the countries. (Internally displaced people, IDP's). Further, earth earthquake of 2005 and the flood of 2010 in Pakistan forced millions of people to move to urban areas.

Effects of Urbanisation: It is seen that urbanisation increases the energy consumption [19], it transforms of rural lifestyle to urban one, with more usage of urban facilities like transport, electricity, house construction, etc. People like to have more electrical appliances and a more advanced form of living standards [20] [21]. According to the International Energy Agency reports, city dwellers consume 67.6% of the world's energy. If the percentage of urban population increases, it will have its impact on energy consumption [19] . Solarian and Shabaz [22] found a bidirectional relationship between electricity consumption and urbanisation; a similar relation is seen in Malaysia by Islam, between population and energy consumption. Cole and nuemar [23] found that urbanisation is directly related to the energy demand because of the rise in the housing units. Further, the increase in the income level of urbanites changes the consumers' necessities, which results in more energy consumption [24] [25].

The positive impact of urbanisation on the residential energy demand is seen in China, [26]. It is argued [27] As a result of urbanisation, the concentration of population increased, which generated economic activities, and thus caused more energy consumption. The positive impact of population growth and urbanisation is seen by [28] on the economic growth and energy consumption [29] . The housing and industrial sectors are recognised as major causes of energy pressure in Lahore, [30] [19] the urban places in Pakistan were 218 in 1951, which increased to 515 as per the census of 1998 (Qadeer 2006). According to International Cooperative Alliance (ICA-2009), the housing estate of Pakistan added 2600 cooperative societies and accommodates around 12.9M housing units.

Housing Sector Growth Causes

The first data ever recorded on housing in Pakistan was collected in

- The census of 1960,
- the housing economic and demographic survey 1973
- The housing census of 1980

The findings showed that the housing industry was growing at a lower rate than the population growth. As per the 1980 census, with the number of 6.7 persons per house, 9M additional dwellings would be required by the year 2000. (It was 5.5 persons per house in 1960, which increased due to population growth) It was estimated that 7 people per house in 1987, more than half of the housing units in Pakistan had one room and an occupancy of 6 persons. [31] Stated that the housing industry of Pakistan is among the top 20 countries of the world, and still, there is a shortage of 0.27M houses every year [32] [33].

In 1998, there were 19.3M housing units in Pakistan, and 10.6M were in Punjab, and 32% urban units in Pakistan and 30% of Punjab housing units were in urban areas. [34] . As per 2011, there were 21.7M houses in Pakistan against the population of 186M, so the average number comes out to be 8.6 persons per house. And there was a shortage of 9M houses units based on the average number of 6 person per house. [16] In 2008, the estimated demand for housing units was 0.57M, whereas the supply was only 0.3M, so there was a net shortage of 0.27M houses. As a result, people were destined to live in squatter settlements. (National Housing Policy 2001) [16] It was estimated (2012) that there is a shortfall of 8M units, and it would be 10M by the year 2020 [16] There were 19.3M housing units in Pakistan in 1998, and an overall shortage of 4.3M housing units was estimated (as per 6.5 persons per house) [16] [35] Between 1981-1998, the urban housing units increased by 70% while rural units increased by 50% [36].

Pakistan needs around 0.7M housing units annually just to meet the natural growth rate of population, and roughly 0.35M are required in the urban sector, but Pakistan can hardly build 0.3M houses per year [37]. It is believed that 0.5M houses must be built every year for the next 20 years to meet the demand and cover the backlog.

There were 7.8M housing units in Pakistan in 1960, 12.6M in 1981, and 19.3M in 1998. This indicates that there was a 2.46% increase in the household from 1960 to 1998. While the population in 1960 was 45.5M and in 1998 125M, so there is increase of approximately 3% in the same time [38]. Urban housing units during this period grew (3.6-6.1M) 70% while rural housing units increased (9.1-13.2M) 45%, so there was more trend of housing unit growth, showing more urbanisation. Further, the average household size is also increased during this period from 6.7 to 6.8, and this increase is more evident in urban areas, where it increased from 6.1 to 7 persons per house, causing congestion in the urban areas. The rapid urbanisation in Pakistan caused many housing problems, urban areas occupy less than 0.75% of the total land area of Pakistan and contain above 30% of the population. According to the national housing policy, Pakistan needs 0.57M houses annually.

Power Sector Development Causes

Pakistan is going through a severe power crisis. Even though presently [39] (as of 2012-13) 35% of the population in Pakistan is destitute of power, at present, 5-7GW more power is needed(Mahmood, Javaid et al. 2014), catering for 31% of the total load of 17GW. As a result country has to face 15 hours of power cuts [40] in villages and 6- 8 hours in cities. Figure 4 recapitulates the present condition as of 2017.

Figure 4 Energy Situation in Pakistan 2017

It is important to understand where this energy is being consumed in Pakistan. And what is the share of the domestic sector in the overall energy share? This will help us understand the importance of the domestic sector, which is the focus of this research paper. Energy in Pakistan is largely consumed by commercial, domestic, industrial, agricultural, government and transport sectors. Each sector has a different quota of energy consumption in the overall energy available in Pakistan [41].Figure 5, illustrates different percentages of energy being consumed by different sectors, we see that in 2008, there are three main sectors like industry, transport and domestic which consumes most of the energy, 42.6%, 29.30% & 20.4% respectively. [42] This trend of energy use changes by the time (in 2005, domestic sector was using 21.2%, [41] [43] and there is gradual increase in domestic energy consumption and it goes to 25% by the year 2015. (Rafique and Rehman 2017).

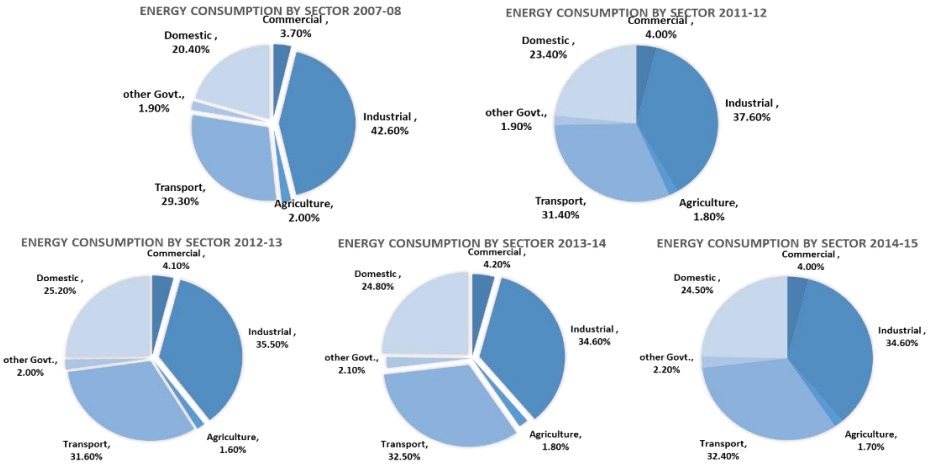


Figure 5 Energy Consumption by Sectors, Source: Energy Year Books of Different Years(Farooq and Kumar 2013) (Author's Production)

The above data and the modifying tendency of energy use, expressed in Figure 5, throughout the past decade dictates the Domestic sector is become one of the main users of energy in Pakistan and consequently, its importance cannot be ignored. This allows exploring one of the reasons of power crisis, if it is investigated where in the domestic sector power is going? We also need to explore the power usage of the domestic sector. Largely, power in Pakistan is being exhausted by agriculture, industry and household. These three areas are consistent in electricity consumption since decades. [44] Figure 6 beneath shows the electricity consumption since 1981 to date, and evidently flashes that housing part remained the largest consumer of electricity and its proportion share is boosted from 24% in 1981-82 to 47% in the year 2014, and its usage is increasing every year.

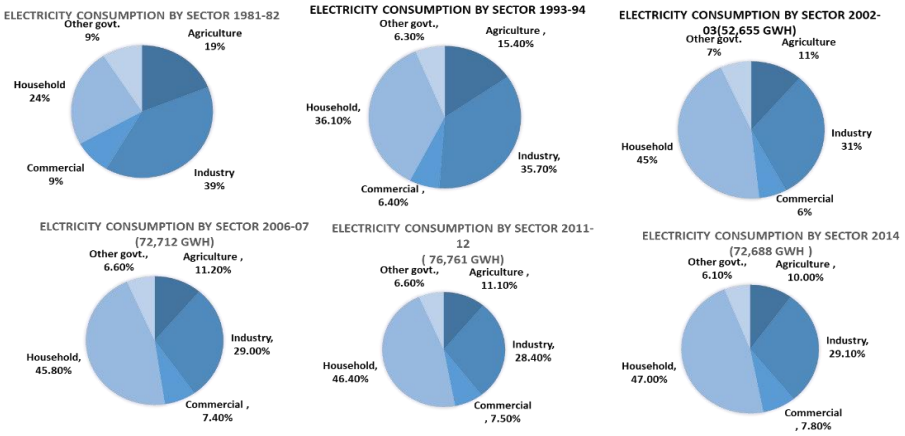


Figure 6 Sectoral consumption of Electricity in Pakistan, source: Pakistan Petroleum Information System 2014, Hydrocarbon Department of Pakistan, Energy yearbooks, multiple sources, (Author's Production)

The above statistic clearly indicates that the power is mostly utilised by the domestic sector, and its future demand must be clearly understood to know the actual need of power by domestic sector, which is the focus of this paper. Pakistan's power requirement is rising at a high rate, as per one estimate, it would be 100 GW in 2030 Figure 7 explains the case.The above projected values of energy or power, demand and supply suggests that Pakistan would be lacking behind in the fulfillment of its energy demand and this gap will continue to increase in future.

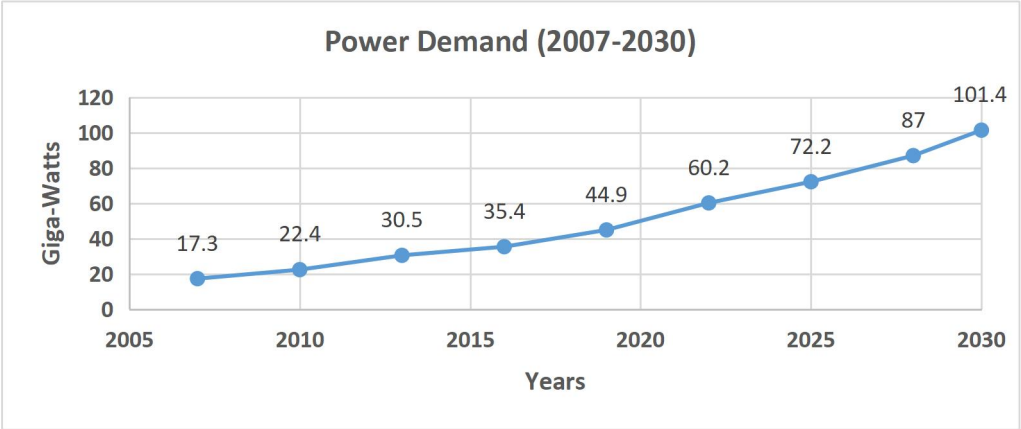


Figure 7 Power Demand Projection source: [45]

A brief discussion on Power Crisis

At the time of the independence of Pakistan in 1947, the generation capacity was 0.06GW, which was enough to meet the demand at that time. Power demand and supply needs were reasonably met until the early 1990s, when there emerged a power shortfall, because of many reasons, and some of them are identified in the Figure 8 below.

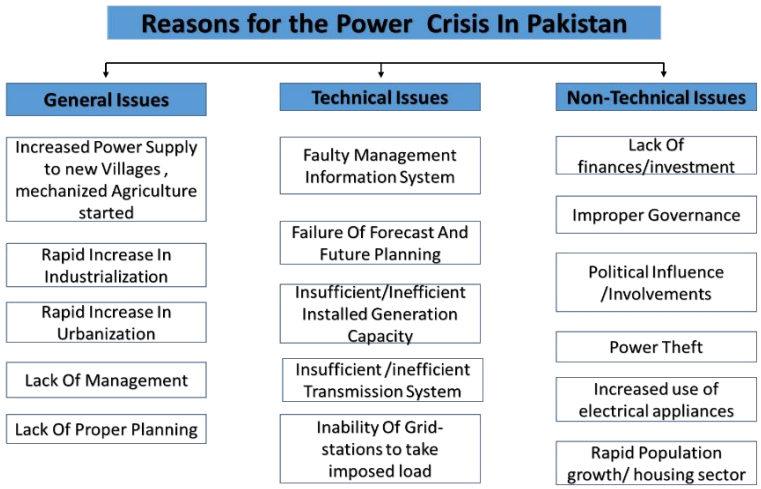


Figure 8 Reasons of the Power Crisis in Pakistan, Source Author's Production

Multiple reasons have caused the current power crisis in Pakistan, some are technical [46] administrative and non-technical issues [47] [48] . As shown in Figure 8 above, like in other Asian countries rapid increase in industrialisation in the country [49] in the 80s, demanded huge amount of power supply was demanded, but the power system was not able to cope with the increasing demand, as impropriate additions to the supply side were made. During this time and later in 90s, the political parties started to gain people's attention with the slogan of supplying electricity to the remote and far-off areas of Pakistan [50] [51] , which added to the severity of the issue, without prior arrangements of a supply-side increase [52].

The increasing trend of urbanisation played an important role in the power crisis of Pakistan. the 80s & 90s were the time when huge urbanisation took place. People were more attracted towards cities because of better life quality and job prospects in urban areas. Unfortunately, the management and planning [53] in the energy sector was very poor for decades, which resulted in a wrong information system, unrealistic forecasts, insufficient generation and a faulty transmission & distribution system, causing power menace. It is estimated that approximately 3222 GWh or nearly 5% of current capacity can be increased by taking efficient measures, which can further decrease the cost of electricity production by 0.52 cents and outage of electricity by 2- 3 hours [54].

Other factors are related to governance [55] , financial and political, for most of the time, Pakistan is a politically unstable country, because of this, no government could take long-term measures to overcome the power crisis, every government relied on short-term solutions, which were achievable within their unpredicted short tenures [52] . Pakistan has never been a financially strong country, and it has not invested well in the power sector.

Among other reasons, the government's strategy to invest in thermal power plants was the wrong decision taken at that point in time in the 80s & 90s. Oil and gas prices are not in the hands of the government, as most of the oil is imported. IPPs, also largely invested in thermal production of power. Resultantly, the power tariffs were high, and were not in the hands of domestic policy makers. [54].Further, under develop T& D(distribution loses 19-22%, [56] , infrastructure [57] , electricity theft, price mismatch and poor performance of utilities added to the situation [58]. According to one estimate, 66% of business activities are affected by the power shortage, and it has caused a 2% decrease in GDP and loss of approximately 40,0000/- jobs annually [59] [60] [61].

Pakistan's economy is greatly affected by the energy crisis. It is estimated that the energy shortfall has la-di-da the GDP of Pakistan by 4% in recent years. (an increase of 1.25% is required in electricity supply to increase 1% of GDP in Pakistan, e.g. from 1991 to 2013, electricity consumption enhanced from 31.54k GWH -76.8K GWH, resulting GDP growth of 143.5%, whereas supply increased from 40.1K GWH-96.5K GWH) Consequently, many factories and industries have shutdown, resulting large number of unemployment [62].

Research Methodology

To achieve the objective of this research, firstly we have thoroughly seen the causes of population and housing sector growth along with the investments made in parallel to power sector to cope with the increasing demands of Pakistan. The method mainly used in this research was 'Literature Review' for the initial understandings as well as for the analysis of growth Figure 9, explains the simple process followed in various steps.

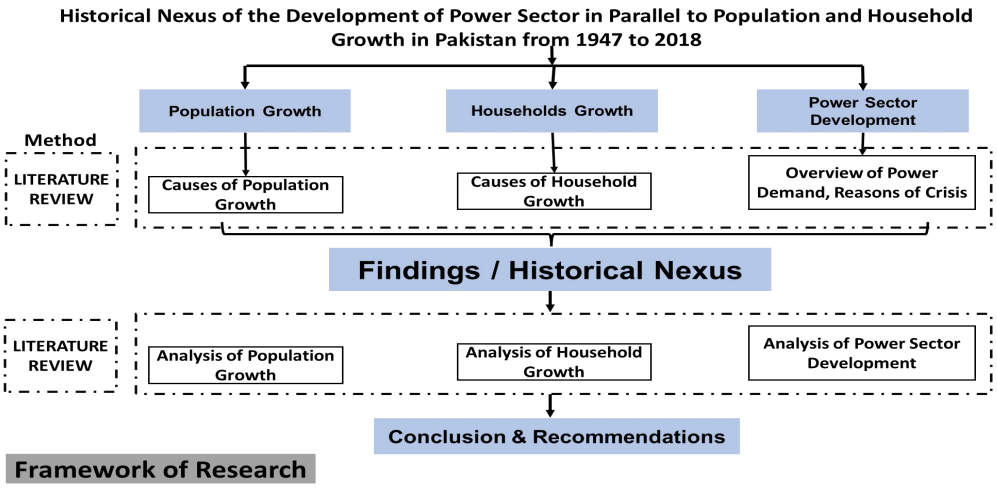


Figure 9 Framework of Research

FINDINGS

To understand the Historical Nexus among population growth, housing sector growth and power sector development, we will precisely and critically go through and perform an in-depth analysis of these through the established literature.

Population Growth Analysis of Pakistan and an in-depth focus on Punjab

The population of Pakistan has been growing at different growth rates, it was highest (5.5%) in the early time of its creation (1947-1951). There was a huge migration that took place between India and Pakistan at this time, and more people came to Pakistan than the people went to India. According to one estimate, 1.5M people were added to Pakistan during this early migration. After this early addition, the growth rate was not very high, it remained below 3%, but after 80's because of better life conditions, it went above 3.5%. In the early part of 90's the government took effective birth control initiatives, and the campaign was launched at the national level, guiding people on how to control the birth rate by using contraceptives, pills and oral guidance was given to people at very low cost and at their doorsteps. Due to these efforts, the growth rate came below 2.5%. In the 2000's due to an increase in the fertility rate, better hygienic conditions, low infant mortality rate, the AGR went above 3% again. At present, the population is growing at a high growth rate (3.8%), government has started taking more initiatives and trying to bring it

down to 2% to match international standards. At the time of independence, there were 39 p/km^2 and by 2018 it had increased to 263 p/km^2, this is almost a 680% increase in the density over a period of 70 years (Figure 10).

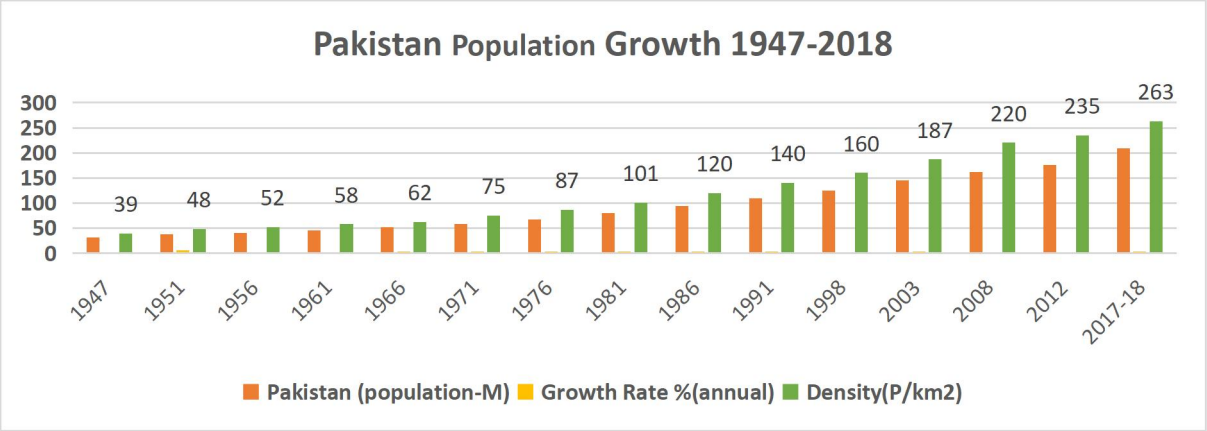


Figure 10 Historical Population growth of Pakistan, source: Census reports. [63], [64] , [65] [66], [67], [68]

Punjab Population Growth 1947-2018: Punjab also had different AGR, 4.4% being the highest in the early 70's. Punjab (area 205344 km^2) had a density of 106p persons/km^2 in the first census (1951) of Pakistan, and now it has a density of 536 persons/km2, which is a 500% increase. Currently, Punjab (2018) have a population of 110M, and it is growing with a controlled growth rate of 1.2-1.5% annually (Figure 11). The detailed analysis of different districts of Punjab is shown in Table 1, indicating District Lahore, with its no match, has been the most populous area, having a density of 6281 p/km^2. Districts Gujranwala, Faisalabad, Sialkot and Multan lie in the second tier, having densities of 1386, 1346, 1290 and 1277 respectively. Districts Rawalpindi, Okara and Gujrat lie in the third tier with the population densities of 1023, 1012 and 868, respectively. District Bahawalpur is the least populated area in Punjab, having a density of 148p/km^2. The historical population growths of all 36 Districts are shown in the Table 1 below.

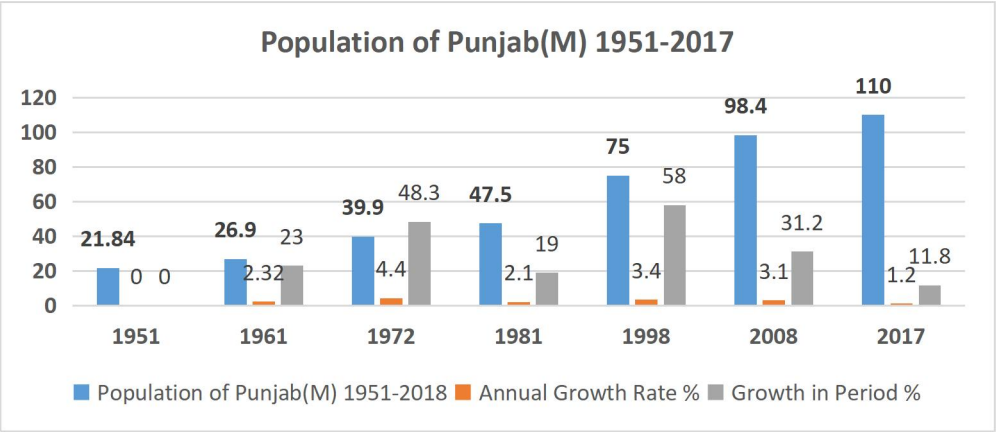


Figure 11 Historical Population Growth of Punjab source: Census reports, [63], [64] , [65] [66], [67], [68]

Table 1 District Wise Historical Population of Punjab Source: Census reports, [63], [64] , [65] [66], [67], [68] Author's Production

Sr. No.	District	Area (km²)	Population M (1951)	Population M (1961)	Population M (1972)	Population M(1981)	Population M (1998)	Population M (2017)	Current Density (P/km²)
1	Attock	6858	0.48	0.53	0.74	0.88	1.27	1.89	276
2	Bahawalnagar	8878	0.63	0.82	1.1	1.37	2.06	2.99	337
3	Bahawalpur	24830	0.53	0.74	1.1	1.45	2.43	3.67	148
4	Bhakkar	8153	0.23	0.33	0.5	0.67	1.05	1.65	202
5	Chakwal	6524	0.46	0.51	0.7	0.78	1.08	1.49	228
6	Chiniot	2643	0.33	0.4	0.57	0.7	0.96	1.37	518
7	Dera Ghazi Khan	11922	0.38	0.48	0.69	0.95	2.64	2.87	241
8	Faisalabad	5856	1.54	2	3.2	3.56	5.42	7.88	1346
9	Gujranwala	3622	0.8	1	1.6	2.11	3.4	5.02	1386
10	Gujrat	3192	0.74	0.84	1.2	1.41	2.05	2.77	868
11	Hafizabad	2367	0.25	0.29	0.44	0.57	0.84	1.16	490
12	Jhang	8809	0.55	0.7	1.03	1.27	2.84	2.75	312
13	Jhelum	3587	0.37	0.42	0.6	0.66	0.94	1.23	343
14	Kasur	4796	0.76	0.85	1.2	1.53	2.4	3.46	721
15	Khanewal	4349	0.64	0.77	1.1	1.37	2.07	2.92	671
16	Khushab	6511	0.27	0.36	0.55	0.64	1.21	1.28	197
17	Lahore	1772	1.1	1.6	2.6	3.55	6.32	11.13	6281
18	Layyah	6291	0.16	0.27	0.49	0.067	1.12	1.83	291
19	Lodhran	2778	0.29	0.37	0.56	0.74	1.17	1.7	612
20	Mandi Bahauddin	2673	0.42	0.5	0.72	0.85	1.16	1.6	599
21	Mianwali	5840	0.32	0.41	0.6	0.71	1.06	1.55	265
22	Multan	3720	0.73	0.98	1.51	1.97	3.12	4.75	1277
23	Muzaffargarh	8249	0.59	0.71	1.1	1.5	2.64	4.33	525
24	Narowal	2337	0.51	0.55	0.84	0.91	1.27	1.71	732
25	Nankana Sahib	2960	0.36	0.42	0.63	0.77	1.05	1.37	463
26	Okara	3004	0.73	0.83	1.1	1.49	2.23	3.04	1012
27	Pakpattan	2724	0.38	0.44	0.62	0.84	1.29	1.83	672
28	Rahim Yar Khan	11880	0.67	1	1.4	1.84	3.14	4.82	406
29	Rajanpur	12319	0.24	0.3	0.45	0.64	1.11	2	162
30	Rawalpindi	5286	2.2	2.5	3.8	2.1	3.37	5.41	1023
31	Sahiwal	3201	0.6	0.74	0.94	1.28	1.85	2.52	787
32	Sargodha	5854	0.89	1.1	1.6	1.91	2.67	3.71	634
33	Sheikhupura	15960	0.56	0.66	1	2.1	2.32	3.46	217
34	Sialkot	3016	0.96	1.1	1.5	1.8	1.69	3.89	1290
35	Toba Tek Singh	3252	0.61	0.69	1.1	1.14	1.63	2.2	677
36	Vehari	4364	0.56	0.7	1	1.33	2.09	2.89	662
	Total	220377	21.84	26.91	39.88	47.457	74.96	110.14	

Housing Sector Growth Analysis

Pakistan: The first ever calculation of household or housing units in Pakistan was done in the census of 1961, according to this, there were 7.8M households in the entire Pakistan. At present there are 32.2M(2017-18) households. Figure 12 shows that there is the growth of 415% in the number of households in the time of 57%.

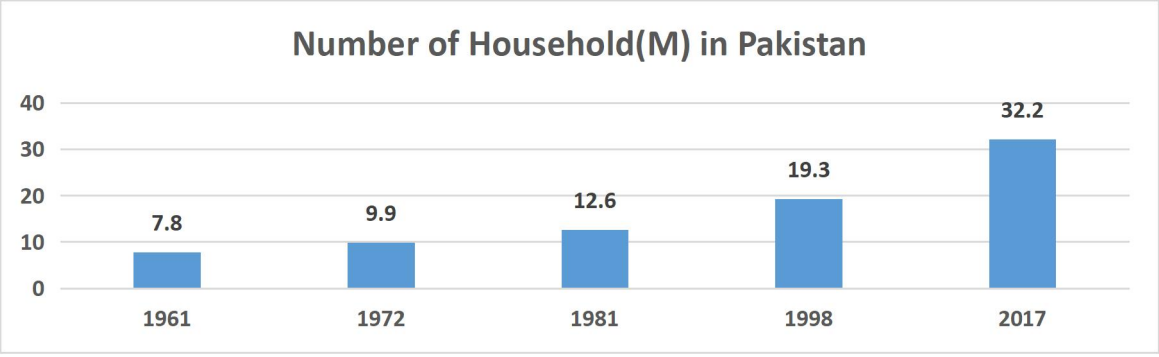


Figure 12 Historical development of Households in Pakistan, source: Census reports. [63], [64] [69] [33]

Punjab: In the census of 1961, Punjab had 2.7M households, which grew to 17.27M in the year 2018, having an overall growth of 635% in the time of 57 years Figure 13, which is higher than the overall growth of households in Pakistan(415%).

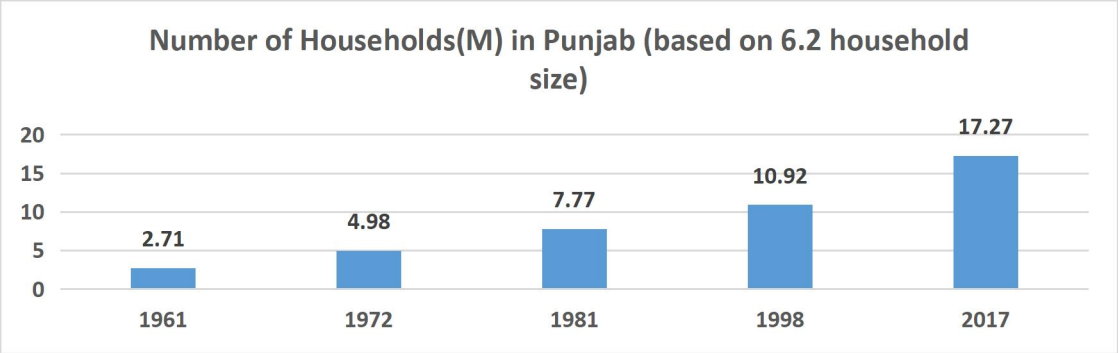


Figure 13 Historical development of Households in Punjab, source: Census reports, [63], [64] [69] [33]

Lahore District has the highest household density of 993 HH/km^{2,} and District Rajanpur have the lowest density of 21 HH/km^2. The details of household densities of all districts of Punjab have been shown in Table 2

Table 2 District-wise historical development of Households in Punjab, source: Census reports, [63], [64] [69] [33], Author's Production

Sr. No.	District	Area (km^2)	Households M (1961)	Households M (1972)	Households M(1981)	Households M (1998)	Households M (2017)	Current Density (HH/km^2)
1	Attock	6858	0.16	0.16	0.16	0.21	0.307	45
2	Bahawalnagar	8878	0.15	0.17	0.22	0.31	0.48	54
3	Bahawalpur	24830	0.014	0.18	0.23	0.36	0.59	24
4	Bhakkar	8153	0.07	0.006	0.11	0.16	0.27	33
5	Chakwal	6524	0.004	0.005	0.12	0.19	0.27	41
6	Chiniot	2643	0.01	0.01	0.06	0.12	0.22	83
7	Dera Ghazi Khan	11922	0.11	0.13	0.14	0.21	0.35	29
8	Faisalabad	5856	0.35	0.43	0.55	0.75	1.23	210
9	Gujranwala	3622	0.18	0.28	0.31	0.45	0.75	207
10	Gujrat	3192	0.09	0.18	0.23	0.31	0.44	138
11	Hafizabad	2367	0.06	0.07	0.09	0.12	0.18	76
12	Jhang	8809	0.01	0.21	0.34	0.43	0.44	50
13	Jhelum	3587	0.01	0.15	0.17	0.19	0.21	59
14	Kasur	4796	0.09	0.11	0.26	0.34	0.53	111
15	Khanewal	4349	0.002	0.01	0.22	0.29	0.47	108
16	Khushab	6511	0.004	0.005	0.11	0.15	0.21	32
17	Lahore	1772	0.36	0.61	0.54	0.89	1.76	993
18	Layyah	6291	0.05	0.07	0.11	0.15	0.28	45
19	Lodhran	2778	0.005	0.02	0.08	0.16	0.26	94
20	Mandi Bahauddin	2673	0.004	0.005	0.14	0.17	0.25	94
21	Mianwali	5840	0.07	0.1	0.12	0.15	0.24	41
22	Multan	3720	0.05	0.28	0.34	0.43	0.76	204
23	Muzaffargarh	8249	0.18	0.2	0.23	0.36	0.77	93
24	Narowal	2337	0.05	0.1	0.14	0.17	0.24	103
25	Nankana Sahib	2960	0.06	0.08	0.12	0.16	0.22	74
26	Okara	3004	0.01	0.02	0.23	0.37	0.49	163
27	Pakpattan	2724	0.01	0.05	0.14	0.2	0.31	114
28	Rahim Yar Khan	11880	0.08	0.22	0.27	0.42	0.7	59
29	Rajanpur	12319	0.03	0.06	0.1	0.15	0.26	21
30	Rawalpindi	5286	0.22	0.28	0.35	0.52	0.89	168
31	Sahiwal	3201	0.01	0.12	0.23	0.27	0.39	122
32	Sargodha	5854	0.02	0.18	0.31	0.41	0.6	102
33	Sheikhupura	15960	0.14	0.26	0.34	0.45	0.52	33
34	Sialkot	3016	0.03	0.13	0.27	0.37	0.58	192
35	Toba Tek Singh	3252	0.01	0.04	0.17	0.23	0.34	105
36	Vehari	4364	0.009	0.05	0.22	0.3	0.46	105
	Total	220377	2.712	4.981	7.77	10.92	17.267	

Power Sector Development Analysis

Is the population and housing growth aligned with the Power generation capacity in the history of Pakistan? At the time of independence in 1947, the electricity generation capacity of Pakistan was 0.06GW for a population of 31.5 million, which is 525 kW/capita. Soon after this, there was a rapid increase in the population size, and there were many villages which were electrified. WAPDA was established in 1958, and investments were made in the power sector, and generation capacity was increased to 0.12GW in the year 1959. By the efforts of WAPDA Figure 15, in the hydro and thermal projects, the capacity was raised to 0.64GW in the year 1964-65, the increase in power was nearly 2.5 GWh from 0.79 GWh. When WAPDA was formed in 1958, there were only 609 electrified villages, and their number increased approximately 300%, i.e. 1882 in the year 1965 [70] . Because of this rapid electrification of the villages and an increase in the social and economic standards in the country, people observed a new life.

In the year 1970, the capacity increased to 1.33GW, in 1980 to 3.0GW, and the years 1990-91, it rose to 7.0GW by the addition of two hydro projects namely Mangla & Tarbella dams, Pakistan power sector was able to cope with the demands of energy, but during the 1980's, there was rapid industrialization, huge economic growth, it became impossible by the power sector to meet the demand, and by the year 1994 there was shortfall of 2.0GW in the country [70] Figure 14 illustrates the generation capacity in the history of Pakistan.

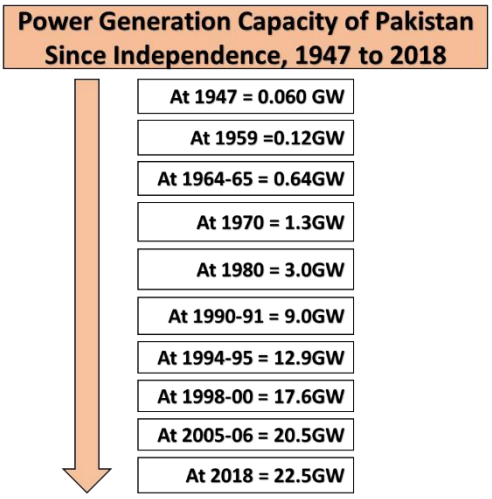


Figure 14 Power Generation Capacity in the History of Pakistan Source: [71] Author's Production

The power structure of Pakistan consists of three main tiers, i.e. generation, collection and distribution by its different agents and management. The National Transmission and Distribution Company (NTDC) is responsible for overall power collection and distribution. The different supply companies supply power to various cities, and the whole system is illustrated in Figure 15.

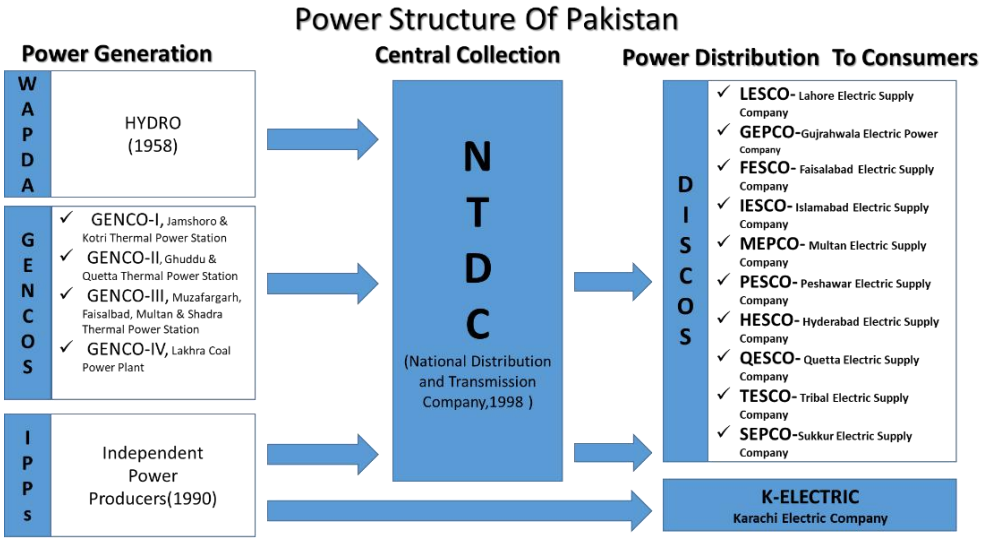


Figure 15 Power Structure Framework of Pakistan

During the 1990s, it was estimated that there would be an increase of 8% in the annual power demand, but to meet the increased demand in the generation capacity, there were not sufficient finances available [72] . So, in 1994, the government announced the 'Power Policy' and offered attractive incentives to foreign investors. These investors invested in the thermal power projects, largely oil-based. Thermal projects were chosen firstly, because they were easy to install in less time, secondly, the hydro projects were provocative because of the provincial political reasons. For instance, the 'Kala Bagh Dam' project was highly politicised [73].

The total installed capacity of power generation is 21.3 GW as of 2012, but it only produces approximately 12- 15.0 GW (due to changing patterns of rainfall because of global warming and unavailability of thermal sources, against the current demand of 17- 18 GW). Mainly, electricity is produced by WAPDA, which constitutes about 11.6 GW from both hydro and thermal sources. The details of other power generation are given in the Figure 16, which illustrates the overall capacity of power generation, showing that 64% (13.66GW) is being produced by thermal sources, causing huge carbon emissions and global warming. Table 3 & Table 4 give a breakdown of each power project and its capacity.

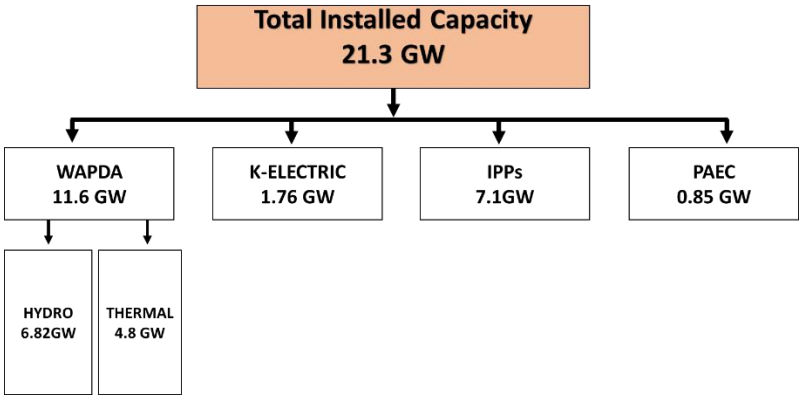


Figure 16 Installed Capacity of Power Generation in Pakistan, Source: (Rauf et al. 2015) and Author's Production

Table 3 WAPDA and IPP Projects and Capacities

Sr.No	WAPDA Thermal Power Plants	GW
1	Gas Turbine Power Station, Shahdra	0.06
2	Steam Power Station, Faisalabad	0.13
3	Gas Turbine Power Station, Faisalabad	0.25
4	Gas Power Station, Multan	0.2
5	Thermal Power Station, Muzaffargarh	1.35
6	Thermal Power Station, Guddu	1.66
7	Gas Turbine Power Station, Kotri	0.17
8	Thermal Power Station, Jamshoro	0.85
9	Thermal Power Station, Larkana	0.15
10	Thermal Power Station, Quetta	0.04
11	Gas Turbine Power Station, Panjgur	0.04
12	Thermal Power Station, Pasni	0.02
	TOTAL	4.81

S. no.	WAPDA Hydro project	Installed capacity (GW)
1	Tarbela	3.48
2	Ghazi Barotha	1.45
3	Mangla	1.0
4	Warsak	0.24
5	Chashma	0.18
6	Malakand	0.02
7	Dargai	0.02
8	Rasul	0.02
9	Shadiwal	0.01
10	Chichoki Malian	0.01
11	Nandipur	0.01
12	Kurram Gari	0.004
13	Reshun	0.003
14	Renala	0.001
15	Chitral	0.001
16	Jagran-I	0.03
17	Kathai	0.002
18	Kundel Shahi	0.002
19	Leepa	0.002
20	Northern Area	0.09
21	Small/Micro Hydel Stations	0.003
	Total	6.6

Sr. No.	IPP POWER PROJECTS	Installed Capacity GW
1	Hub Power Project	1.29
2	Mahmood Kot Muzaffargar	0.36
3	Mahmood Kot Muzaffargar	0.36
4	Altern Energy Ltd, Attock	0.03
5	Fauji Kabirwala Power , Khanewal	0.16
6	Gul Ahmad Energy Ltd, Korangi	0.14
7	Habibullah Coastal Power Limited	0.14
8	Japan Power Generation, Lahore	0.12
9	Kohenoor Energy Limited, Lahore	0.13
10	Liberty Power Limited, Ghotki	0.23
11	Rousch Power, Khanewal	0.41
12	Saba Power, Sheikhupura	0.11
13	Southern Electric Power, Raiwind	0.11
14	Tapal Energy Limited, Karachi	0.13
15	Uch Pwr., D. M. Jamali, Nasirabad	0.59
16	Attock Gen, Morgah Rawalpindi	0.17
17	Atlas Power, Sheikhupura	0.23
18	Kot Addu Power (Privatized)	1.64
19	Saif Power Qadirabad, Sahiwal	0.23
20	Sitara Energy	0.08
21	Nishat Chunian Power	0.20
22	Nishat Power Limited	0.20
	TOTAL	7.1

Table 4 PAEP and K-Electric Power Projects and Capacities

Sr. No.	Pakistan Atomic Energy Projects(PAEP)	Installed Capacity GW
1	KANUPP	0.14
2	CHASNUPP-1	0.33
3	CHASNUPP-2	0.34
4	KHUSHAB	0.05
	TOTAL	**0.85**

Sr. No.	K-Electric Power Projects	Installed Capacity GW
1	Thermal Power Station, Korangi	0.32
2	Gas Turbine Power Station, Korangi	0.08
3	Gas Turbine Power Station, SITE	0.01
4	Thermal Power Station, Bin Qasim	1.26
	Total	**1.76**

Rental Power Plants (RPRs): Rental power plants were taken as a short-term solution to meet the demand of energy. It is brought and installed on site as required. [74] [75] The names, capacity and fuel type being used by these RPPs are shown in the Table 5 below, the total capacity of these is around 2.73GW, and most of them are using oil as source of power generation.

Table 5 Rental Power Projects in Pakistan and their capacities, Source: PPIB and PEPC

No.	RPPs name	Net capacity (GW)	Fuel type	Contracts status
1	Pakistan Power Resources, Guddu	0.11	Low BTU gas	Effective
2	Pakistan Power Resources, Piranghaib, Multan	0.19	Residual fuel oil	Signed
3	Techno Rental Power Project-1, Summundri, Faisalabad	0.15	Residual fuel oil	Effective
4	Techno Rental Power Project-2, Sahuwal, Sialkot	0.15	Residual fuel oil	Effective
5	Young Gen Power, Faisalabad	0.2	Residual fuel oil	Effective
6	Gulf Rental Power, Gujranwala	0.06	Residual fuel oil	Effective
7	Independent power Limited	0.2	Residual fuel oil	Under process
8	Kamoki Energy Limited	0.07	Residual fuel oil	Signed
9	Karkey Karadeniz, Karachi (Karkey)	0.23	Residual fuel oil	Effective
10	Premier Energy	0.58	Residual fuel oil	Under process
11	Reshma Power Generation, Manga-Raiwind Road	0.2	Residual fuel oil	Effective
12	Ruba Power Generation, Manga-Raiwind	0.15	Residual fuel oil	Signed
13	Sialkot Rental Power, Eminabad	0.06	Residual fuel oil	Signed
14	Walter Power International, Karachi	0.2	Residual fuel oil	Signed
15	Abbas Steel	0.1	Residual fuel oil	Under process
16	Karkey Karadeniz, Karachi (Karkey 1)	0.22	Residual fuel oil	Under process
17	Techno-E-Power (Pvt.) Limited, Faisalabad	0.15	Residual fuel oil	Signed
18	Walter Power International, Naudero-I	0.05	Gas	Effective
19	Walter Power International, Naudero-II	0.05	Gas	Under Process
20	**Total**	**2.73**		

Additional Electricity Generation Projects: The Government of Pakistan has taken some initiatives to install new projects to overcome the power crisis. Mixed fuel is going to be used for power generation, mainly thermal and hydro will be the sources to produce electricity. There are a few solar projects as well, with a total capacity of 0.9GW. There would be the addition of around 16.6 GW of power by the end of 2018. A list of projects and their capacity is given in the Table 6 below [52] [76] [77].

Table 6 New Power Projects in Pakistan, source: (Khalid and Kumar 2013) [77]

Sr. No.	Year	Name of the Projects	Capacity GW	Agency	Fuel
1	2014	Guddu-1	0.24	GENCOs	GAS
2		Nandipur Power Project	0.43	GENCOs	OIL
3		Guddu-2	0.24	GENCOs	GAS
4		Quaid-e-Azam Solar Park (Phase-I)	0.10	PPDB	SOLAR
5		Quaid-e-Azam Solar Park (Phase-II)	0.30	PPDB	SOLAR
6		Guddu Steam (3)	0.26	GENCOs	GAS
7	2015	Quaid-e-Azam Park slr. (Phase-III)	0.60	PPDB	SOLAR
8	2016	Neelum Jhelum Hydel	0.97	WAPDA	HYDRO
9		Golen Gol	0.11	WAPDA	HYDRO
10		Patrind HPP	0.15	PPDB	HYDRO
11	2017	Tarbela 4th Extension	1.41	WAPDA	HYDRO
12		Coal Plant at Sahiwal	1.20	PPDB	COAL
13	2018	Coal Plant at Jamshoro	1.32	GENCOs	COAL
14		Thar Coal Plant	1.32	GENCOs	COAL
15		Coal Plant Larkana	1.32	GENCOs	COAL
16		Gadani Power Park	6.60	Pvt.Ltd	OIL
		Up to 2018 addition in Generation	**16.6**		

It is also estimated that by 2030, 2040 & 2050, the renewables resources would be producing 17.9, 18.6 and 19.3 GW of power respectively, utilising solar, wind and small hydro [78] [76] . NEPRA has its upcoming plans to finance in the renewable resources and total generation by the year 2030 would be 9.7 GW (Figure 17)

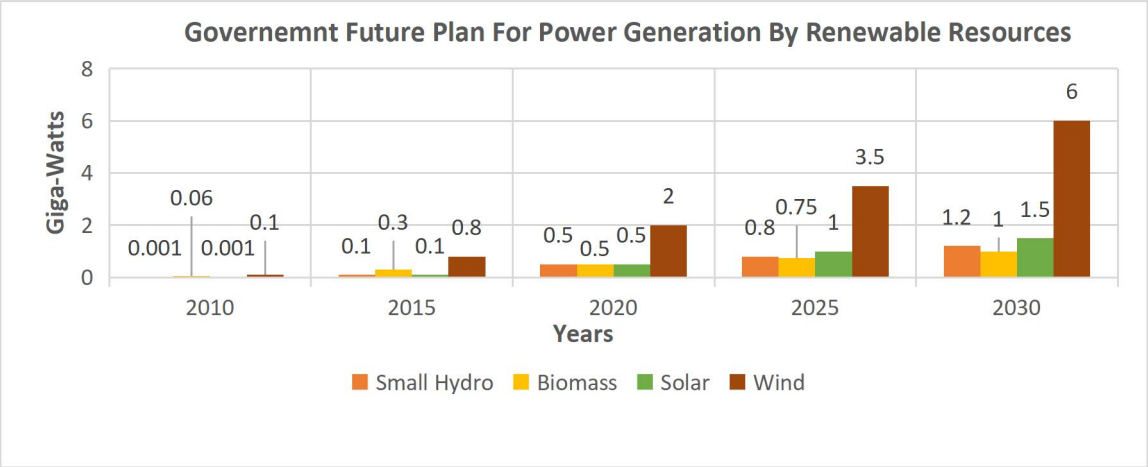


Figure 17 Government Plan for power generation from renewable resources, source: [79],[NEPRA]

The domestic sector has been the prime consumer of electricity in the last fifteen years, and there is a linear growth of electricity consumption and percentage (Figure 18 & Figure 19). Electricity consumption growth in Pakistan is related to the foreign investment, population and income. If there is 1% bourgeon in the above variables, there is 0.056%, 1.605% & 0.97%respectively (Zaman, Khan et al. 2012). The growing population in Pakistan is discussed earlier, and it indicates that there would be a huge increase in electricity demand, and which needs to be addressed. According to one estimate, demand for electricity is growing at the rate of 10% annually verses supply rate of 7%, and resulting in many hours of electricity outage.

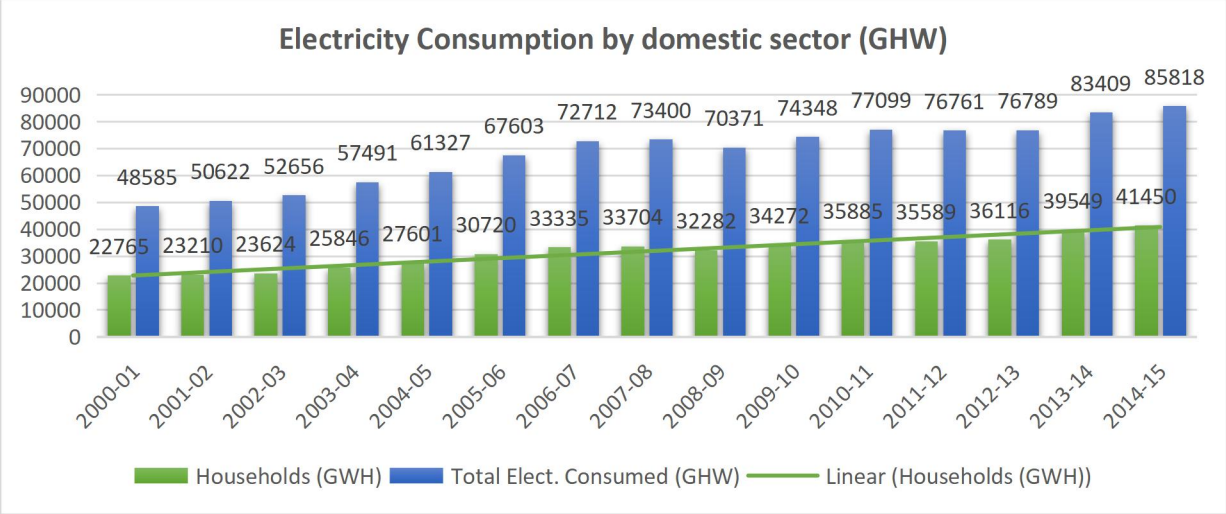


Figure 18 Electricity consumption by domestic sector, Source: Pakistan Economic survey 2015-16(Author's Production)

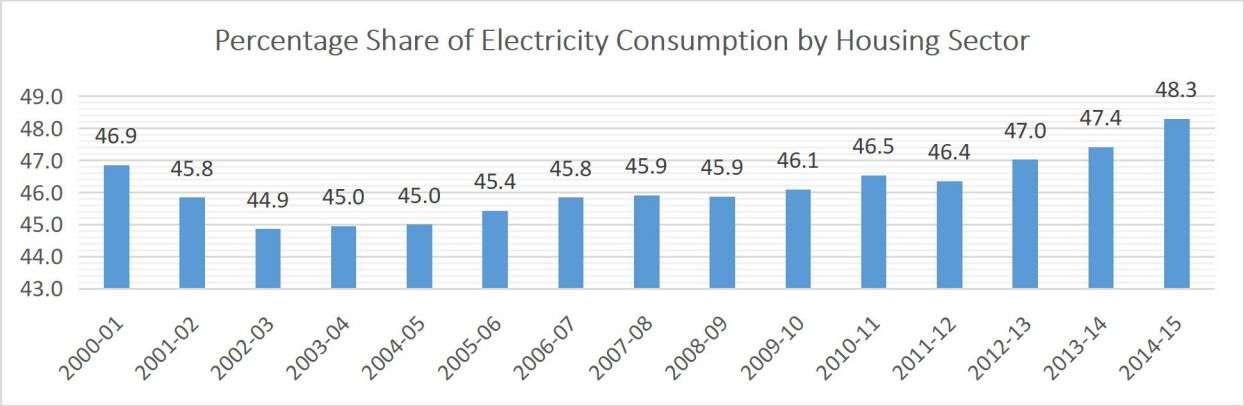


Figure 19 Percentage share of electricity consumption by housing sector, Source: Pakistan Economic Survey 2015-16(Author's Production)

In Pakistan, the domestic sector has the largest number of consumers, 14.8M, Figure 20 showing the percentages of other consumers as of 2006, with only the domestic sector using 84%, which is huge. Punjab had 9.9M domestic consumers at this time, out of a total of 14.8M in Pakistan.

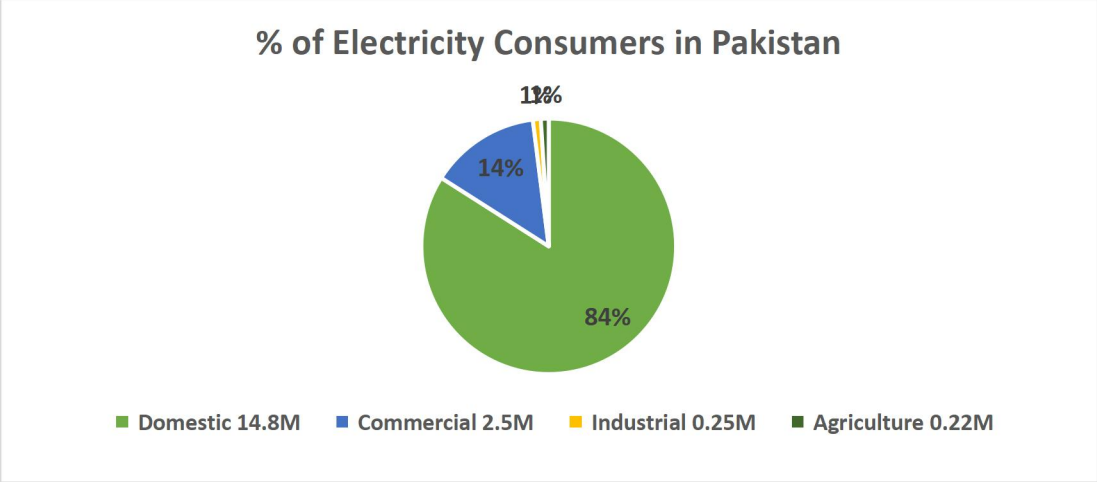


Figure 20 Percentage of Electricity Consumers in Pakistan as of 2006 Source: [71]

Punjab has been consuming a major share of the electricity produced in the country. year-wise consumption from 1990-2012 is shown below in Figure 21 below, showing 57.5 to 62 per cent respectively.

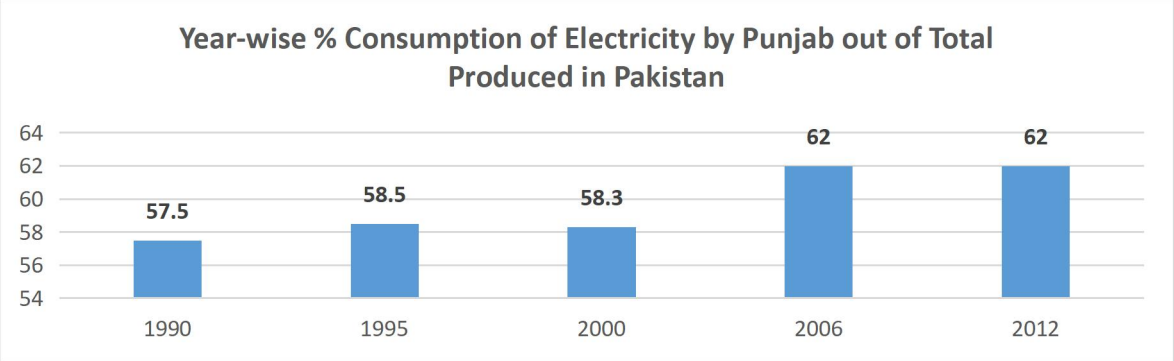


Figure 21 Year-wise Electricity Consumption of Punjab out of Total Produced in Pakistan, source: [71] [80]

Punjab consumes 62% of the electricity produced in the country, out of which 85.6% [81] It is used by the domestic sector. (Figure 22), which is 53% of the total power produced in the country. Its use by the domestic sector increased drastically during 2006-12, jumping from 43.3% to 85.6%.

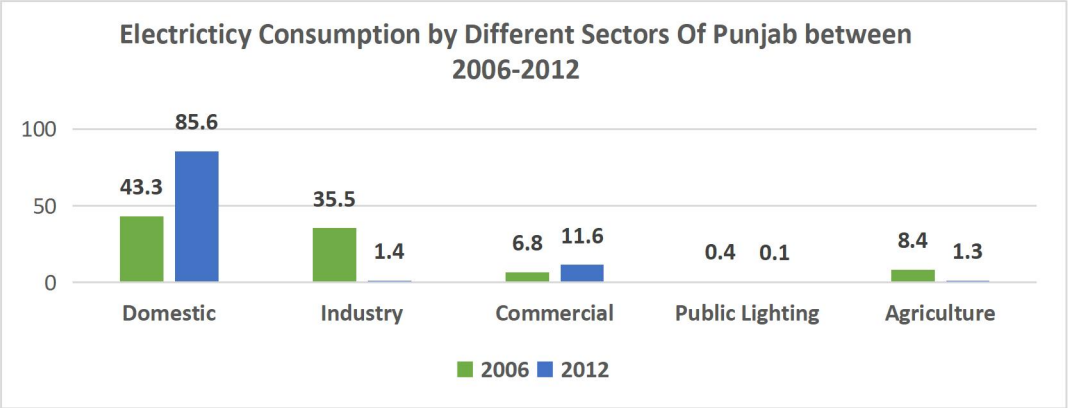
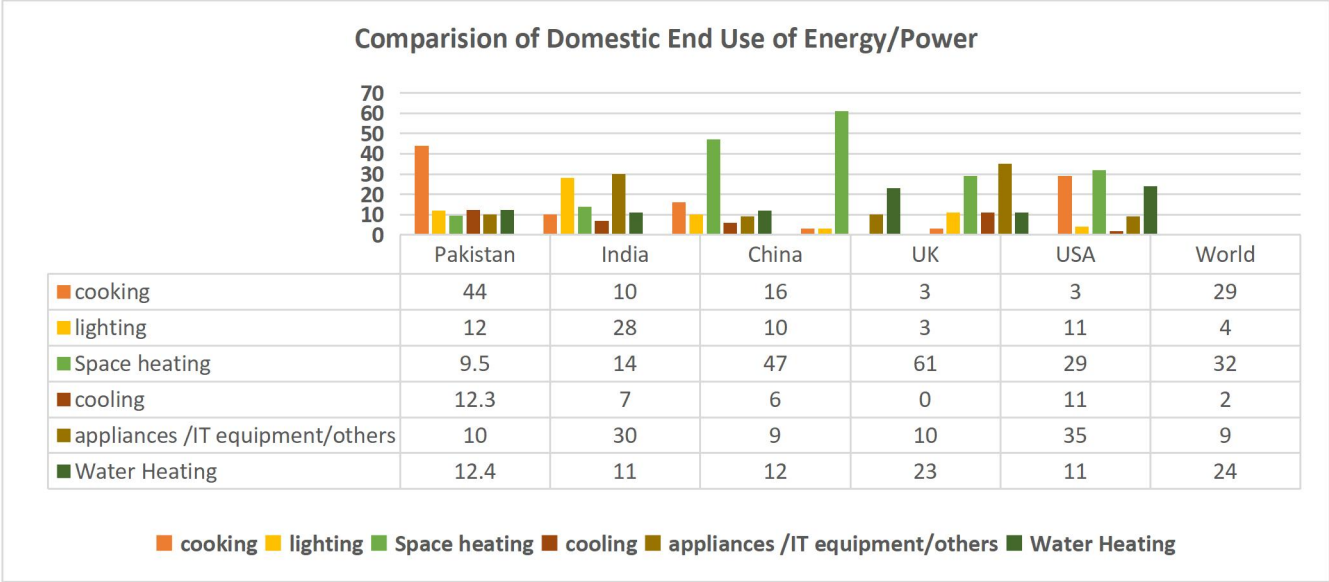


Figure 22 Electricity Usage in Punjab by different sectors 2006-2012 Source: [71] [80]

We have seen where power and overall energy is being used in the domestic sector of Pakistan and made a brief comparison with the other countries. Figure 23 shows that mainly cooking and cooling of spaces are the consuming variables.



	Pakistan	India	China	UK	USA	World
cooking	44	10	16	3	3	29
lighting	12	28	10	3	11	4
Space heating	9.5	14	47	61	29	32
cooling	12.3	7	6	0	11	2
appliances /IT equipment/others	10	30	9	10	35	9
Water Heating	12.4	11	12	23	11	24

Figure 23 International Comparison of domestic end use of energy 2015, Source: IEA, Energy Departments of respective countries. EIA, DTI, DEEFRA, Author's Production

CONCLUSION & RECOMMENDATIONS

In this unique research paper, we have tried to understand how historically the population, housing and power sector developed parallel. The current power crisis in Pakistan has shaken every walk of life, due to unavailability and huge power cuts, especially in the summer season. This research throughs light on the nexus among these three variables, and highlights the severity caused by either of them. The broader research covers the situation in the whole of Pakistan with special emphasis on the province of Punjab. The current urban population of Pakistan is 39.7%, and it would be 50.3% by the year 2050. In Punjab, currently 42.4% of the population are urbanites, and it would increase to 63.2% by 2050 with a growth rate of 1.2 %. This urbanisation would also result in an increased demand for power by the domestic sector. It is believed that Pakistan needs 0.7M new houses every year to meet the demand. The domestic

sector consumes 24.5% of total available energy in Pakistan (Figure 5) and 47% of total electricity produced (Figure 6). According to one estimate, the power demand of Pakistan would go up to 101 GW (Figure 7). We have also identified the reasons for power crises of Pakistan as technical, non-technical and general issues (Figure 8). Pakistan started with a generation capacity of 0.06GW, which rose to 22.5GW in 2018. (Figure 14) A detailed breakdown of power generated through all sources is provided. When Pakistan got independence, its population was 31M, grew to 209M by the year 2018, as per one estimate, it would be 310M by 2050. (Figure 10). Punjab had 21.8M according to the first census, now (2018) it had 110M inhabitants and it would have 177M by the year 2050. (Figure 11).

By 2018, Pakistan had 32.2M of households, and it is forecasted to be 50.8M by the year 2050 based on an average household size of 6.1(Figure 12 &Table 2). Punjab have 17.3M households currently and would have 28.6M by 2050 based on an average population growth rate of 1.5% and a household size of 6.2(Figure 13).

The power generation capacity of Pakistan is around 22.5GW, and the current demand is 17GW, but it is not producing enough power to meet the current demand, and there is a shortage of 5GW Figure 14. Considering all future projects, Pakistan would be able to produce 43.3GW by the year 2030, and its demand would be 54.4GW. The domestic sector is the largest consumer of power, having 84% of consumers in the entire country (Figure 20). Punjab consumes 62% (Figure 21)of the total electricity produced in the country and out of this 85.6% (Figure 22)is consumed by the domestic sector of Punjab, so in total domestic sector of Punjab consumes 53% of the power consumed in Pakistan.

Overall, we see that the population growth and the need for more houses are the driving factors of rapid power demand in Pakistan. Historically, the investments in the thermal fuel-based power plants are the main cause of the crisis in the country, it should have been avoided. The green energy generation policy seems to be the way forward to reduce dependency on non-renewable resources. The future policies should focus more on wind, solar and hydro projects.

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