Pakistan - 2023

PREAMBLE AND SUMMARY

This report provides information on the status and development of nuclear power programmes in Pakistan, including factors related to effective planning, decision making and implementation of the nuclear power programme that together lead to safe and economical operation of nuclear power plants.

The CNPP summarizes organizational and industrial aspects of nuclear power programmes and provides information about the relevant legislative, regulatory and international framework in Pakistan.

Pakistan has two nuclear power plants sites containing six operating units, constituting a total electricity generation capacity of 3262 MWe. One site in the Punjab province, near the city of Mianwali, is called the Chashma Nuclear Power Generating Station (CNPGS) that houses four units C-1, C-2, C-3 and C-4, all based on a 300 MWe pressurized water reactor (PWR) design. The second site near the city of Karachi, in the Sindh province, is called the Karachi Nuclear Power Generating Station (KNPGS). Two identical plants at KNPGS, KANUPP-2 and KANUPP-3, are based on a 1100 MWe advanced PWR design. A 137 MWe pressurized heavy water reactor (PHWR) design unit named KANUPP-1 at KNPGS is being decommissioned, after completing 50 years of operation.

1. COUNTRY ENERGY OVERVIEW

1.1. ENERGY INFORMATION

1.1.1. Energy Policy

The Government of Pakistan (herein referred to as the Government) has formulated several policies for the development of the power sector in the past. The aims of these policies were elimination of inefficiencies in existing generation, transmission and distribution systems, as well as diversification of the energy generation mix, with maximum utilization of indigenous energy resources to supply reliable, affordable and clean electricity to the general public.

The National Power Policy 2013 issued by the Government aimed to develop an efficient and consumer-centric power generation, transmission and distribution system that could meet the needs of the people and boost the economy of the country in a sustainable and affordable manner. The goals of the policy were explicitly defined, as were the resulting targets and the extent of meeting the targets, which would gauge the success of the policy. The targets of the prescribed policy included:

- Complete elimination of load shedding;
- Decreasing the average cost of electricity generation to below 10 Pakistani rupee/kWh;
- A decrease in transmission and distribution losses from 23–25% to 16%;
- An increase in the revenue collection from the current 85% to 95%;
- A reduction in the time required for decision making at the ministry level or other related departments to a minimum.

In 2015, the Government introduced the Power Generation Policy 2015 offering incentives to private investors to increase private investment in the power sector. The policy offered the private sector incentives to not only set up new power generation projects but also to invest in public sector power generation projects in different phases of development or already developed and looking for divestment. The objectives of this policy are achieving sufficient least cost power generation capacity in the country, prioritizing utilization of indigenous resources, facilitating all stakeholders involved in the transaction and safeguarding the environment.

In 2019, the Alternative and Renewable Energy Policy was introduced to further assist the development of renewable resources in the country. The main objectives of the policy were to produce a conducive environment for the development of renewable power projects, increase the share of installed ‘green capacity’ to 20% by 2025 and 30% by 2030 and introduce private capital in the area.

The National Electricity Policy 2021 envisages on the development of a liquid electricity market design that is efficient and affordable to financially transform this sector. It also envisions diversifying the fuel mix of the generation capacity to ensure optimal utilization of energy resources like coal, gas, hydropower and nuclear and reduce reliance on imported fuels. Steps will also be taken for the development of the power sector in a way that it is environmentally and technically sustainable.

1.1.2. Estimated Available Energy

Pakistan’s energy resources consist of fossil fuels (coal, gas, oil), uranium and renewables (hydropower, wind, solar, biomass, etc.). The fossil fuel reserves and the renewable energy potential of Pakistan are listed in Table 1.

TABLE 1: ESTIMATED AVAILABLE ENERGY SOURCES

Energy Sources	Electricity Supplied [GW(e)*h] Net	Installed Capacity [GW(e)]	Share (%)
Total	137363		
Nuclear	22280		16.2
Fossils	49250		35.9
---Coal (hard coal, lignite)	23730		17.3
---Gas	15130		11
---Oil	10390		7.6
Renewables	40740		29.7
---Hydro (with tide wave)	35320		25.7
---Solar(PV)	810		0.6
---Wind	4610		3.4
Others	1190		0.9
Others	22990		16.7
---Baggase	1190		0.9
---RLNG	22990		16.7

Data as of 2022-12-31 from IAEA Power Reactor Information System
*Solid (coal), liquid - million tonnes; gas - billion m3; uranium ore - million tonnes.

The country possesses meagre dependable oil reserves and the indigenous oil production in the year 2021 was barely enough to meet around 16.6% of national oil consumption that year. A large part of oil demand in the country is met by importing crude oil and oil products. The inability to drastically expand Pakistan's oil reserves for the past many years is resulting in a gradually decreasing share of indigenous oil in the total oil consumption of the country. In 2021, Pakistan imported oil products worth around US $8.2 billion.

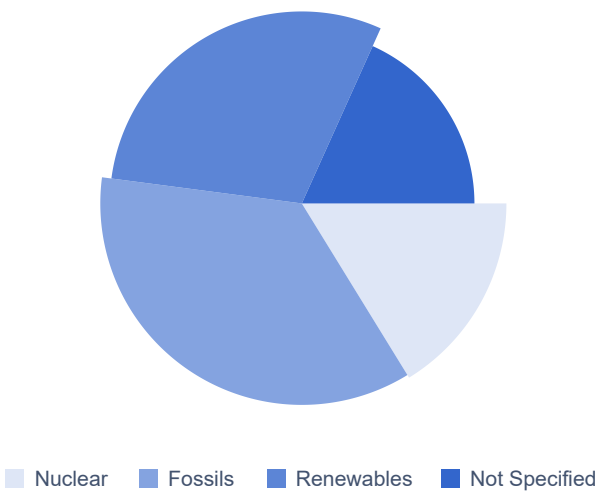
The natural gas reserves of the country are also limited and quickly regressing due to the increasing demand. While the Government actively seeks to develop new exploratory wells to increase the domestic gas cache, it has to rely on imported liquefied natural gas (LNG) and piped gas. Infrastructure to handle imported LNG has been established and that for import of gas from neighbouring gas rich countries is also being developed. In the year 2020–2021, around 416 million MMBtu (metric million British thermal units) of LNG, worth around US$ 2.7 billion, was imported, corresponding to around 28% of the total natural gas supply in the country.

In the past decade, coal has been the fuel of choice for electricity generation in Pakistan, with its capacity jumping from almost zero in 2016 to currently touching the 4 670 MW mark. The current coal based electricity generation configuration is relying heavily on imported coal. This trend is likely to change as units based on the Thar coal field, the largest coal reserves in the country, are added to the electricity generation mix. The first Thar power plant, with a capacity of 660 MW, became operational in the first quarter of 2019–2020. According to the Indicative Generative Capacity Expansion Plan (IGCEP) developed by the Transmission and Despatch Company (NTDC), five more units with 2970 MW capacity will become operational by the year 2030.

The total estimated hydropower potential of Pakistan is around 60 000 MW, of which nearly 18% is currently being exploited. The hydropower potential lies in the northern part of the country, in the provinces of Gilgit Baltistan (GB), Khyber Pukhtunkhwa (KP) and Azad Jammu & Kashmir (AJK), far from load centres of the country consisting of rugged terrain and home to some of the highest peaks in the world. High investment cost for the setting up a hydel plant, development of an electricity transmission network and resettlement of the affected population are a few hurdles in the way of hydropower development. IGCEP envisages an additional committed capacity of 13 446 MW by the year 2030, consisting of 14 hydro units.

Pakistan has wind corridors that can accommodate about 50 000 MW [3] of wind based capacity and the potential for solar power is also high, as sunlight is available abundantly almost throughout the country. Currently, the capacity share of these renewable resources is small, but it is expected to increase sharply, as reflected in the Alternative and Renewable Energy Policy 2019 and IGCEP targets.

CHART 1: ESTIMATED AVAILABLE ENERGY SOURCES



Electricity Supplied [GW(e)*h]

1.1.3. Energy Consumption Statistics

Energy consumption statistics from the year 2000 are given in Table 2. In these 21 years, the total energy consumption (including bioenergy) of the country has more than doubled, at an average growth rate of 4.2%, while electricity consumption increased at an average growth rate of 4.6%.

Since the turn of the century, indigenous oil production has hovered around the 60 000 barrels a day mark (peaking at 95 000 barrels per day in 2015), barely enough to cater for one fifth of the total oil demand in the country. The rest of the oil demand was met by importing crude oil and refined products. This heavy dependence on imported oil over the years has been severely denting the economy, especially when international oil prices soared, forcing policy makers to subsidize natural gas to replace oil in every sector of the economy. As a result, from 2000 to 2010, the use of natural gas doubled while that of oil was reduced by 5%, putting immense pressure on the gas infrastructure, especially during winters, when the shortage of gas paralysed almost every sector of the economy as a result of directing the supply of gas where it was needed the most, the residential sector. In the recent past, domestic gas fields have been showing gradual decrease in production and, while the demand of gas is rising, the output — which once stood at more than 4000 MCF per day in 2012 — dropped to almost 3500 MCF per day in 2021. Import of LNG was allowed at that time to compensate for the shortage of gas in the system.

Use of coal saw double digit growth of almost 11% in the past two decades (tripled in the last six years) owing to an increasing demand in the power and cement sectors. In the year 2020–2021, 9.2 million tonnes of coal were produced locally, mainly by coal mines in the two southern provinces of Sindh and Baluchistan that produced 90% of the total domestic coal. Thar coal field in Sindh alone produced 3.7 million tonnes of coal. Local coal production met only 25% of the total coal demand, while 75% of the coal requirement was met by imported coal.

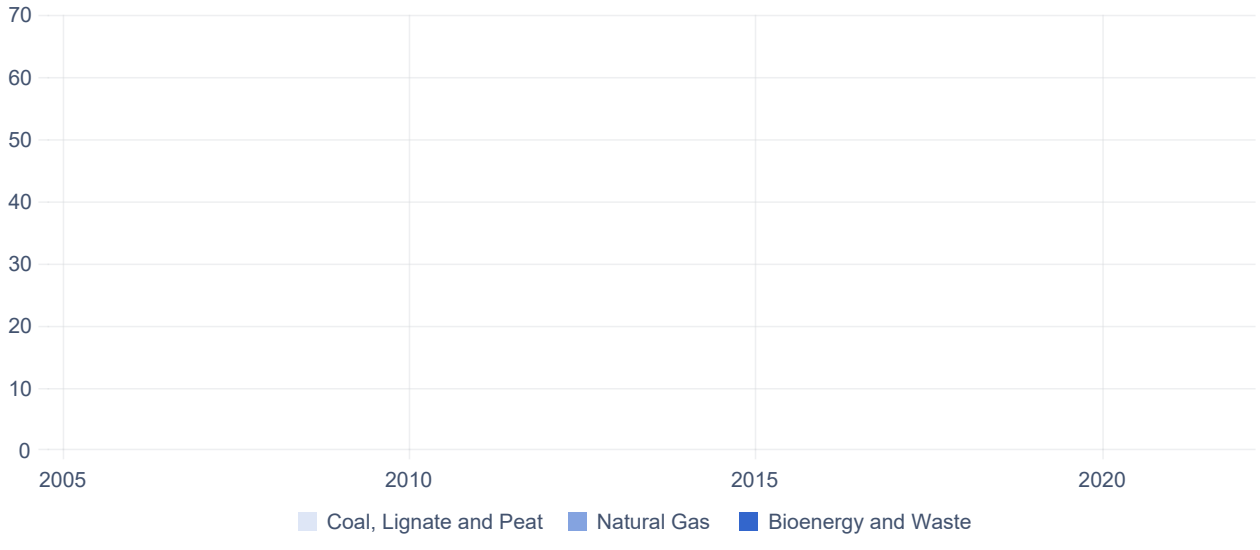
Use for gas and coal is expected to keep growing at the current level, in the short to medium term, due to their use in the domestic and industrial sectors while the consumption of electricity is also expected to grow with growing urbanization, increasing access to electricity and an increasing share of electricity in the domestic and transport sector.

TABLE 2: ENERGY CONSUMPTION

Final Energy consumption [PJ]	2005	2010	2015	2020	2022	Compound annual growth rate (%)
Coal, Lignate and Peat	148	169	205	290		
Oil	483	482	731	715		
Natural gas	650	800	759	810		
Bioenergy and Waste	1112	1244	1383	1532		
Electricity	244	277	325	387		
Heat	0	0	0	0	0	
Total	2637	2972	3403	3734	0	-100

Data as of 2022-12-31 from IAEA Referential Data Series 1
*Latest available data, please note that compound annual growth rate may not be representative of actual average growth.

CHART 2: ENERGY CONSUMPTION



Final Energy consumption [PJ]

1.2. THE ELECTRICITY SYSTEM

1.2.1. Electricity System and Decision Making Process

Historically, the power sector of Pakistan has been under the ownership of two public utilities: the Water and Power Development Authority (WAPDA) and Karachi Electric Supply Corporation (KESC). KESC was responsible for the generation, transmission and distribution of electric power for the city of Karachi and its surrounding areas, and WAPDA was responsible for the country's remaining electricity supply system. The sharply rising demand for electricity at the turn of the past century surpassed all expansion expectations and the electricity generation infrastructure became inadequate.

To improve the performance of the power sector, a new institutional framework was set up. The National Electric Power Regulatory Authority (NEPRA) was established in 1997, as an independent regulator to ensure a transparent, competitive and commercially oriented power market in Pakistan. WAPDA was unbundled into four Generation Companies (GENCOs), NTDC and eight (later rearranged into ten) Distribution Companies (DISCOs). KESC was privatized in 2005 and later rebranded as K-Electric.

Pakistan Electric Power Company (PEPCO) also came into existence, responsible for restructuring and preparation for privatization. The Private Power Infrastructure Board (PPIB) was established to facilitate private investment in the power sector. The Alternative Energy Development Board (AEDB) was created to oversee the development of renewable energy resources. Development of nuclear power remained the responsibility of the Pakistan Atomic Energy Commission (PAEC).

The overall planning of the electricity system is under the control of the National Economic Council (NEC), which is the supreme body responsible for development activities in the country. It was created in December 1962 under Article 145 of the Constitution of Pakistan. The NEC is headed by the Prime Minister. Its members include Federal Ministers, the Governors/Chief Ministers of the provinces and the Deputy Chairman of the Planning Commission.

The Planning Commission is the chief instrument for formulating the national plans, while the Energy Wing of the Planning Commission formulates energy plans based on information obtained from all concerned entities. NTDC formulates detailed short and long term national electricity system expansion plans. The NEC approves all plans and policies relating to development of the energy and electricity sector. The Executive Committee of the National Economic Council (ECNEC) supervises the implementation of the energy policy laid down by the Government, and approves any energy sector project to be built by the public sector.

1.2.2. Structure of the Electric Power Sector

The Ministry of Water and Power has recently been divided into the Ministry of Energy, responsible for development of power resources, and the Ministry of Water Resources, responsible for water resources in the country. The Ministry of Energy (Power Division) handles all issues related to electricity generation, transmission, distribution and pricing, exercising this function through respective organizations. It also performs specific functions such as coordination of power sector plans and formulation of policies and specific incentives and liaises with provincial governments on all related issues.

The following entities are major stakeholders in the electricity sector of Pakistan.

1.2.2.1. Public Sector Generation Companies (GENCOs)

Currently, there are four GENCOs operating in Pakistan. Jamshoro Power Company Ltd (GENCO-I) has one plant with a generation capacity of 880 MW. Central Power Generation Company Ltd (GENCO-II), with a total generation capacity of 1790 MW, currently has two generation plants. Northern Power Generation Company Ltd (GENCO-III), with a capacity of 2060 MW, has three generation plants. Lakhra Power Company Ltd. (GENCO-IV) has one power plant with a capacity of 150 MW but its generation licence is currently expired.

1.2.2.2. Pakistan Water and Power Development Authority (WAPDA)

WAPDA is responsible for planning and execution of large hydropower projects. At present, WAPDA operates at 9 443 MW hydroelectric capacity.

1.2.2.3. Pakistan Atomic Energy Commission (PAEC)

PAEC is responsible for planning, implementation, operation and maintenance of nuclear power plants. At present, the total nuclear installed capacity is 3530 MW, comprising of four nuclear power plants at the Chashma site (C-1 (325 MW), C-2 (325 MW), C-3 (340 MW) and C-4 (340 MW)) and two nuclear power plants at Karachi site (K-2 (1 100 MW) and K-3 (1 100 MW)). One nuclear power plant has been shut down KANUPP (originally 137 MW, de-rated to 100 MW).

1.2.2.4. National Transmission and Despatch Company (NTDC)

NTDC is responsible for constructing, operating and maintaining the electricity transmission infrastructure of the country, which comprises transmission lines of 220 kV and 500 kV and grid stations linking all power plants of the country. It also provides services to the distribution companies in the design and construction of 132 kV transmission lines and grid stations.

1.2.2.5. Distribution Companies

There are currently eleven electricity distribution companies operating in the country: Peshawar Electric Supply Company (PESCO), Islamabad Electric Supply Company (IESCO), Gujranwala Electric Power Company (GEPCO), Lahore Electric Supply Company (LESCO), Faisalabad Electric Supply Company (FESCO), Multan Electric Power Company (MEPCO), Hyderabad Electric Supply Company (HESCO), Quetta Electric Supply Company (QESCO), Sukkur Electric Power Company (SEPCO), Tribal Areas Electricity Supply Company Ltd (TESCO) and K-Electric.

All these distribution companies, except K-Electric, are public entities. K-Electric, responsible for generation, transmission and distribution of power to the city of Karachi and surrounding areas (Uthal and Bela districts), has been privatized. It owns and operates a 2 084 MW electricity generation capacity.

1.2.2.6. Private Power and Infrastructure Board (PPIB)

PPIB provides support to the private sector in implementing conventional power generation projects, including hydropower projects with a capacity of more than 50 MW. In Pakistan, 39 thermal independent power producers with an installed capacity of 18 750 MW and nine independent hydropower producers with a total installed capacity of 1192 MW are operational.

1.2.2.7. Alternative Energy Development Board (AEDB)

AEDB is responsible for promoting and facilitating the development of renewable energy resources in Pakistan. As of March 2022, 36 wind power plants with a total capacity of 1 838 MW are operating. Eight more wind power plants with a total capacity of 410 MW are under construction [3, 4]. Furthermore, 536 MW of installed capacity based on solar power and 369 MW based on bagasse is operating in the country.

1.2.2.8. Regulators

1. National Electric Power Regulatory Authority (NEPRA)

- NEPRA is responsible for: (i) granting licenses for the generation, transmission and distribution of electric power; (ii) determining electricity tariffs for the consumers, distributors, transmitters and producers; and (iii) prescribing and implementing performance standards for generation, transmission and distribution companies.

2. Pakistan Nuclear Regulatory Authority (PNRA)

- PNRA is responsible for granting licenses to all nuclear installations in the country, including nuclear power plants. The authority formulates and implements effective regulations to ensure safe operation of all nuclear installations, including nuclear power plants.

3. Indus River System Authority (IRSA)

- IRSA is responsible for regulating and monitoring the distribution of water sources of the Indus River in accordance with the Water Accord amongst the provinces. The Indus River hosts all major domestic hydropower plants.

1.2.3. Main Indicators

Table 3 reports the data of electricity production in the country over the past two decades and Table 4 provides energy related ratios.

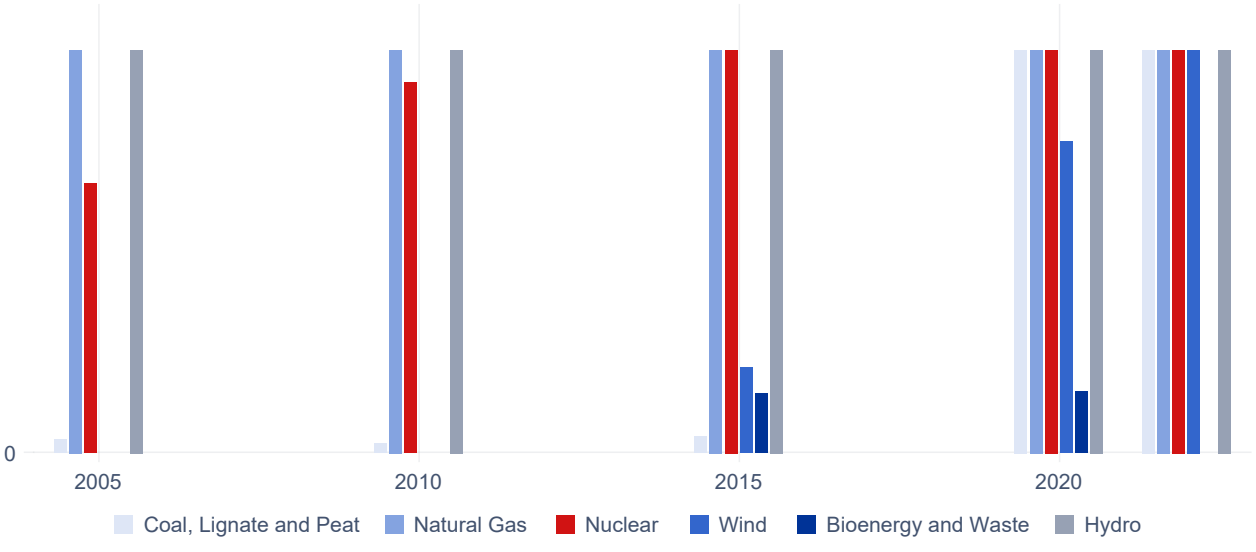
TABLE 3: ELECTRICITY PRODUCTION

Electricity production (GWh)	2005	2010	2015	2020	2022	Compound annual growth rate (%)
Coal, Lignate and Peat	129	88	148	25736	23730	35.9
Oil	18868	33186	35362	13100	10390	-3.45
Natural gas	41286	25879	35001	44268	15130	-5.73
Hydro	30862	31811	34633	33991	35320	0.8
Nuclear	2484	3420	4605	11495	22280	13.77
Wind	0	0	786	2882	4610	
Solar	0	0	207	795	810	
Geothermal	0	0	0	0	0	
Total	93629	94384	111298	132829	137363	2.28

Data as of 2022-12-31 from IAEA Referential Data Series 1

*Latest available data, please note that compound annual growth rate may not be representative of actual average growth.

CHART 3: ELECTRICITY PRODUCTION



Electricity production (GWh)

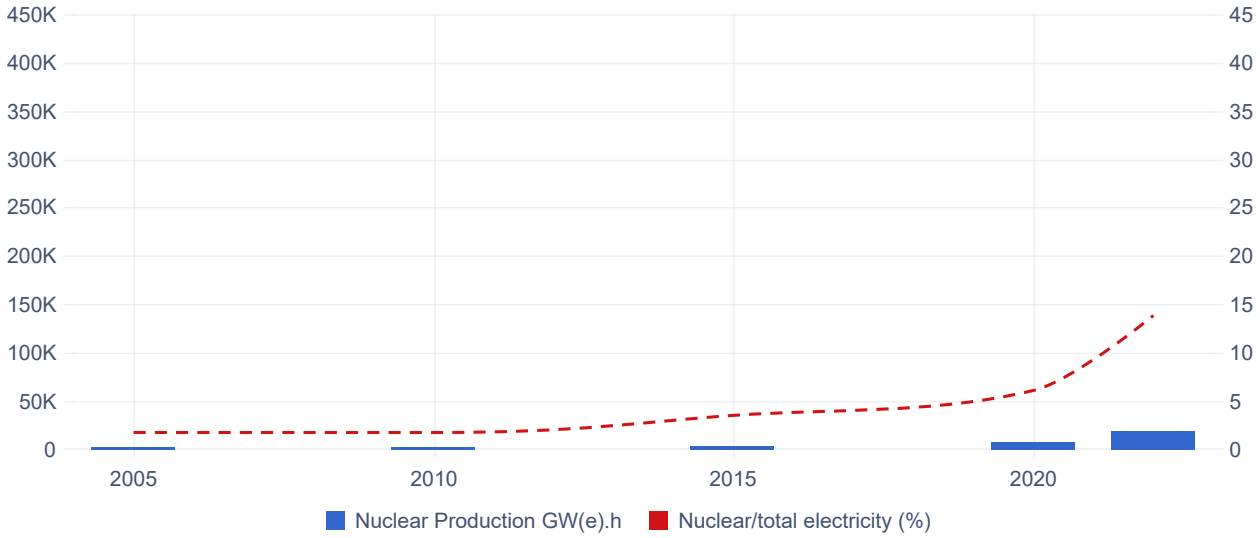
TABLE 4: ENERGY RELATED RATIOS

	2005	2010	2015	2020	2022

Nuclear/total electricity (%)	2.8	2.6	4.4	7.1	16.2

Data as of 2022-12-31 from IAEA Power Reactor Information System
*Latest available data.

CHART 4: NUCLEAR SHARE TREND



2. NUCLEAR POWER SITUATION

2.1. HISTORICAL DEVELOPMENT AND CURRENT ORGANIZATIONAL STRUCTURE

2.1.1. Overview

PAEC was established in 1955. The Ordinance for PAEC was promulgated by the President of Pakistan and later approved by the National Assembly in 1965. The functions of PAEC include research work necessary for the promotion of peaceful uses of nuclear energy in the fields of agriculture, medicine and industry, and the execution of development projects, including nuclear power plants for generation of electric power. PAEC is guided by instructions of the Government.

2.1.2. Current Organizational Structure

PAEC has a Chairman and nine full time members.

2.2. NUCLEAR POWER PLANTS: OVERVIEW

Construction of KANUPP, the first nuclear power plant in Pakistan, started in 1966 at a coastal site close to the city of Karachi. The plant was connected to the national grid on 18 October 1972. KANUPP, a PHWR of 137 MW gross capacity, was constructed by Canadian General Electric (CGE) under a turnkey contract. In 1976, the Canadian vendor support for the supply of spare parts and fuel to KANUPP was withdrawn and the plant was shut down. PAEC had to establish an indigenous facility to manufacture spare parts and nuclear fuel, for KANUPP. The plant was back online in 1980 and successfully operated using fuel and spares manufactured locally by PAEC. KANUPP was retired on the 1 August 2021 after completing 50 years of operation.

Despite Pakistan's interest in more electricity generating nuclear power plants, the construction of the second nuclear power plant in the country started more than two decades later. This was due to international embargoes imposed on access to nuclear technology coupled with a lack of domestic technological and industrial infrastructure.

The construction of Pakistan's second nuclear plant, C-1, a PWR, was made possible in 1993 with the help of China National Nuclear Corporation (CNNC). The plant started commercial operation on 15 September 2000 and has a gross capacity of 325 MW. Another unit at the same site and with the same design and capacity, named C-2, started commercial operation on 18 May 2011. The next unit to operate at the same site was C-3, which started commercial operation on 6 December 2016 and has a gross capacity of 340 MW. Then another unit, C-4, with characteristics similar to those of C-3, started commercial operation on 19 September 2017. The Chashma site is now called Chashma Nuclear Power Generating Station (CNPGS) and has a total of four nuclear power units with a total installed capacity of 1330 MW.

First concrete pours to mark the start of the construction of Karachi Coastal Power Project — a project containing two nuclear units, K-2 and K-3 (1100 MW each), based on an improved PWR design — were conducted on 20 August 2015 and 31 May 2016, respectively. K-2 started its commercial operation on 21 May 2021, while K-3 started its commercial operation on 18 April 2022. This site is now called Karachi Nuclear Power Generating Station (KNPGS) and has two nuclear power units with a total installed capacity of 2200 MW.

2.2.1. Status and Performance of Nuclear Power Plants

TABLE 5A: STATUS OF REACTORS UNDER CONSTRUCTION

Reactor Unit	Type	Capacity [MW(e)]	Status	Operator	Supplier	Cancellation Date

No data

Data as of 2022-12-31 from IAEA Power Reactor Information System

Table 5 reports the status and performance of nuclear power plants in Pakistan.

TABLE 5B: STATUS OF REACTORS IN OPERATION

Reactor Unit	Type	Capacity [MW(e)]	Status	Operator	Supplier	First Grid Date	Commercial Date	Suspension Date
CHASNUPP-1	PWR	300	Operational	PAEC	CNNC	2000-06-13	2000-09-15	
CHASNUPP-2	PWR	300	Operational	PAEC	CNNC	2011-03-14	2011-05-18	
CHASNUPP-3	PWR	315	Operational	PAEC	CNNC	2016-10-15	2016-12-06	
CHASNUPP-4	PWR	313	Operational	PAEC	CNNC	2017-06-25	2017-09-19	
KANUPP-2	PWR	1017	Operational	PAEC	CZEC	2021-03-18	2021-05-21	
KANUPP-3	PWR	1017	Operational	PAEC	CZEC	2022-03-04	2022-04-18	

Data as of 2022-12-31 from IAEA Power Reactor Information System

TABLE 5C: STATUS OF REACTORS IN PERMANENT SHUTDOWN

Reactor Unit	Type	Capacity [MW(e)]	Status	Operator	Supplier	First Grid Date	Commercial Date	Shutdown Date
KANUPP-1	PHWR	90	Permanent Shutdown	PAEC	CGE	1971-10-18	1972-12-07	2021-08-01

Data as of 2022-12-31 from IAEA Power Reactor Information System

2.2.2. Plant Upgrading, Plant Life Management and Licence Renewals

After the Fukushima Daiichi accident, the Fukushima Response Action Plan was formulated for all the nuclear power plants in the country. Under the plan, internal safety reviews were carried out, the design safety of future plants was enhanced, safety against external hazards was upgraded and emergency response programmes were strengthened.

At CNPGS, review comments of PNRA on Ageing Management Review Reports, (Safety Factor-04) for the Periodic Safety Review of C-1 and C-2 were discussed with PNRA and addressed accordingly. Work on the agreed corrective action plan is in progress. Ageing management programmes for switch gears, batteries, the spent fuel pool and boric acid corrosion control were prepared. Ageing management programmes for the cables, control rod drive mechanism, containment, WUH cooling towers, pressurizer, steam generator and oil immersed transformer were revised. Inspection of civil structures containing the cooling towers and containment of C-1 and C-2 were conducted for ageing evaluation. Trending reports of chemistry parameters across the steam generator and turbines were developed on a quarterly basis.

At KNPGS, the ageing management database of important structures, systems, and components was updated. Ageing management programmes for the transformer, emergency diesel generator, AAC, steam generator, reactor pressure vessel and cables, a chemistry control programme and a corrosion monitoring and control programme were prepared.

The following are some of the latest design modifications performed at CNPGS:

- Replacement of the residual heat removal system, SRH system, isolation valves and associated piping of C-1;
- Replacement of manual valves with motorized valves on WDS pumps in the header recirculation line of C-1;
- Fixing of supports (sliding plates) on main steam and main feed-water system piping of C-1;
- Segregation and re-routing of drain lines of high pressure heaters of C-1;
- Enlargement of bypass piping and valve of condensate system of C-1;
- Change of support scheme of low pressure turbines in the cavity/slope drain lines of C-1;
- Change of the material of the turbine extraction steam piping/fittings of C-1;
- Provision of exhaust hoods for new equipment in the chemistry laboratory of C-2;
- Provision of additional supports on the recirculation piping of the condensate pump of C-3;
- Enlargement of the drain piping of the gland housings of DCW pumps of C-4;
- Provision of permanent nitrogen gas supply to VWN chillers of C-4;
- Shifting of plant to house load operation on grid under-frequency transient at C-4;
- Elimination of SPV of the main feed water pumps of C-1;
- Provision of separate power supply to the pressure transmitters of the digital electro-hydraulic system of C-1;

- Change of pressure monitors on cross-over piping of C-1;
- Change of data acquisition instruments in the CIT system of C-1;
- Provision of parameters of CMC031CB on the CPC system of C-1;
- Change of oil level instrumentation of reactor coolant pump bearing housings of C-1;
- Installation of dual linear variable differential transformer.

After successful completion of PSR2, a plant operating licence was granted by PNRA to C-1 for the next ten years on 31 December 2020. The licence is valid until 31 December 2030.

A fuel load permit to K-2 was issued on 28 November 2020. An initial criticality permission to K-2 was issued by PNRA on 26 February 2021. Provisional acceptance was approved after completing all performance tests on 21 May 2021. An application for the operating licence was submitted to PNRA in November 2021. A fuel loading permit for K-3 was issued by PNRA on 16 December 2021.

2.2.3. Permanent Shutdown and Decommissioning Process

KANUPP was the first nuclear power plant (137MWe, PHWR type) of Pakistan. The KANUPP reactor was made critical for the first time on 1 August 1971 and, after completion of 50 years of safe operation, same was permanently shut down on 1 August 2021 in an orderly manner owing to ageing of its major components. It may be noted that the design life of KANUPP was 30 years; however, it was operated for two additional decades using several indigenous upgrades and modifications.

TABLE 6: STATUS OF DECOMMISSIONING PROCESS OF NUCLEAR POWER PLANTS

Reactor Unit	Shutdown Date	Shutdown Reason	Decommissioning Strategy	Current Decommissioning Phase	Decom. Licensee
KANUPP-1	8/1/2021	Lifetime completed	Dd+SE		PAEC

Data as of 2022-12-31 from IAEA Power Reactor Information System
Please refer to RDS2 Publication Table 17 for more information on status of Decommissioned reactors

2.3. FUTURE DEVELOPMENT OF NUCLEAR POWER SECTOR

2.3.1. Nuclear Power Development Strategy

The Government, realizing the importance of nuclear power in securing electric supply, fuel diversity, the environment, technological advancements, job creation etc., is keen to maintain a significant share of nuclear electricity in the energy mix of Pakistan. In line with these objectives, PAEC plans to improve the existing nuclear infrastructure and human resources to keep up with future nuclear power requirements. The plan also puts an impetus on nuclear technology indigenization that in turn will reduce import dependence and nuclear electricity generation cost.

TABLE 7: CONSIDERED AND PLANNED NUCLEAR POWER PLANTS

Reactor Unit	Type	Capacity	Status	Expected Construction Start	Expected Grid Year

		[MW(e)]		Year	
CHASNUPP-5			Considered		
KANUPP-4			Considered		
KANUPP-5			Considered		
M-1			Considered		
M-2			Considered		

Data as of 2022-12-31 from IAEA Power Reactor Information System
Note: Table is completely generated from PRIS data to reflect the latest available information and may be more up to date than the text of the report.

2.3.2. Project Management

All existing nuclear power plants of Pakistan are turnkey projects. During construction and installation, PAEC has been involved in various project management activities. This experience will help PAEC to manage the construction phase of future nuclear power plants. The engineering and design offices of PAEC provide design and engineering services to the operational nuclear plants and those under construction and will contribute to the construction of future nuclear plants in the country.

2.3.3. Project Funding

C-1 was funded through government funds only. All other nuclear power plants were funded through net revenues from operating power plants, government funds and loans from banks. The funding for future nuclear power plants will be available from (i) government allocations for the power sector, (ii) income from sale of electricity from operational nuclear power plants, and (iii) loans from banks/ financial institutions.

2.3.4. Electric Grid Development

The construction, expansion and upgrading of the national electric grid are the responsibilities of NTDC.

2.3.5. Sites

PAEC conducted a detailed site study of many probable sites that could house a nuclear power plant in the country. Sites that met stringent PNRA regulatory requirements and were able to accommodate a cluster of multiple nuclear units were selected to install nuclear power generating stations. Site studies on different locations are being conducted to accommodate extension of the nuclear power programme.

2.3.6. Public Awareness

Public awareness is enhanced through seminars, workshops and electronic/print media.

2.4. ORGANIZATIONS INVOLVED IN CONSTRUCTION OF NPPs

PAEC, CNNC and PNRA are involved in various phases of the construction of nuclear power plants in Pakistan.

2.5. ORGANIZATIONS INVOLVED IN OPERATION OF NPPs

PAEC, PNRA, NTDC, NEPRA and CCPA are involved in the operation of nuclear power plants in Pakistan.

2.6. ORGANIZATIONS INVOLVED IN DECOMMISSIONING OF NPPs

PAEC and PNRA will be involved in decommissioning nuclear power plants in Pakistan.

2.7. FUEL CYCLE INCLUDING WASTE MANAGEMENT

PAEC initiated nuclear fuel cycle activities in the early 1960s. A uranium ore processing plant, using indigenous ore, is in operation. Essential laboratory facilities have also been established to support exploration and ore process development work. Fuel for KANUPP was fabricated by PAEC.

Appropriate waste management systems have been designed for the KNPGS and CNPGS sites to remove radioactive waste from the plants. The radioactive waste management systems collect, store, allow sufficient radioactive decay and process the waste through filtration, ion exchange, evaporation, solidification, vitrification and drumming.

In addition, the spent fuel dry storage facility established for KANUPP spent fuel, will provide interim spent fuel storage to the KNPGS plants.

2.8. RESEARCH AND DEVELOPMENT

2.8.1. Research and Development Organizations

1. Research institutes/centres

   PAEC has the following research institutes/centres:

- Pakistan Institute of Nuclear Science and Technology (PINSTECH) engages in basic and applied research in physics, chemistry, materials, safety, radioisotope applications and radiation protection;
- Instrumentation, Control and Computers Complex (ICCC) oversees instrumentation and control of nuclear power plants, simulators, plant computer systems, etc.;
- Engineering design organizations of PAEC provide design and engineering services to operational, under construction and future nuclear power plants.

2. Research reactor facilities

   Pakistan has two research reactors:

- PARR-1, swimming pool type, 10 MW;
- PARR-2, tank in pool type, 30 kW.

2.8.3. International Cooperation and Initiatives

Pakistan is a member of the IAEA and World Association of Nuclear Operators (WANO) and receives assistance from their programmes for enhancement of the safety and reliability of nuclear power plants.

2.9. HUMAN RESOURCES DEVELOPMENT

The Directorate of Human Resource Development (DHRD) has the responsibility to plan, develop and implement human resource strategies to induct, retain and develop a knowledge workforce to implement the PAEC programme. DHRD has well established in-house training system namely a three tiered model to train PAEC employees. The model is focused on the personal development of young, mid-level and senior cadre officers. This system has been designed in line with organizational objectives and needs. In addition, DHRD is playing a vital role in implementing and promoting the PAEC higher studies programme. PAEC provides the opportunity to its employees to pursue MSc and PhD studies in order to achieve organization goals and keep pace with contemporary development.

PAEC also invests in human resource capacity building initiatives through its Human Resource Development Institutes (HRDIs) to fulfil the workforce requirements of the expanding nuclear power programme of the country. The HRDIs of PAEC have been making a significant contribution to the development of human resources in the field of science and technology in the country, in particular, in applications of nuclear science and technology. PAEC hires talent from a pool of nationally approved and chartered universities, including technical and vocational training institutes. The following HRDIs train and prepare the recruited young scientists, engineers and technicians in various disciplines every year using focused training programmes tailored to organizational needs.

2.9.1. Humans Resource Development Institutes

2.9.1.1. Pakistan Institute of Engineering & Applied Sciences (PIEAS)

PIEAS is one of the highest-ranking engineering universities in Pakistan. It provides the core of human resource needs in fields that are essential for the technological development of Pakistan and PAEC, offering programmes in already established and newly emerging technological fields. PIEAS offers undergraduate and postgraduate programmes in various science and technology fields leading to the higher qualification of PhD. In addition, the PIEAS School of Leadership & Policy Studies under the three tiered model manages the senior officers' management and leadership course for senior and potential top management officers. PIEAS also organizes training courses in various specialized areas, such as nuclear security and physical protection systems. With the assistance of Pakistan Nuclear Regulatory Authority (PNRA) and IAEA, PIEAS has established nuclear security education laboratories that are being used for national and international training courses. PIEAS was designated an IAEA Collaborating Centre in December 2019, supporting Member States in research, development and capacity building in the application of advanced and innovative nuclear technologies.

2.9.1.2. Karachi Institute of Power Engineering (KINPOE)

KINPOE was established by PAEC to develop qualified human resources for its nuclear power programme. The main task of KINPOE is to develop human resources in the field of nuclear power technology, for which it provides education and training to scientists, engineers and technicians recruited particularly for nuclear power plants. The main training programmes offered by the institute include a Masters programme in nuclear power engineering, a post graduate training programme (PGTP) for engineers and a post diploma training programme (PDTP) for technicians.

2.9.1.3. CHASNUPP Centre of Nuclear Training (CHASCENT)

CHASCENT is specialized institute of human resource development for the nuclear power sector. It primarily focuses on the training of newly recruited engineers, scientists and technicians. In addition to the one-year regular training programmes PGTP and PDTP, CHASCENT also coordinates and offers certification programmes for operators and maintenance workers working at PAEC nuclear power plants. CHASCENT is equipped with well established laboratories and three full scope training simulators (FSTS) of nuclear power plants. CHASHCENT is playing a vital role by organizing and conducting short training courses for the continuing learning and development of engineers, scientists and other professionals.

2.9.1.4. National Centre for Non-Destructive Testing (NCNDT)

NCNDT provides training in non-destructive testing techniques to engineers and technicians of PAEC and local industry.

2.9.1.5. Pakistan Welding Institute (PWI)

PWI provides specialized training in industrial welding techniques to professionals of PAEC and industry.

2.9.1.6. Pakistan Institute of Nuclear Science and Technology (PINSTECH)

PINSTECH is the premier research and development set-up within PAEC and offers on the jobs development of scientists and researchers. It has some of the most advanced operational research facilities and carries out multidisciplinary research. The scientists and engineers at PINSTECH also participate actively in joint research with various international scientific organizations, including the IAEA.

2.10. STAKEHOLDER INVOLVEMENT

PAEC has well established communication with national and international stakeholders (i.e. PNRA, NEPRA, IAEA, WANO, etc.).

2.11. EMERGENCY PREPAREDNESS

Submitting an emergency preparedness plan to PNRA is a mandatory prerequisite for the licensee. The requirements include classification of a nuclear emergency, urgent protective actions, information and instructions to the general public, medical response management, protective measures for the general public/workers/agriculture, conducting recovery operations, etc.

The emergency response plan requires attention to detail not only for the plant personnel but also for people, the environment and property in the declared emergency zone according to the potential accident classification. The plan is unique for every nuclear power installation and involves coordination amongst many city administration offices that are trained for potential scenarios. Scheduled emergency scenarios that simulate different levels of disaster situation are periodically exercised to strengthen the coordination of the parties involved in the plan.

3. NATIONAL LAWS AND REGULATIONS

3.1. REGULATORY FRAMEWORK

3.1.1. Regulatory Authority(s)

With the promulgation of the PNRA Ordinance in January 2001, the PNRA was established as an independent nuclear regulatory body for regulation of nuclear safety and radiation protection in Pakistan. The PNRA Ordinance empowers it to devise, adopt, make and enforce regulations for the protection of workers, the public and the environment against the harmful effects of ionizing radiations.

3.1.2. Licensing Process

PNRA has an elaborate licensing process that includes the following steps as per its Regulations for Licensing of Nuclear Installations in Pakistan-PAK/909 (Rev. 1):

- Site registration;
- Construction licence;
- Permission for commissioning;
- Permission to introduce nuclear material into the installation;
- Operating licence;
- Revalidation of operating licence;
- Licensing beyond design life;
- Licence for decommissioning of a nuclear installation or closure of a waste repository;
- Removal from regulatory control.

3.2. MAIN NATIONAL LAWS AND REGULATIONS IN NUCLEAR POWER

Main laws in nuclear power:

- Pakistan Nuclear Regulatory Authority Ordinance 2001.

Main regulations in nuclear power:

- Pakistan Nuclear Safety and Radiation Protection Regulation 1990;
- Regulations on Licensing Fee by Pakistan Nuclear Regulatory Authority (PAK/900);
- Regulations on Transaction of Business of Pakistan Nuclear Regulatory Authority (PAK/901);
- Regulations on Radiation Protection (PAK/904);
- Regulations for Licensing of Nuclear Safety Class Equipment and Components Manufacturers (PAK/907);
- Regulations for Licensing of Nuclear Installation(s) in Pakistan (PAK/909);
- Regulations on the Safety of Nuclear Installations — Site Evaluation (PAK/910);
- Regulations on the Safety of Nuclear Power Plants — Design (PAK/911);
- Regulations on the Safety of Nuclear Power Plants — Quality Assurance (PAK/912);
- Regulations on the Safety of Nuclear Power Plants — Operation (PAK/913);
- Regulations on Management of a Nuclear or Radiological Emergency (PAK/914);
- Regulations on Radioactive Waste Management (PAK/915);
- Regulations for the Safe Transportation of Radioactive Material (PAK/916);
- Regulations on Physical Protection of Nuclear Material and Nuclear Installations (PAK/925);
- Regulations on Security of Radioactive Sources (PAK/926);

- Regulation on Decommissioning of Facilities using Radioactive Material (PAK/930);
- Pakistan Nuclear Regulatory Authority Enforcement Regulation (PAK/950);
- Trade Policy: 2012–15, Ministry of Commerce, Import Policy Order 2013, Export Policy Order 2013 and Import and Export Control Act 1950;
- National Policy on Safe Management of Radioactive Waste, Decommissioning and Spent Fuel in Islamic Republic of Pakistan (RWP-01/2018);
- National Safety Policy (NP-02/2020);
- Regulations on Dispute Resolution (PAK/949);
- Regulations for The Safe Management of Spent Nuclear Fuel (PAK/918).

APPENDIX 1. INTERNATIONAL, MULTILATERAL AND BILATERAL AGREEMENTS

Agreements with the IAEA

Agreement : INFCIRC No.116
Countries : Pakistan
Signature Date :
Ratification Date :
Notes : Entry Into Force; 17 June 1968 Description; Project agreements/Booster Rods for KANUPP

Agreement : INFCIRC No.135
Countries : Pakistan
Signature Date :
Ratification Date :
Notes : Entry Into Force; 17 October 1969 Description; Karachi Nuclear Power Plant (KANUPP)

Agreement : INFCIRC No.34
Countries : Pakistan
Signature Date :
Ratification Date :
Notes : Entry Into Force; 5 March 1962 Description; Pakistan Research Reactor-1 (PARR-1)

Agreement : INFCIRC No.393
Countries : Pakistan
Signature Date : 1991-09-10
Ratification Date :
Notes : Description; Supply of miniature neutron source reactor (MNSR)/PARR-2

Agreement : INFCIRC No.418
Countries : Pakistan
Signature Date :

Ratification Date :
Notes : Entry Into Force; 24 February 1993 Description; Supply of Chashma Nuclear Power Plant-1 (CHASNUPP-1)

Agreement : INFCIRC No.705
Countries : Pakistan
Signature Date :
Ratification Date :
Notes : Entry Into Force; 22 February 2007 Description; Supply of Chashma Nuclear Power Plant-2 (CHASNUPP-2)

Agreement : INFCIRC No.816
Countries : Pakistan
Signature Date :
Ratification Date :
Notes : Entry Into Force; 15 April 2011 Description; Supply of Chashma Nuclear Power Plant-3 (CHASNUPP-3)

Agreement : INFCIRC No.920
Countries : Pakistan
Signature Date :
Ratification Date :
Notes : Entry Into Force; 3 May 2017 Description; Supply of Karachi Nuclear Power Plants-2&-3 (KANUPP-2/KANUPP-3)

Other relevant international treaties

Agreement : Agreement on privilege and immunities with IAEA
Countries : Pakistan
Signature Date :
Ratification Date :
Notes : 16 April 1963

Agreement : Improved procedure for designation of safeguard inspector
Countries : Pakistan
Signature Date :
Ratification Date :
Notes : 20 December 1988

Agreement : Regional Cooperative agreement for research, development and training related to Science and Technology (RCA)
Countries : Pakistan
Signature Date : 1974-09-06
Ratification Date :
Notes :

Agreement : Revised Supplementary agreements concerning the Provision of Technical Assistance by the IAERA (RSA)
Countries : Pakistan
Signature Date :
Ratification Date :
Notes : Entry Into Force; 22 September 1994

Agreement : Voluntary Reporting to IAEA on Exports of any Np and Am to CSA States
Countries : Pakistan
Signature Date :
Ratification Date :
Notes : 18 January & 4 October 2000

International treaties

Agreement : Acceptance of NUSS codes
Countries : Pakistan
Signature Date :
Ratification Date :
Notes : Decision on adoption of IAEA NUSS; May 1981

Agreement : Amendment to the Convention on the Physical Protection of Nuclear Material
Countries : Pakistan
Signature Date :
Ratification Date :
Notes : Took Effect; 8 May 2016

Agreement : Convention on assistance in the case of a nuclear accident or radiological emergency
Countries : Pakistan
Signature Date :
Ratification Date :
Notes : Took Effect; 12 October 1989

Agreement : Convention on early notification of a nuclear accident
Countries : Pakistan
Signature Date :
Ratification Date :
Notes : Took Effect; 12 October 1989

Agreement : Convention on nuclear safety

Countries : Pakistan
Signature Date :
Ratification Date :
Notes : Took Effect; 29 December 1997

Agreement : Convention on the physical protection of nuclear material
Countries : Pakistan
Signature Date :
Ratification Date :
Notes : Took Effect; 12 October 2000

APPENDIX 2. MAIN ORGANIZATIONS, INSTITUTIONS AND COMPANIES INVOLVED IN NUCLEAR POWER RELATED ACTIVITIES

National nuclear energy authority

Organization Name	Address	Contact	Website
Pakistan Atomic Energy Commission (PAEC)	P.O. Box 1114, Islamabad, Pakistan	Tel.: +92 51 9209032-7 Fax: +92 51 9204908	
Pakistan Nuclear Regulatory Authority (PNRA)	P.O. Box 1912, Islamabad, Pakistan	Tel.: +92 51 9263019 Fax: +92 51 9263009	

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Number	Source	Link
[1]	Pakistan Energy Year Book 2020 and earlier issues, Hydrocarbon Development Institute of Pakistan, Ministry of Petroleum and Natural Resources, Government of Pakistan, Islamabad	
[2]	Hydro Potential in Pakistan, Water and Power Development Authority, Oct. 2013	
[3]	State of Industry Report 2021 and earlier issues, National Electric Power Regulatory Authority	
[4]	Alternative Energy Development Board Website, http://www.aedb.org (accessed on 03 May 2021).	
[5]	Power System Statistics 2019–20, 45th Edition, National Transmission and Despatch Company	
[6]	Medium Term Development Framework 2005–2010, Planning Commission, Government of Pakistan, May 2005	
[7]	Indicative Generation Capacity Expansion Plan, IGCEP 2021 – 2030, May 2021, National Transmission and Despatch Company	

No data

COORDINATOR INFORMATION

Dr. Muhammad Shahzad,
Director (International Cooperation),
Pakistan Atomic Energy Commission, P.O. Box 1114, Islamabad, Pakistan

Tel.: +92 51 9246034, Fax: +92 51 9204908
Email: ic3022@outlook.com