Nuclear Energy Scenario of Pakistan

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Power Sector of Pakistan

Electricity Generation Capacity

	Installed (MW)	Available (MW)
Total	21,690	16,330-19,288
Oil/Gas	14,429	12,219
Coal	165	45
Hydro	6,634	3,676-6,634
Nuclear	462	390

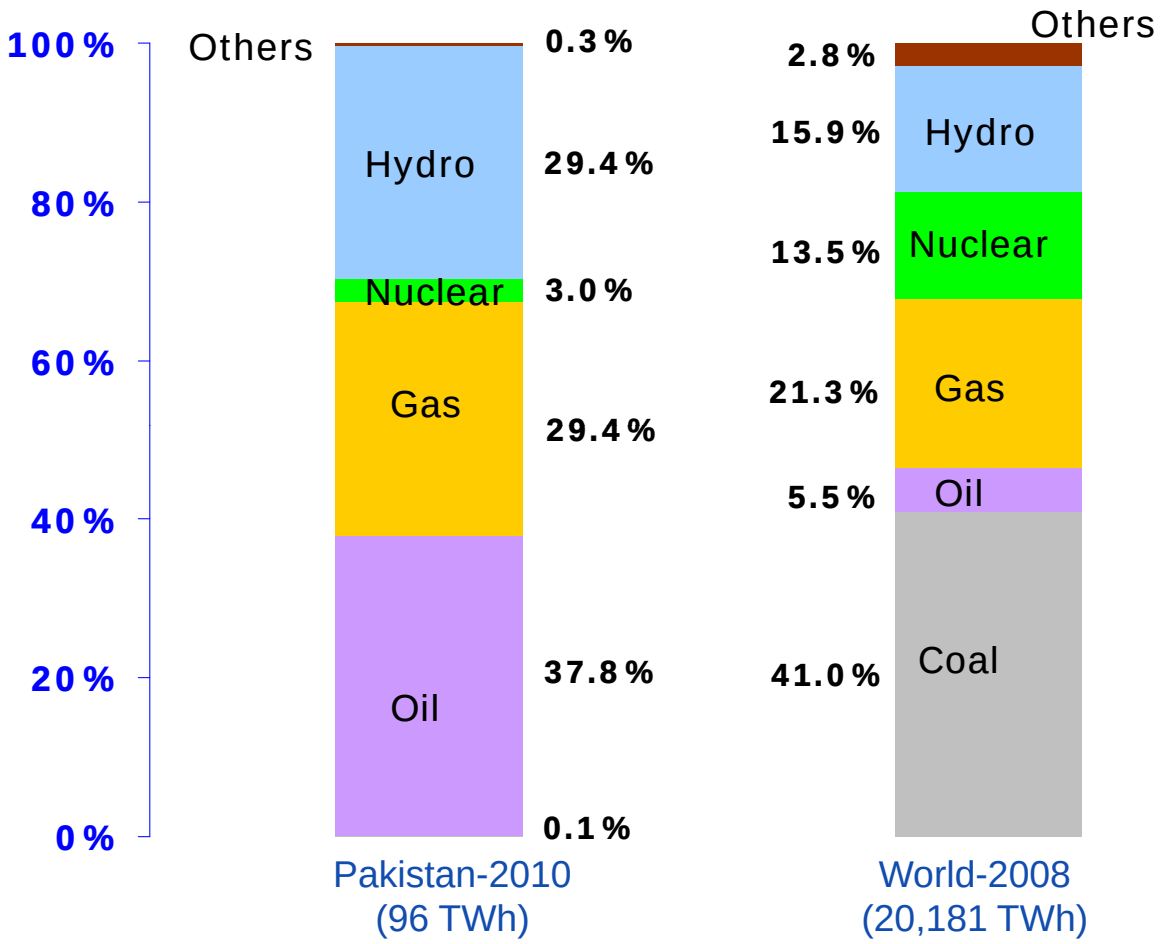
Peak Demand : 21,063 MW

Shortages of electricity supply primarily due to:

- De-rated capacity of some plants,
- Shortage of:
  - Natural gas due to other uses
  - Furnace oil due to circular debt
- Seasonality of hydro (Capacity factor ~50%).

The above result in load shedding at times of up to 5,500 MW

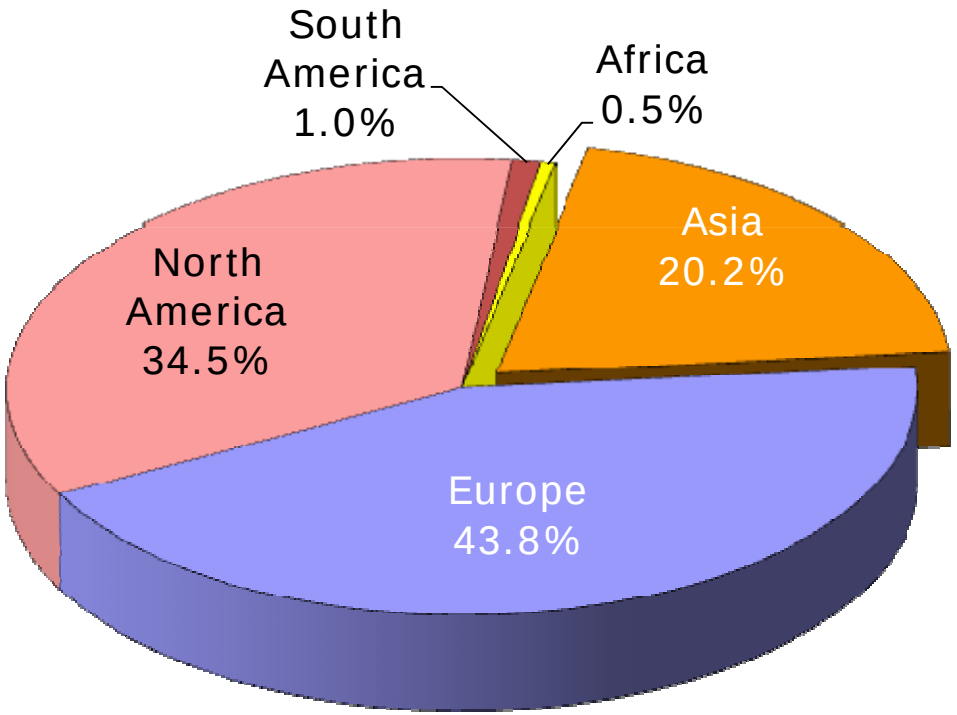
Electricity Generation Mix of the World and Pakistan



* Others include imported electricity for Pakistan and geothermal, wind, solar etc for the world.

Regional Distribution of Nuclear Power Generation

Total nuclear electricity generation during 2010: 2,585 Billion kWh



Source: International Atomic Energy Agency

Top Ten Producers of Nuclear Electricity

2010 Data

Producer	Billion kWh	% of World Total
USA	807	31.2
France	408	15.8
Japan	279	10.8
Russia	155	6.0
Korea	142	5.5
Germany	130	5.0
Canada	85	3.3
Ukraine	84	3.2
China	77	3.0
Spain	59	2.3
Rest of the world	359	13.9
World	**2,585**	**100.0**

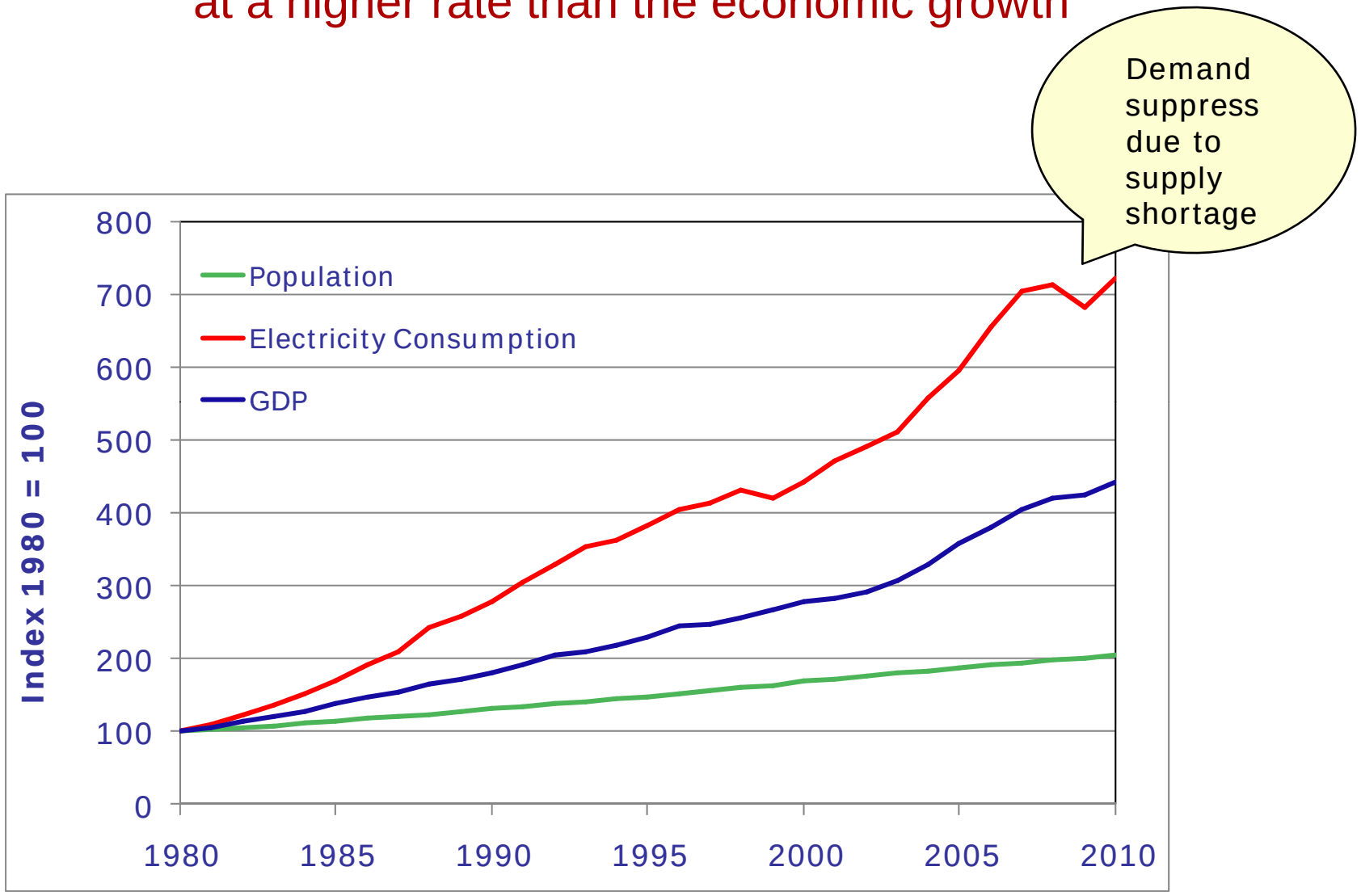
2009 Data

Producer	% of nuclear in total electricity generation
France	75.2
Ukraine	48.6
Sweden	37.4
Korea	34.8
Japan	28.9
Germany	26.1
USA	20.2
Russia	17.8
Canada	14.8
China	1.9
Rest of the world*	11.9
World	**13.8**

* Excludes countries with no nuclear production

Source: International Atomic Energy Agency

Electricity demand in Pakistan has been increasing at a higher rate than the economic growth



Sources: Pakistan Energy Yearbook, Pakistan Economic Survey

Projected Energy Needs of Pakistan

	2011	2030 Medium Term Development Framework of 2005	2022 Integrated Energy Plan of 2009
Current/Projected Economic Growth	2-3% per year	7-8% per year	5% per year
Installed/Projected Capacity (MW)	21,690	162,590	55,000

Sources: (a) Medium Term Development Framework (2005-2010), Planning Commission, May 2005.

(b) Integrated Energy Plan 2009-2022, Economic Advisory Council, M/o Finance, March 2009.

Options Available to Pakistan for Electricity Generation

- Hydro (storage type and run-of-river plants)
- Simple and Combined Cycle plants on gas
- Nuclear
- Wind
- Oil-fired Steam/Diesel engine (expensive option)

Possible in Near Future

- Combined Cycle plants based on imported gas.
- Steam plants on domestic coal and imported coal.

Prospects of Hydro Development

- Potential : 55,000 MW

Already exploited : 6,634 MW (12% of the potential)

- Potential located in mountainous region, away from load centers. High investment cost and losses in electricity transmission

- The investment cost of major hydro power plants is high

- Socio-political issues i.e., water allocation among provinces, and resettlement of people.

- Total hydro built – last 15 years: 1808 MW

Indigenous Fossil Fuel Reserves

If whole resource is used for power generation

Fuel	Unit	Proven reserves	
		Quantity	For 1000 MW size plants of 30-year life
Oil	Million Barrels	307	1
Gas	Trillion Cubic Feet	27.6	15
Coal	Billion Tonnes	3.5*	33

* Total resource is about 186 billion tonnes (~ 1746 plants of 1000 MW of 30 year life).

Source: Based on data in Pakistan Energy Yearbook 2010

Oil and Gas

Oil

- Small Reserves
- The country meets its more than 80% oil requirements through import

Gas

- Production is already insufficient to meet the current requirement
- Demand/supply gap could by 17 billion cubic feet per day by 2030*

* Medium Term Development Framework

The Coal Option (1/2)

- Large resource
- 95% of the coal resources are located in Thar. Current resource classification of Thar field is:
  - Measured (3.5 billion tonne) can support 33,000 MW capacity
  - Indicated (12 billion tonne) can support 111,000 MW capacity
  - Inferred (17 billion tonne) can support 534,000 MW capacity
  - Hypothetical (114 billion tonne) can support 1068,000 MW capacity
  - Total (186 billion tonne) can support 1746,000 MW capacity
- Thar coal is lignite with more than 40% moisture. Power plants at mine mouth because of high moisture and low energy contents, resulting in large investment on electricity transmission.
- Emission of particulates, acidic precursors and greenhouse gases.

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The Coal Option (2/2)

- Thar coal can be extracted by surface mining, however the cost is relatively high
- Thar coal development constraints include:
  - Coal drying, disposal of underground water, etc.
- An underground coal gasification (UCG) pilot project is being setup to find technical and economic feasibility of this process for Thar coal field

Sources: a) Pakistan Energy Yearbook 2010, HDIP.
b) Thar coal feasibility study by Rheinbrown of Germany 2004.
c) Integrated Energy Plan 2009-2022, EAC, M/o Finance, March 2009.

Prospects of Renewables Development

Wind

- Potential
  - Theoretical = ~ 55,000 MW
  - Exploitable = ~ 11,000 MW considering availability of land with about 23 -28% capacity factor
- Currently, wind generation projects are demanding 12 cent/kWh tariff

Solar

- Potential is high. But have techno-economic issues.

The Nuclear Option (1/3)

- The country has limited oil and gas reserves
- Coal of lignite quality, though abundant, is hampered by the daunting requirement of large scale mining infrastructure
- Hydro resources are associated with socio-political and project financing issues
- Renewable resources are in initial stages of development and unable to meet the base-load electricity requirements

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Nuclear Option (2/3)

- Nuclear power is a base-load electricity generation option and helps to enhance security of supply
  - Substitute imported fuels
  - A 1000 MW nuclear plant avoids use of 46 billion cubic feet of gas annually
- Nuclear Power provides sustainability of electricity price because of low share of fuel cost . Fuel cost share in electricity generation:
  - Nuclear : 10 - 15%
  - Coal : 20 - 45%
  - Gas : 50 - 70%
  - Oil : 60 – 80%

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Nuclear Option (3/3)

Pakistan has:

- Qualified manpower – professionals now experiencing the construction of fourth and fifth nuclear power plants

- More than 47 reactor years of operation experience to its credit. During this period, safety has been the hallmark of the country's nuclear industry.

Nuclear Power; Challenges

- High investments/financing costs
- Long gestation period
- Large impacts of nuclear accidents
- International embargoes (Pakistan perspective)

Nuclear Power Program of Pakistan

Milestones in Development of Nuclear Power in Pakistan

1955 : Establishment of Pakistan Atomic Energy Committee,

1965 : - Ordinance for Pakistan Atomic Energy Commission was promulgated by the President of Pakistan

- Pakistan's first research reactor became critical at PINSTECH

- Construction of KANUPP started

1960s: A number of scientists/engineers were sent abroad for education and training

1971 : Pakistan's first nuclear power plant became critical

KANUPP

- Type: CANDU-Pressurized Heavy Water Reactor
- Commercial operation: 1972
- Contract: Turn-key with Canadian General Electric (CGE), Canada
- Power: Now restricted to 90 MWe (Design: 137 MWe)
- A 400,000 US gallons/day nuclear desalination demonstration plant was installed in 2010

Pakistan was the 15th country to have commissioned the first nuclear power plant

	Canada				
	Belgium		Slovenia		
	Italy		Brazil		
	Japan		Hungary		
	Sweden		S. Africa		
	Germany	Pakistan	Slovakia		
UK	Spain	Argentine	Czech Republic		
USA	Netherlands	Finland	Lithuania		
USSR	India	South Korea	Bulgaria	China	
France	Switzerland	Taiwan	Mexico	Romania	None
1950s	**1960s**	**1970s**	**1980s**	**1990s**	**2000s**

Grid connections of first nuclear plant of various countries

KANUPP: Threats Converted into Opportunities

- Vendor support was stopped in 1976 following the nuclear test by India. Other developed countries also imposed embargoes on transfer of nuclear technology to Pakistan
- This initiated a self-reliance program leading to:
  - Development of indigenous fuel
  - Development of technical support system including fuel management and safety assessment
  - Manufacturing of spare parts
- KANUPP operated safely, completed its design life in 2002 and was re-licensed after a number of safety retrofits had been carried out.

Development of Engineering and Technical Services

- Scientific Engineering Services
  - Heavy Mechanical Complex
  - Nuclear Equipment Workshop
  - National Center for Non-Destructive Testing
  - Welding Institute
- Instrumentation Control and Computer Complex
- Works and Services Organization

Human Resource Development (1/2)

- HRD Program of PAEC started with a small team with post-graduate qualification who were trained in Canada for the first nuclear power plant (KANUPP)

- Now PAEC has training/education centers to develop manpower in the various disciplines of nuclear power technology.

- Pakistan Institute of Engineering and Applied Sciences (PIEAS)
  - Masters and Ph.D programs in engineering and sciences

Continue…

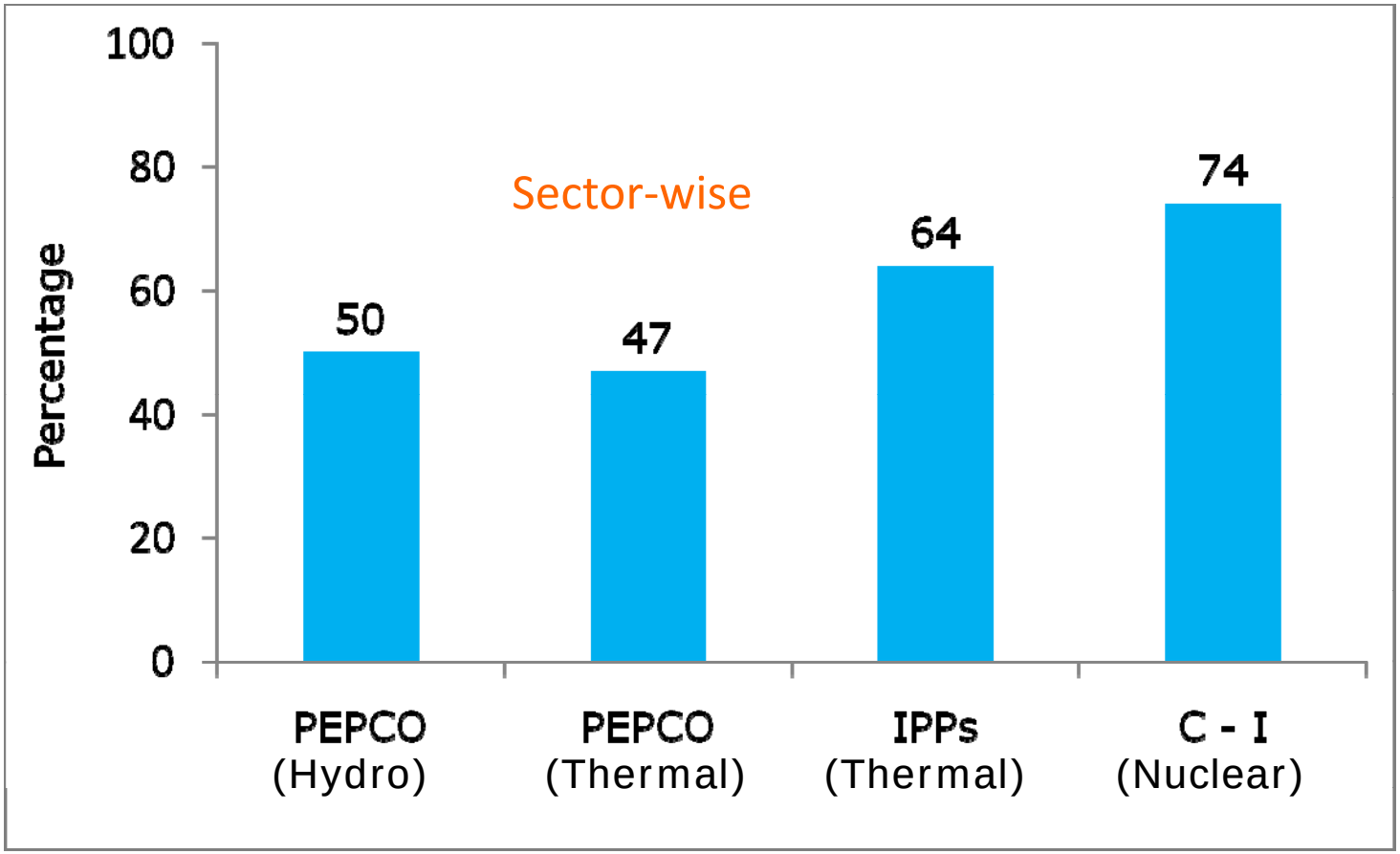
PAEC HRD Centers (2/2)

- Karachi Institute of Nuclear Power Engineering (KINPOE)
  - Masters Program in Nuclear Power
  - One year Post-Graduate Training Program in nuclear power technology
  - One Year post-Diploma program for technicians in nuclear power technology
- CHASNUPP Centre of Nuclear Training (CHASCENT)
  - Masters and One-Year post-graduate Training Program
  - One Year post-Diploma program for technicians
  - Training for licensing of PWR Operations Shift Supervisors using a full scope training simulator
- National Centre for Non-Destructive Testing and Pakistan Welding Institute
  - For short-term trade and qualifying courses

Chashma Nuclear Power Plant Unit 1: C-1

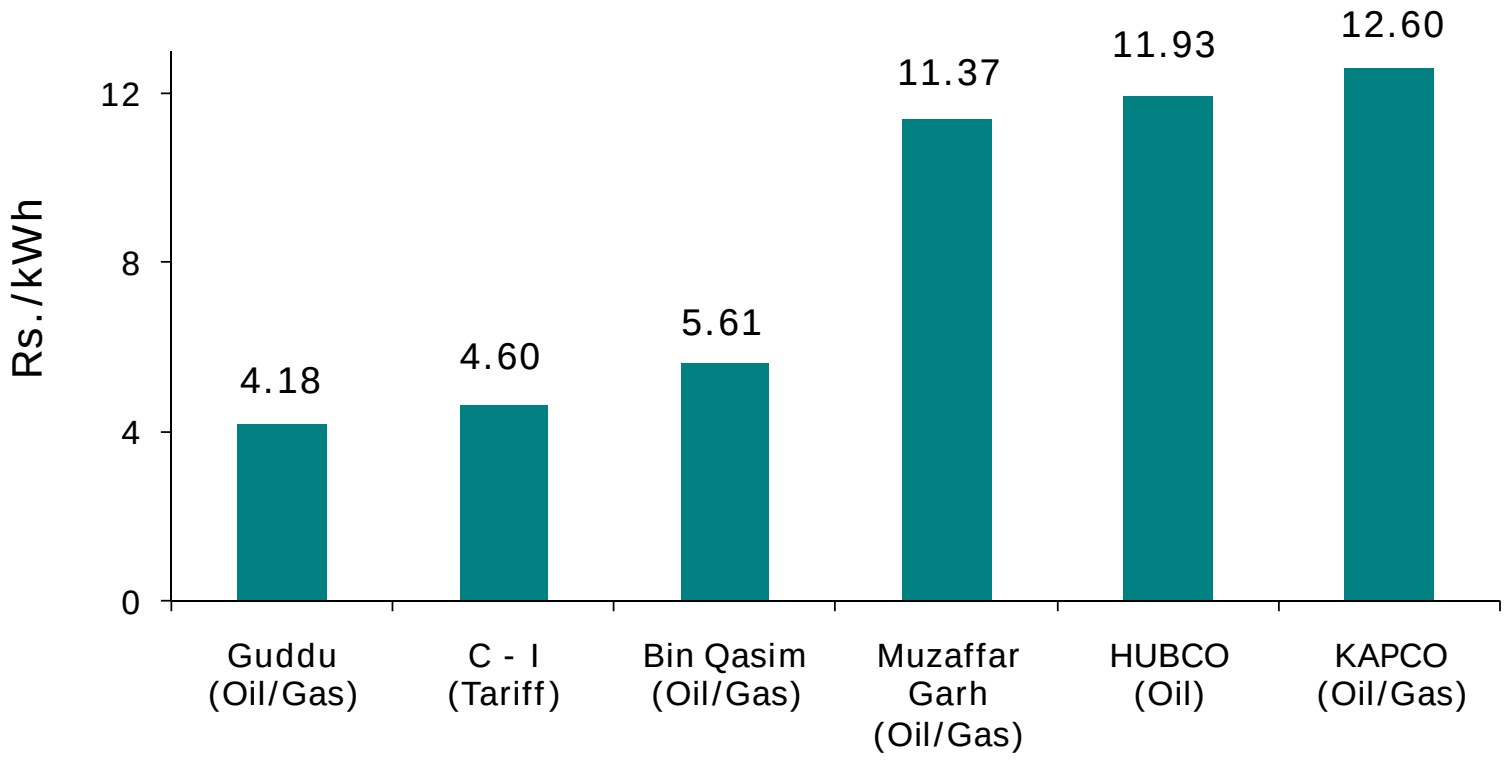
- Type : Pressurized Water Reactor (PWR), 325 MWe
- Commercial operation: September 2000
- Contract: Turn-key with China National Nuclear Corporation (CNNC)
- O&M: By PAEC since day 1
- Lifetime capacity factor achieved : 70.5%
- Capacity factor last 5 years : 76.8%
- Capacity factor since last RFO : 95.3%

Capacity Factor Compared to Other Plant Types of the Country (2009-10)



Source: State of Industry Report 2010, NEPRA

Electricity Generation Cost (2010)



Source: State of Industry Report 2010, NEPRA

Chashma Nuclear Power Plant Unit 2: C-2

- Type: Pressurized Water Reactor, 340 MWe
- Contract: Turn-key with CNNC
- Construction started : Dec 2004
- Grid connection : 14 Mar 2011
- Planned full scale commercial operation : 30 Apr 2011
- Planned provisional acceptance : 15 May 2011

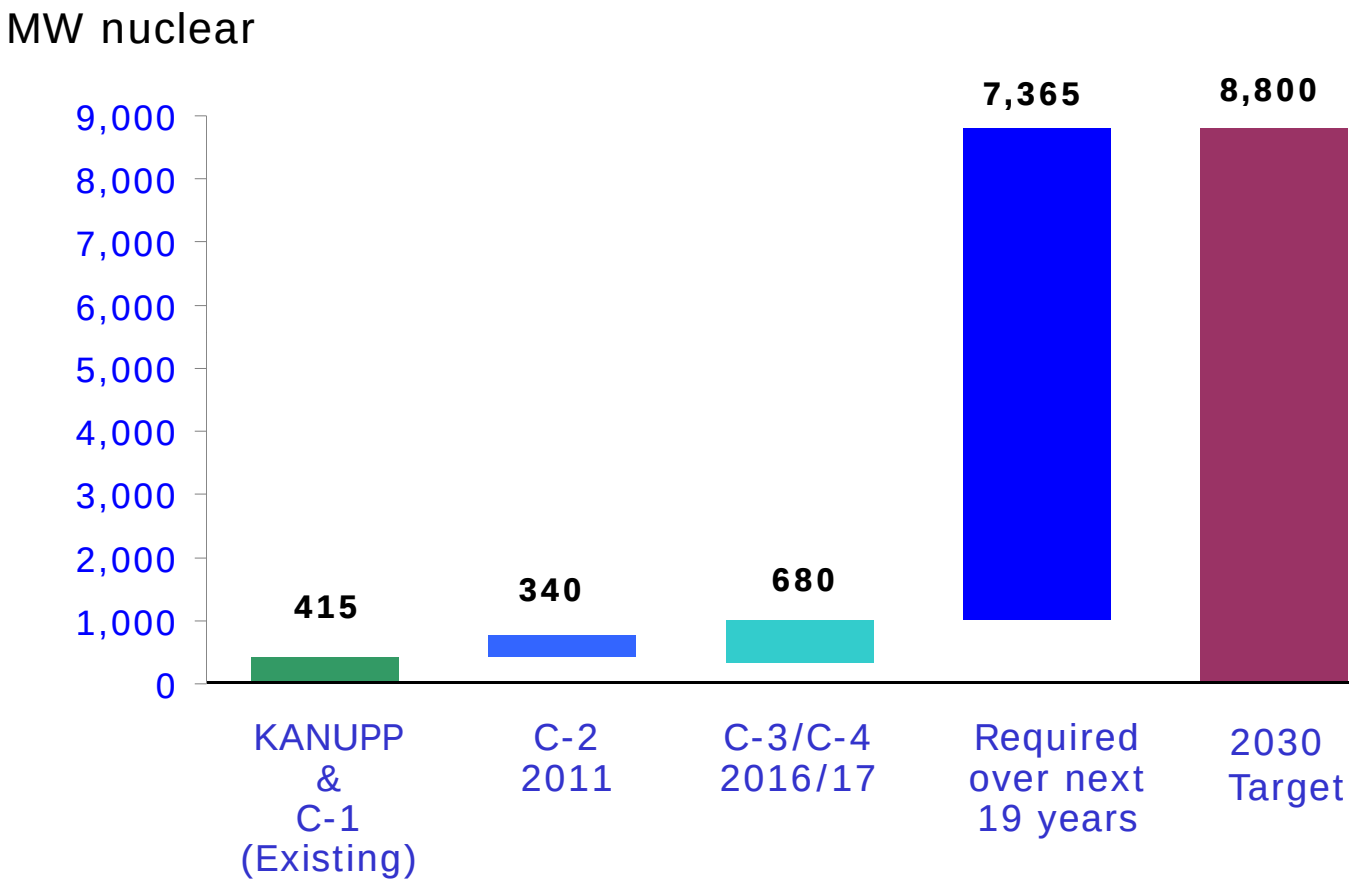
Chashma Nuclear Power Plant Units 3/4: C-3/C-4

Pressurized Water Reactor, 2x340 MW

Contract: Turn-key with CNNC

	C-3	C-4
Contract Signing	20 Nov 2008	20 Nov 2008
Contract Effective Date	31 Mar 2010	31 Mar 2010
Groundbreaking	5 Aug 2010	1 Apr 2011
First Concrete Pouring	4 Mar 2011	Jan 2012
IAEA Approval of Safeguards	8 Mar 2011	8 Mar 2011
Commercial Operation (as per contract)	31 Dec 2016	Oct 2017

Nuclear Power Program as per Medium Term Development Framework of GoP



Indigenous Capability for Nuclear Power Development

- Integrated Energy Planning
- Site Evaluation Studies
- Design, Analysis, Engineering
- Commissioning of Equipment and Systems
- Operation & Maintenance
- Fuel Cycle
- Waste Management
- Quality Assurance
- Human Resource Development
- Regulatory Frameworks

PAEC Plant Safety

Safety of PAEC Plants: Design Features

- Design of safety systems of PAEC reactors has some favorable features. e.g.,
  - Fail-safe control rod drop/ heavy water dump for scram
  - Large free containment volume to hold vapor/gases.
- While KANUPP is an old vintage plant, but it is being operated at a much reduced power. Many safety retrofit were built in during the 2002-2004 relicensing shutdown
- Chashma plants are Generation 2 Plus with many severe accidents countermeasures built in.
- Both plants have an oversize containment

Safety of PAEC Plants: Natural Disasters

KANUPP (Tsunami/cyclones)

- G value raised from 0.15g to 0.23g through retrofits
- KANUPP site 6.1 meter above sea level
- Maximum wave ride in 1945 tsunami was 1.5 meter

CHASNUPP design

- At 0.25-0.32 g earthquake against
  - Khisor Fault (17 km) of Richter Scale 6 (5 km depth), maximum recorded is 4
  - Marwat Fault (28 km) of Richter Scale 7 (10 km depth), maximum recorded is 4.4
- Against flood and dam breaks
  - Kalabagh dam if built can have the most impact (one meter rise, 201 meters above sea level), the minimum level of finished plant area is 201.3 meters. For safety related structures, it is 203 meters

Establishment of an Independent Regulatory Authority

- Regulatory setup was established within PAEC at the time of construction of KANUPP in 1965 which gradually evolved into an independent regulatory body
- Almost coincident with the commissioning of C-1, an independent regulatory body Pakistan Nuclear Regulatory Authority (PNRA) was established in 2001
- PNRA is empowered to:
  - Control, regulate and supervise all matters related to nuclear safety and radiation protection in Pakistan
  - Develop and enforce rules and regulations, issue guidelines for safety and radiation protection

Fukushima Accident: Lesson

- The most important lesson is that while we;
  - Need to ensure safety in design and operation, 'must have' various built-in redundant and diverse engineered safety features
  - Need to make a systematic effort to develop Safety culture
  - Must also be equally ready to face 'What if all of them fail to act'.

PAEC Response to Fukushima

- Enhancement of efforts for emergency response/ preparedness. Three levels of urgency
  - Immediate (by 30 June 2011)
  - Short-term (by 30 June 2012)
  - Long-term

- Separate planning for 3 types of plants
  - PHWR old vintage plant (KANUPP)
  - 300 MW class plants (C-1/C-2/C-3/C-4)
  - Future large-size plants

Fukushima Lessons: PAEC Startegy

- Revisit external natural hazards (Earthquake/Tsunami)
- Add means of emergency cooling in case of Station Blackout (SBO)
- Limit hydrogen concentration with no power available
- Add means to maintain Containment integrity at all times
- Ensuring that spent fuel can also be cooled under SBO conditions
- Emphasize emergency Operating Procedures (EOP) and Severe Accident Management Guidelines (SAMG's)
- Think of out-of-box back-up low tech solutions in extreme cases
- Increase off-site emergency preparedness

Summary

- Pakistan is a pioneer developing country in using nuclear technology for producing electrical energy.
- Growing energy needs and inadequate indigenous energy resources dictate large scale use of nuclear power in Pakistan.
- Despite international embargoes, nuclear power program in the country is moving forward - slowly but steadily.
- Safety remains a top priority in nuclear power program of Pakistan.
- Fukushima provide an even bigger drive to enhance safety and develop emergency response program

Thank You

Capital Cost of Nuclear Power Plants (Contracts / Agreements)

Recipient Country	Reactor Type	Capacity (MWe)	Contract/ Agreement Year	Construction Cost		US$/kWe (gross) (in 2010 US$)
				(Billions) US$ (Euro)	US$/kWe (gross)	
China	VVER/AES91	2x1060	Nov-10	3.8	1792	1792
Bangladesh	VVER	2x1000	Apr-09	2.0/plant	2000	2026
India	VVER1000/ AES92	2X1060	2001	3.5	1651	2090
Vietnams	VVER	2X1290	Oct-10	5.6	2171	2171
China	EPR	2x1750	Nov-07	7.3	2086	2257
China	AP-1000	2x1250	Jul-07	5.3	2120	2294
Finland	EPR	1x1720	Dec-03	(3.3)	2302	2786
Bulgaria	VVER/AES92/ V466	2x1060	Jan-08	(4.0)	2755	2898
UAE	APR-1400	4x1450	Dec-09	20.4	3517	3563
Turkey	AES2006	4X1290	May-10	20.0	3876	3876

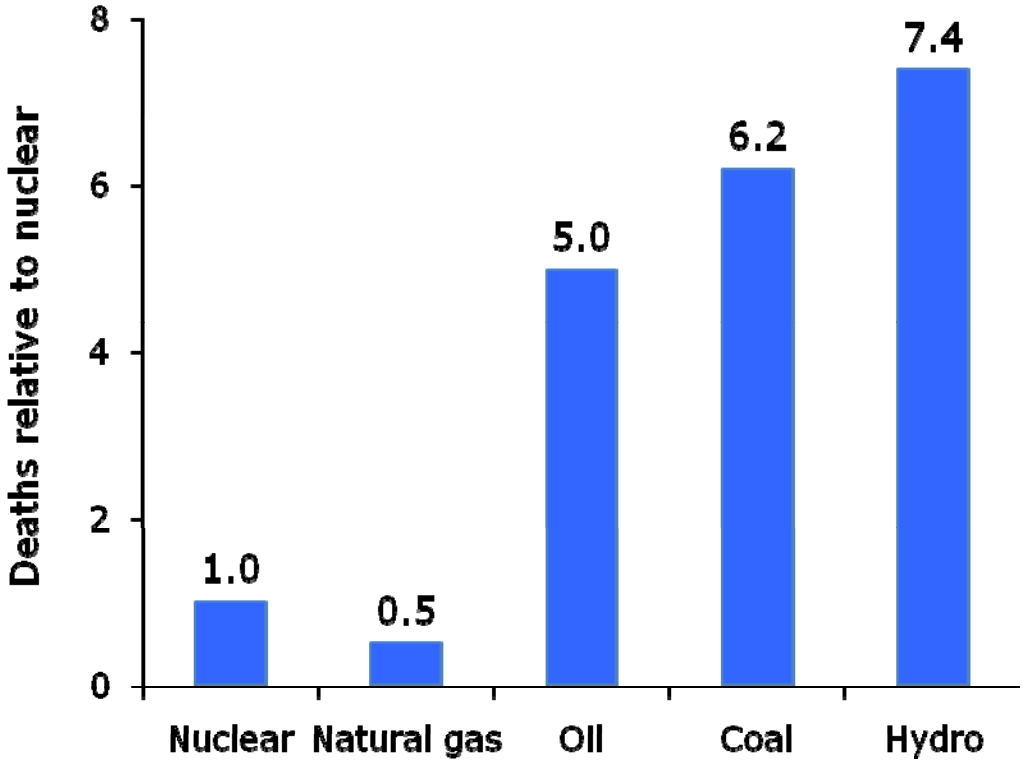
Promising Nuclear Power States

- More than 60 countries- mostly in developing world have shown their interest to IAEA in launching nuclear power programs
- In 42 countries, NPP is being actively considered

Europe	Albania, Belarus, Estonia, Ireland, Italy, Latvia, Norway, Poland, Portugal, Serbia, Turkey
Middle East and North Africa	Algeria, Egypt, Israel, Jordan, Libya, Kuwait, Morocco, Saudi Arabia, Sudan, Syria, Tunisia, UAE, Yemen
West, Central and Southern Africa	Ghana, Namibia, Nigeria, Senegal, Uganda
South America	Chile, Ecuador, Venezuela
Central and Southern Asia	Azerbaijan, Bangladesh, Georgia, Kazakhstan, Mongolia
South East Asia	Indonesia, Philippines, Vietnam, Thailand, Malaysia, Singapore
Australia	Australia, New Zealand

Source: WNA, September 2010

Deaths in Accidents in Energy Chains During the Period 1969-2000



	Nuclear	Natural gas	Oil	Coal	Hydro
Deaths	4056	2023	20218	25107	29938

Sources:

1) Nuclear Energy Outlook 2008, Nuclear Energy Agency.
2) B. K. Sovacool, The Cost of Failure: A Preliminary Assessment of Major Energy Accidents, 1907-2007, Energy Policy (2008).

Economic Competiveness of Nuclear Power

	Furnace Oil-fired Steam	Coal-fired Steam	Gas-fired Combined Cycle	Wind	Nuclear
Rs./kWh	14.51	5.59	7.16	8.42	7.34
Assumptions					
Investment Cost (US$/kW)	1,000	1,500	950	1,800	3,036
Furnace oil price is based on crude oil price of US$ 80/bbl, coal price at US$ 95/tonne and imported gas price at US$ 10/million BTU					

Coal Resources Classification