CHAPTER 3

IS NUCLEAR POWER PAKISTAN'S BEST ENERGY INVESTMENT? ASSESSING PAKISTAN'S ELECTRICITY SITUATION

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Introduction.

The drive for civil nuclear power has resurged around the globe, often under the banner of finding a clean energy alternative to meet growth objectives. Countries like India, Saudi Arabia, United Arab Emirates (UAE), Turkey, Egypt, and Jordan, among others, have all proclaimed a desire for nuclear power generation. Proponents argue that nuclear energy promotes economic development and reduces reliance on foreign sources of energy in a manner that is climate-change friendly due to the lack of carbon emissions.

Similarly, Pakistan has pushed for nuclear power generation using many of the same arguments. Advocates for this initiative have underscored the recent congressional approval of the U.S.-India Civil Nuclear Cooperation agreement, which provides India with access to nuclear equipment and components from Western suppliers. As Pakistan's Prime Minister Yousaf Raza Gilani stated: "Now Pakistan also has the right to demand a civilian nuclear agreement with America. We want there to be no discrimination. Pakistan will also strive for a nuclear deal, and we think they will have to accommodate us."[1] A critical question, however, is whether nuclear power is necessary and vital to economic development in a climate-change friendly manner.

This analysis looks at the economic and resource arguments for nuclear power through 2030 to evaluate whether nuclear power is necessary to meet Pakistan's energy expectations. First, the analysis evaluates the assertion that nuclear energy is vital to meet economic development goals. Second, this chapter analyzes the claim that global carbon emissions will be reduced by such an amount as to make salient the argument for increased Pakistani nuclear power generation capability. Finally, it evaluates whether development of nuclear energy would significantly reduce Pakistan's reliance on foreign energy sources. The framework used to evaluate resource options for electricity development (see Figure 1) includes looking at the total potential capacity, the likely pace of development of different technologies, the relative costs of those options, and the environmental issues and trade-offs inherent with each option.

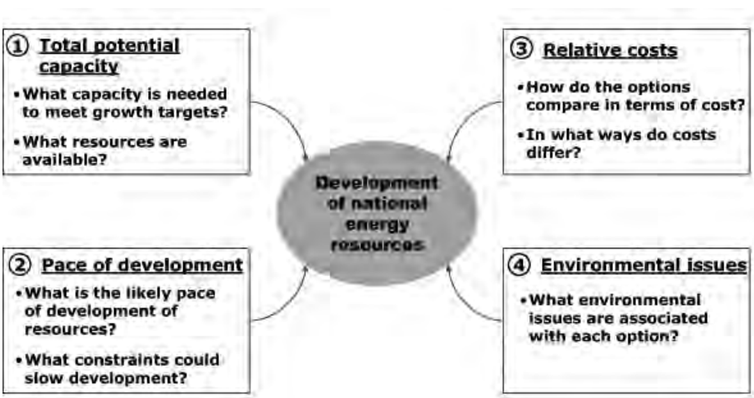


Figure 1. Analytical Framework.

This analysis concludes that nuclear power does not meet the expectations laid out by advocates for its development in Pakistan through 2030. Even under Pakistan's most ambitious growth plans, nuclear energy will continue to contribute a marginal amount of electricity to meet the country's economic goals. Furthermore, with Pakistan's considerable potential of untapped renewable resources, the country has numerous options other than nuclear to meet its development needs. In terms of reductions of carbon emissions, it should be noted that Pakistan currently represents only about 0.4 percent of global emissions. Certainly, while all emissions reductions are necessary, such reductions need to be pursued within the context of other risks, whether from deferred economic development or proliferation of sensitive technologies. Finally, given the sources of energy supplying Pakistan's electricity generation, a significant proportion of which is based on natural gas, Pakistan could reduce its reliance on foreign sources of energy by developing nuclear. However, nuclear in the best case scenarios will provide a limited amount of electricity, and the predominant foreign sources of energy still emit carbon. As such, the route to developing Pakistan's considerable renewable resources can achieve the dual goals on carbon reduction and enhanced self-reliance.

Background: Current and Future Needs.

The primary sources of Pakistan's electricity are natural gas, hydro, and oil/diesel generation (see Figure 2). The total generation capacity of Pakistan in 2005 was 19.5 gigawatts (GW) and consisted of approximately 50 percent from natural gas, 30 percent from hydro power, and 16 percent from oil/diesel.

Nuclear power's current contribution of electricity generation is 3 percent, while the contribution from coal is only 0.2 percent. Notably, renewable energy resources did not contribute to Pakistan's generation capacity in any meaningful way in 2005.

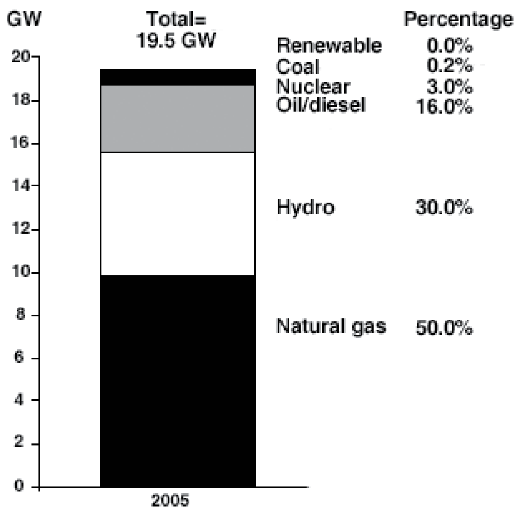


Figure 2. Pakistan's Current Electricity Generation Capacity, 2005 (GW).[2]

Pakistan's current electricity generation capacity also does not meet the current demand, creating significant shortfalls. The country is presently experiencing supply deficits during peak demand periods and the variability of water supply contributes to deficits given the large reliance on hydropower.[3] Nearly half of the population is also estimated to lack connection to the electricity grid, and load shedding has also become necessary in some areas.[4] Some estimates suggest that the grid system requires approximately two additional GW to cover peak demand with an adequate degree of reliability.

Compounding the challenges for meeting current demand, Pakistan's generation capacity requirements are expected to increase significantly through 2030 (see Figure 3). Forecasts for this growth rate vary and are generally tied to gross domestic product (GDP) expansion, which represents the energy intensity of economic growth. The Government of Pakistan estimates are based on an 8 percent GDP growth rate and a corresponding 9 percent generation capacity growth rate, thereby requiring 163 GW of generation capacity by 2030. However, the historical generation capacity growth rate from 1980-2005 was roughly 7.1 percent, and, if this trend continues, the capacity by 2030 would likely be 108 GSs. The actual generation capacity developed by 2030 will likely be somewhere in between these two ranges. However, even assuming a stronger GDP growth rate of 8.5 percent, thereby exceeding the Government of Pakistan projections, the need would be roughly 193 GSs. While the energy intensity varies and tends to decrease as an economy develops, the estimates of generation capacity present a conservative range against which to test the need for specific supply options. Considering the recent global financial and economic downturn, Pakistan's GDP growth rate could be significantly constrained, which could also create a concurrent reduction in the need for generation capacity.

Total Potential Capacity.

Despite the considerable power generation requirement needed by 2030, Pakistan has a wide breadth of potential sources to meet this future demand.

In comparing the potential supply of resources with the generation capacity needed by 2030, this analysis uses both low- and high-end ranges based on various projections of GDP growth. As discussed above, the estimated generation capacity required by 2030 will be between 108 GWs and 193 GWs (shown in Figure 3). For each potential supply, the analysis also uses low and high estimates for the development through 2030.

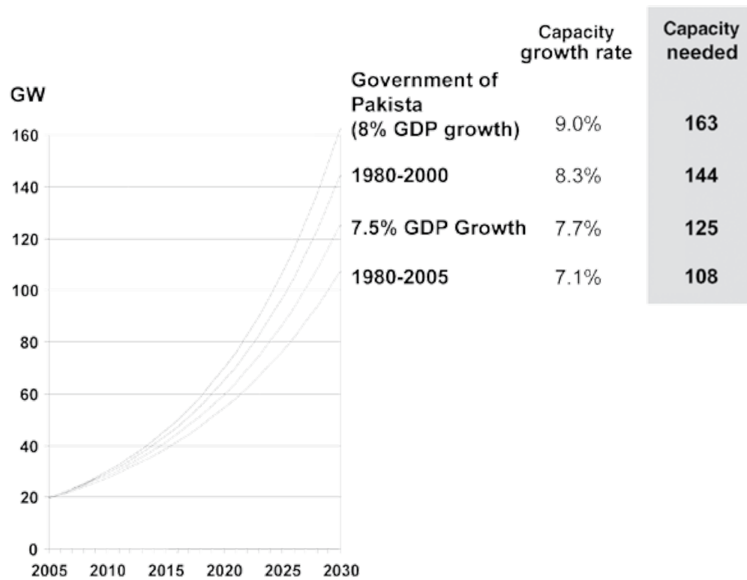


Figure 3. Projections for Pakistan's Generation Capacity Requirements, 2006-2030.[5]

The key finding is that the potential supply of resources should be capable of meeting both low and high estimates for generation capacity needs, although requiring a portfolio approach. The available and likely resources consist of a broad range of supply options involving considerable development of the traditional supply sources of natural gas, hydro, and coal. While indigenous natural gas supplies are expected to dwindle, the Government of Pakistan has committed itself to investing in accessing external sources through pipelines.[6] In terms of coal, Pakistan has approximately 185 billion tons of reserves, even with the anticipated increase of approximately 2.2 GW of coal-generated electricity by April 2009. Renewable energy resources offer significant potential even in the low and medium scenarios, which do not maximize the utilization of these resources, thereby leaving additional potential for well beyond 2030. Energy efficiency options are also likely to be a meaningful contributor to the variety of resources by 2030, offering more potential than that of nuclear power.

Notably, even if the development of nuclear power meets high estimates, it is unlikely to constitute a significant contribution to the overall supply. Currently, Pakistan has two nuclear power plants (Chashma-1 and Kanupp) which generate 300 megawatts (MW) and 125 MW, respectively. Pakistan's third nuclear power plant, Chashma-2, is expected to be completed by 2009 and will be capable of generating 325 MW. The Government of Pakistan estimates suggest a 13 percent growth rate (see Figure 4) which would yield approximately 6-8 GW of nuclear power generation.[7] This represents only about 3-6 percent of the electricity generated in 2030. If those high estimates are not met but instead nuclear power generation grows at a fast yet more reasonable pace of 8 percent, the total nuclear power generation would be roughly 2.8 GW. This would constitute only 1-3 percent of the total generation capacity by 2030.

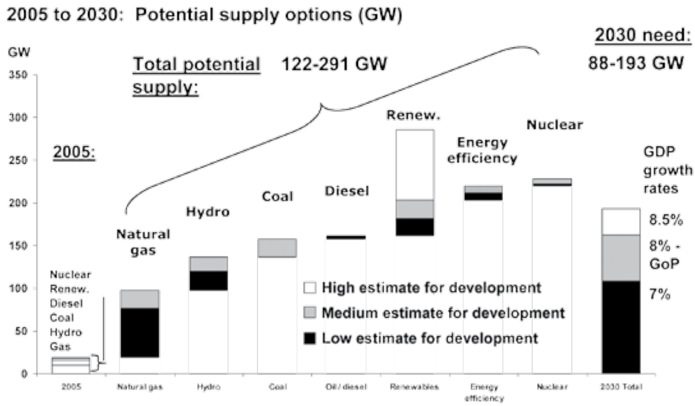


Figure 4. Pakistan's Potential Supply Options for Electricity Generation, 2005-2030.[8]

Pakistan has considerable solar potential that rivals many other regions of the world (see Figure 5). The solarization of the country averages 5.2 kwh/m^2 and nearly half of the country shows economic viability for solar power generation. Few regions, aside from the Sahara, offer better solar potential in the world. Both solar photovoltaic and concentrated solar thermal technologies are becoming increasingly cost effective and commercialized, offering a considerable opportunity for this untapped resource in Pakistan. Although estimates for the total potential generation capacity from solar vary, a reasonable estimate is 70 GW.[9]

The opportunity for wind power generation is also quite significant in Pakistan, at approximately 50 GW of potential generation capacity and a target of 9.7 GW by 2030.

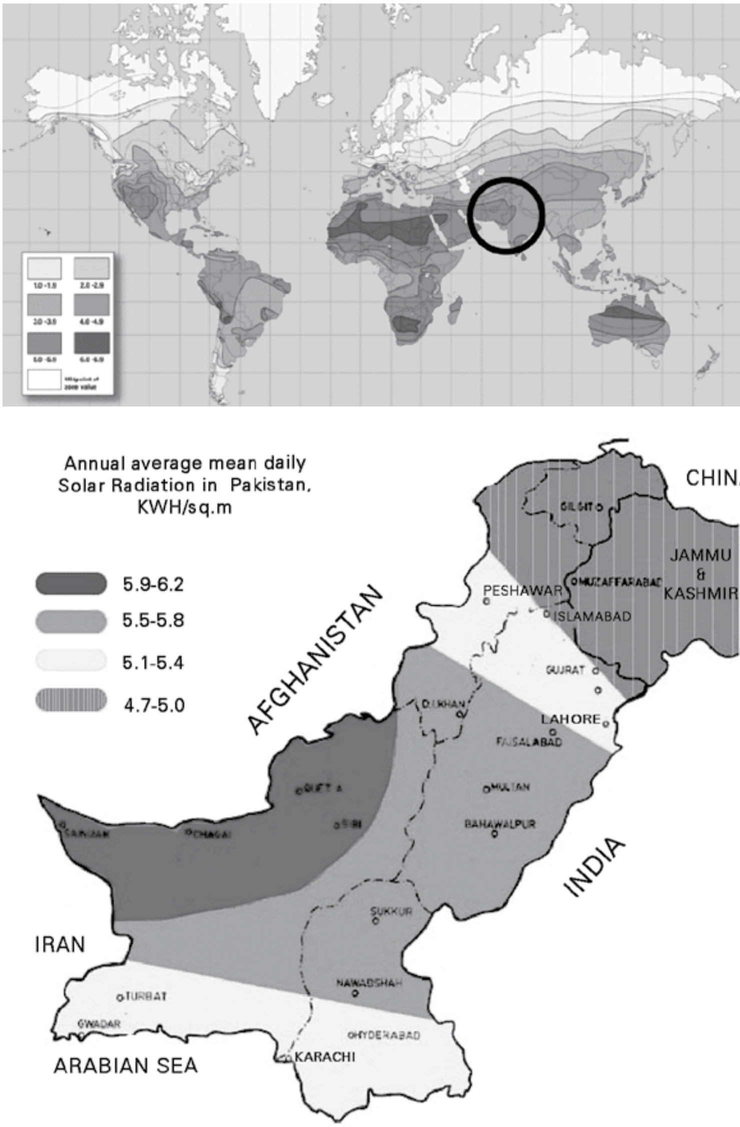


Figure 5. Global Solarization Rates[10] and Solarization across Pakistan.[11]

The AEDB is facilitating favorable rental terms for developers, and numerous letters of intent have been signed, with the target of generating 9.7 GW by 2030.[12] The National Transmission and Despatch Company (NTDC) is constructing new transmission lines to bring the power to markets, and at least two urban hubs, Karachi and Hyderabad, are nearby.[13] The potential of an estimated 50 GW of generation capacity suggests that ample wind capacity will still be available long after 2030.

Figure 6. Location of Pakistan's Wind Corridor Near Gharo-Keti Bandar.[14]

In addition to solar and wind, other promising renewable energy sources exist for Pakistan to develop more fully. For instance, sugar mills in the country use bagasse for cogeneration purposes, and the Government of Pakistan has recently enabled them to sell surplus electricity back to the grid. Other such biomass, biogas, waste-to-electricity, and biofuels could also meaningfully contribute to the energy and electricity supply in Pakistan. The estimate for waste-to-electricity alone is approximately 500 MW per major city.[15]

Given the split between rural and urban populations, decentralized generation sources could also make considerable sense for development in Pakistan. By some estimates, roughly 70 percent of the population lives in rural villages,[16] with nearly half the population lacking a grid connection. With the costs of transmission and distribution, it is often uneconomical to connect these populations to the grid. As such, a centralized power generation source, like nuclear, may not serve to increase electrification rates across the country. Instead, decentralized wind and solar generation can often serve these populations better, and many small scale projects have already been developed throughout the country. The other concern is to have sufficient baseload generation, for which nuclear is normally used. While some renewable technologies raise concerns of intermittency, new technologies are being commercially developed to provide storage and enable use for baseload generation, especially as seen with concentrated solar thermal. And given the small share of nuclear power in the overall generation capacity mix by 2030, other options like hydro will provide significant baseload generation.

Another critical opportunity for meeting Pakistan's electricity needs will be in energy efficiency, or negawatts, which even with conservative estimates will amount to more than nuclear power generation. Energy efficiency efforts can tackle a number of key areas in electricity production and consumption. They can include improving demand or efficiencies, such as switching to improved lights and energy efficiency appliances. Industrial production of goods can similarly be improved to generate considerable negawatts. Electricity generation itself can also be made more efficient, particularly with thermal generation, through equipment upgrades. Finally, transmission and distribution losses, traditionally quite high in developing countries due to technical losses and theft, can be improved for significant savings. Currently, Pakistan's transmission and distribution losses are estimated at approximately 26.5 to 30 percent.[17] The Government of Pakistan set the goal of reducing these by 5 percent by 2010, which could create approximately 8 GW of negawatts cumulatively by 2030.[18] Committing to another 5 percent reduction in transmission losses would double this to roughly 16 GW. In terms of estimating negawatts, this analysis remains quite conservative, having only reflected the potential savings from improving transmission and distribution losses. If demand efficiencies had been incorporated, these estimates could be considerably higher. Regardless, the potential improvements in transmission and distribution losses alone would outpace nuclear power generation by 1.5-3 times.

Pace of Development.

The likely pace of development of various supply options will be especially important for Pakistan and current projections significantly outpace historical development. Government projections often suggest that generation options will develop much more rapidly than historical progress suggests, and projections of nuclear development are no exception. In fact, the projections of nuclear development in Pakistan are predicated on attaining a development trajectory that very few countries in the world have been able to attain.

When projecting likely development of electricity generation sources, it is important to look first at the historical development of various options (see Figure 7). In the case of Pakistan, the development of thermal and nonconventional energy sources (NCES) has risen the fastest over a 25-year period, at approximately an 8 percent growth rate. However, recently (from 2000-05), installed plant capacity from these sources has stagnated at 0 percent growth, while hydro power, at 6 percent, has maintained a consistent growth rate over the entire 25-year time period. Nuclear grew the slowest over this period, at 5 percent from 1980-2005. Recent high growth rates of 28 percent from 2000-05 reflect the small number of nuclear power plants overall. With two plants online and a third scheduled to go live in 2009, each additional plant represents a significant percentage of the total. Overall, generation capacity grew by 7 percent from 1980-2005 and by only 2 percent from 2000-05.[19]

The projections for the various supply options are almost uniformly ambitious, but especially so for nuclear. From 2005 to 2030, it is expected that nuclear generation will increase at a growth rate of 13 percent. Other supply options have similarly high estimated growth rates, such as natural gas at 9 percent, hydro at 10 percent, coal at 13 percent, and renewable energy at 14 percent.

Nearly all of these supply options will undoubtedly face challenges in attaining such growth targets, but fewer challenges are likely be met by those options that face lower barriers in the form of capital intensity, political will, and ready availability of supplies and technology.

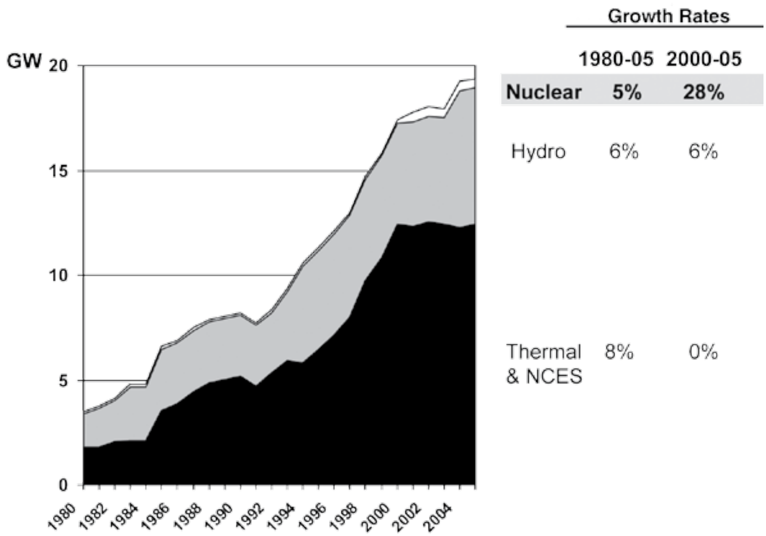


Figure 7. Historical Development of Electricity Generation, 1980-2005 (GW).[20]

Because nuclear faces immense challenges in terms of capital intensity and accessibility of supplies and technology, the growth rates implied for nuclear development suggest the attainment of targets that very few countries in the world have been able to achieve. However, as a nonsignatory to the Non-Proliferation Treaty, there are international embargoes on the transfer of such technology to Pakistan. China is currently the only supplier of nuclear power plants and components to Pakistan, but, to meet the projections, Pakistan would require access to advanced nuclear supplies and technologies from Western countries.[21] Such constraints raise particular questions around nuclear development, where governments are especially prone to overestimate their ability to develop such resources and install generating capacity. (See Figure 8.)

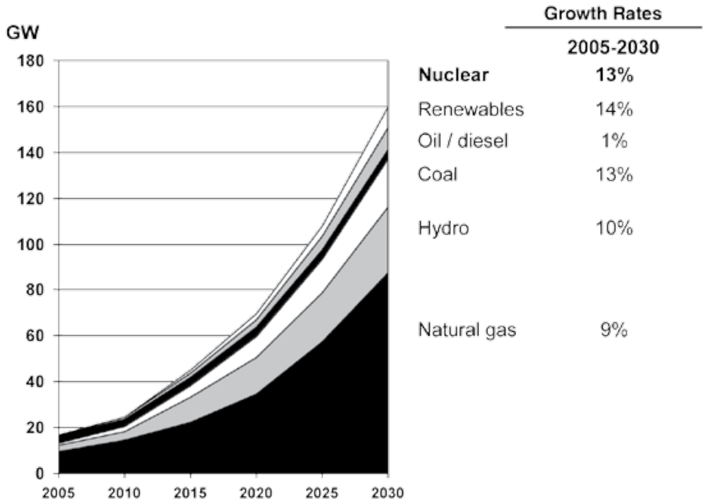
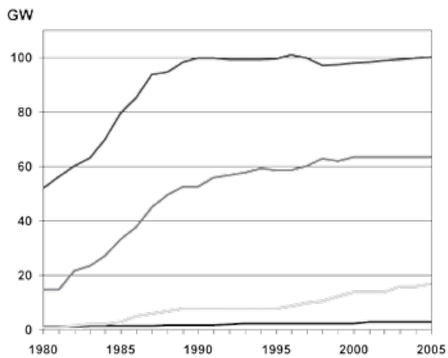


Figure 8. Projected Development of Installed Plant Capacity, 2005-2030 (GW).[22]

Globally, the historical data of nuclear power development suggests that few countries have been able to achieve and maintain a consistently high growth rate for nuclear development as per Pakistan's estimates. South Korea comes the closest to reaching the trajectory and sustainability of nuclear power generation with a 14.3 percent compound annual growth rate (CAGR) over the 15 years from 1980 to 2005. The United States and France both had much faster growth from 1980 until approximately the early 1990s (at 7 percent and 14 percent respectively), but their nuclear development programs have since leveled off.[23] By contrast, India has only attained a 4.9 percent growth rate for its nuclear development.[24] For Pakistan to meet its own nuclear power development estimates over the next 30 years, it would have to emulate or surpass the efforts of countries like South Korea, France, or the United States. (See Figure 9.)



	Installed GW 1980	Installed GW 2005	1980-2005 CAGR
U.S.	52	100	2.7%
France	14	63	6.1%
South Korea	0.59	17	14.3%
India	0.9	2.8	4.9%

Figure 9. Historical Development of Nuclear Power in the U.S., France, South Korea, and India, 1980-2005 (GW).[25]

Nuclear development also requires considerable coordination between the private and public sectors, requiring rather strong government effectiveness, regulatory quality, and control of corruption since nuclear projects require large capital expenditures. Relative to countries such as the United States, France, and South Korea that have successfully developed nuclear power generation at impressive growth rates, Pakistan's measure on these governance indicators is significantly lower. (See Figure 10.) Although these metrics are general governance indicators, the successful implementation of a nuclear power development policy would presumably require even greater government effectiveness, regulatory skills, and control of corruption than ordinary large-scale infrastructure projects. While a lower rating in government effectiveness may suggest a country is less able to orchestrate the necessary level of coordination to get a project initiated and complete, a lower rating in regulatory quality would suggest potential lapses in security and safety, and less control of corruption would suggest that sensitive materials may be more prone to illicit sale and trade. Corruption also matters considerably in terms of the financing of large-scale infrastructure projects. The "corruption tax" on a large project can significantly balloon costs and delay completion. These discrepancies in governance indicators would suggest that the nuclear generation growth rates targeted by the Government of Pakistan may not be achievable.

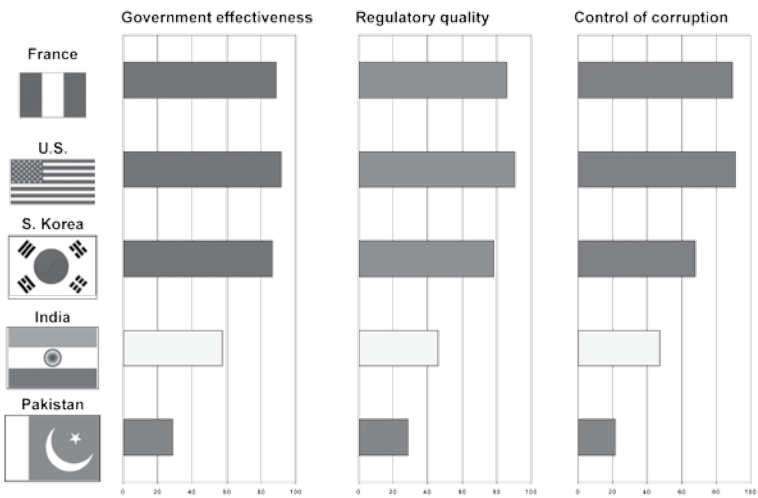


Figure 10. Governance Indicator Comparison, 2007.[26]

At the same time, the regulatory and policy environment for renewable energy development, including wind and solar power, is being increasingly strengthened and geared towards enhancing and accelerating development. Legislation that has been passed includes sales tax, income tax, and customs duty exemptions for imported plants, machinery, and equipment for renewable energy power generation.[27] Further incentives for private sector development of wind power even includes "Wind Risk Coverage," which covers the risk of wind speed variability, making the power purchaser (the Government of Pakistan) absorb the risk of such variability.[28] The AEDB continues to lobby aggressively for investments and, in the case of wind, roughly 93 letters of intent have already been signed for development.[29] This push has benefited from foreign assistance, such as support from the U.S. National Renewable Energy Laboratories under a 2007 U.S. Agency for International Development (USAID) assistance program.[30]

Relative Costs.

The likely development of various supply options is influenced by a number of factors, including the relative costs of those options (see Figure 11). Estimates of the relative costs of different supply options vary widely. By far, the lowest cost options are coal and hydro, while some of the most expensive options are solar photovoltaic and solar thermal. Local costs of supply options can vary considerably, and Pakistan-specific estimates suggest nuclear energy could be on the high-end of the range, at roughly $0.057 cents per kilowatt-hour (kWh).

It is also important to note the trend for the cost curves of renewable energy technologies (see Figure 12). Wind has led the way in becoming economically viable, and solar is expected to follow suit in the medium term. The price of concentrated solar power has dropped at a faster rate than solar photovoltaic (PV), but recent advances in solar PV technology also suggest increased commercial viability.

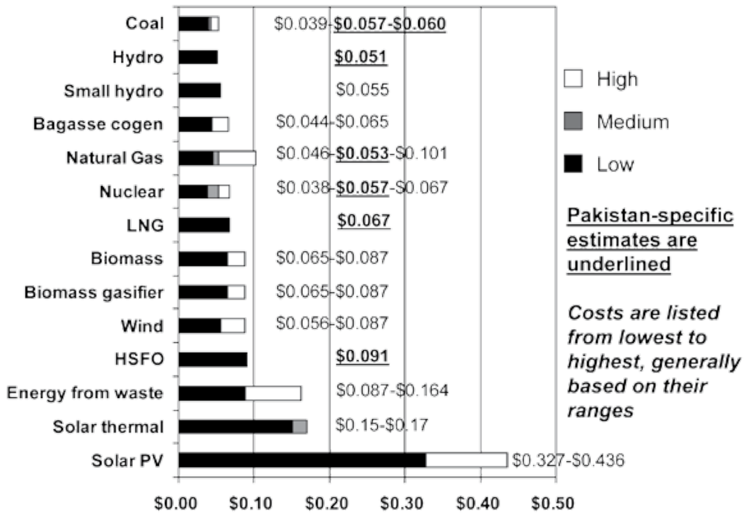


Figure 11. Relative Costs of Various Resource Options.[31]

Furthermore, for many nongrid connected Pakistanis, the trade-off is not necessarily between cheap sources of electricity or renewable options. Rather, it lies in which resources can, or will, be developed in the near-, medium-, and long-term. A more expensive option per kilowatt-hour, like solar or wind, may have lower up-front costs and not rely on the central government to invest in infrastructure requirements for transmission and distribution.

One significant benefit of renewable energy technologies like wind and solar, however, is that they both have predictable (i.e., zero) fuel costs and can also be expanded incrementally. Wind and solar farms can largely be built in stages, with the first phases of installation becoming immediately productive, while a fractional build-out of a nuclear facility cannot produce electricity.

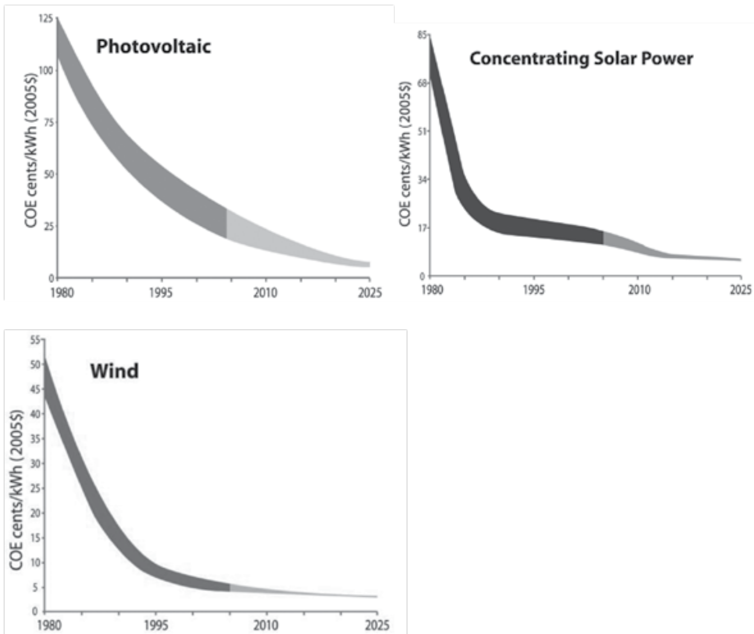


Figure 12. Cost Curve for Solar Photovoltaic, Concentrating Solar Power, and Wind, 1980-2025.[32]

It is also important to note the potential ramifications of the current global financial crisis. As access to capital becomes constrained, it will likely become more difficult to finance large scale investments like nuclear, especially where the production of electricity and generation of cash flows comes much later. Less capital-intensive projects that can be built-out incrementally are more likely to be favored and will be used to meet electricity demand that itself is likely to be reduced due to economic growth constraints.

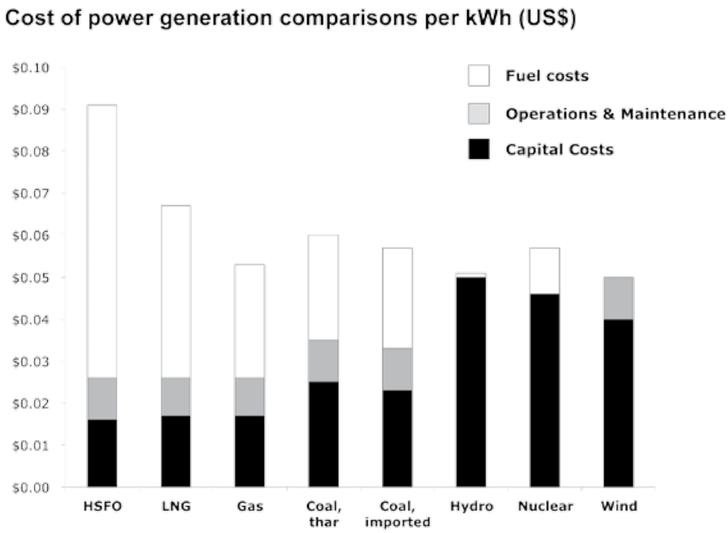


Figure 13. Cost Structure Comparison of Various Supply Options (per kWh, US$).[33]

In the end, it is important to compare the relative costs of different supply options, but meeting Pakistan's electricity needs will require a portfolio strategy. No single option, no matter how attractive from a cost perspective, can meet the full need by 2030. Numerous options need to be pursued, leveraging the strengths and mitigating the risks associated with each.

ENVIRONMENTAL ISSUES

Given the very real risks of climate change, it is vital to consider environmental issues when evaluating electricity supply options in any region of the world. Nuclear is often judged against a "clean" generation technology due to the lack of carbon emitted during electricity generation. While this is true, renewable energy technologies are equally climate-change friendly and are not accompanied by the problems associated with long-lasting radioactive spent fuel and its transportation, storage, and disposal.

It is also important to look at the sources of carbon emissions by country to determine the appropriate intervention to reduce those emissions. In Pakistan, a significant amount of carbon emissions comes from petroleum which serves transportation needs and would not be offset by switching to electricity generation resources, at least until electric cars are widespread in Pakistan. A promising trend in Pakistan's transportation sector, however, is the increased use of compressed natural gas for transportation.[34] Also, while a significant amount of Pakistan's emissions come from natural gas (including for electricity generation), natural gas produces just about half the emissions of coal. (See Figure 14.)

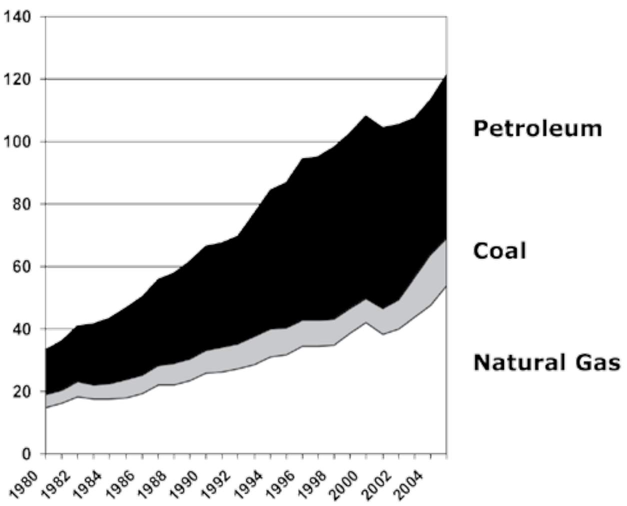


Figure 14. Pakistan's CO2 Emission by Source, 1980-2005 (million metric tons).[35]

Finally, while all emissions reductions contribute to addressing the issue of climate change, Pakistan's emissions should be considered in context when weighing the attractiveness of other options involving different types of risks. In 2005, Pakistan produced just 0.4 percent of total global carbon emissions. By comparison, Pakistan produces only 0.77 metric tons per capita versus 20.14 metric tons per capita in the United States. As such, the degree of the carbon emissions problem in Pakistan may not outweigh other the risks associated with nuclear power generation. This is especially true when considering the ample renewable energy potential in Pakistan, the benefits of decentralized power generation in the country, the decreasing costs of renewable energy sources, and the lack of fuel risks attaching to renewable energy sources (both in terms of price volatility and spent-fuel risks).

CONCLUSIONS

Numerous countries, including Pakistan, are pushing to develop nuclear power generation capacity. These countries often highlight the requirements of economic development to increase their electricity generation. In a carbon constrained world with increasing global awareness of the risks of climate change, nuclear power is judged as a clean and efficient way to meet economic development objectives while limiting carbon emissions. Furthermore, nuclear power is often seen as a means of ensuring greater self-reliance and independence from petroleum imports from unstable neighbors or regions. With the recent approval of the U.S.-India Civil Nuclear Cooperation agreement, Pakistan is also calling for access to nuclear equipment and supplies from Western sources as a measure of fairness and support for its economic development.

However, in the case of Pakistan, the promises of nuclear power generation are largely exaggerated through 2030. While it remains true that Pakistan currently has an electricity generation capacity shortage and will need considerably more capacity by 2030, there is ample potential supply from numerous other sources. Traditional sources such as natural gas and hydro will continue to be important for Pakistan, but increasingly, the potential of renewable energy will be harnessed. Pakistan is extremely well-endowed not only with large-scale hydro, but also world-leading solar and wind resources. The government has recognized this by establishing the AEDB, and has increased the amount of investments in this sector.

With a portfolio approach encompassing traditional and renewable energy sources along with energy efficiency measures, Pakistan can meet its electricity needs through 2030 if it chooses to forego nuclear power development. The role of nuclear in the mix of electricity generation sources by 2030 is not vital. First, the estimates for nuclear development are quite ambitious and rest on the assumption that Pakistan could replicate the development trajectory of the United States, France, and South Korea. Second, nuclear development requires significant private and public sector coordination resting on a solid foundation of government effectiveness, regulatory quality, and control over corruption. Compared with those countries that have successfully developed nuclear power in the past, Pakistan falls short of these metrics. Finally, even if the high estimates are achieved by Pakistan, the resulting contribution would represent only 3-6 percent of total electricity generation capacity. Furthermore, Pakistan's overall contribution to global carbon emissions remains miniscule at 0.4 percent, so substitution through an aggressive nuclear energy program does not suggest meaningful progress on the climate change agenda.

ENDNOTES - CHAPTER 3

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the projected 13 percent growth rate for the high estimate and an 8 percent growth rate which is still very high compared with other countries histories of nuclear development.

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31. Sources: Pakistan-specific estimates (others are benchmarks, with some estimates from elsewhere in South Asia) from Mukhtar Ahmed, "Meeting Pakistan's Energy Needs," Woodrow Wilson Report, *Fueling the Future: Meeting Pakistan's Energy Needs in the 21st Century*; Energy Information Administration, *Annual Energy Outlook*, DOE/EIA-0383(2006), Washington, DC, February 2006; Government of India, Planning Commission, *Integrated Energy Policy: Report of the Expert Committee*, New Delhi, India: Government of India, August 2006; David G. Victor, "The India Nuclear Deal: Implications for Global Climate Change," Testimony before the U.S. Senate Committee on Energy and Natural Resources, July 18, 2006, available from *www.cfr.org/publication/11123/india_nuclear_deal.html*. Notes: For the levelized cost comparison of coal, natural gas (advanced combined cycle), the low estimate for wind, and nuclear, the cost comparison is for U.S. plants that would come online in 2015. For the nuclear generation estimates by David Victor, for light water reactors: the lowest at 3.8 U.S. cents comes

from Bharadwaj, Anshu; Rahul Tongia, and V. S. Arunachalam, "Whither Nuclear Power?" *Economic and Political Weekly*, Vol. 41, No. 12, 2006, pp. 1203-1212. The medium cost of 4.2 cents per kWh and 6.7 cents per kWh come from *The Future of Nuclear Power: an Interdisciplinary Study*, Cambridge, MA: MIT Press, 2003. Using the US DOE's levelized costs and incorporating the fact that Indian fuel is 2-3 times costlier, a cost of 6.6 cents per kWh is estimated. "HSFO" is heavy fuel oil.

32. U.S. National Renewable Energy Laboratory.

33. Mukhtar Ahmed, "Meeting Pakistan's Energy Needs." U.S. DOE levelized cost calculations.

34. Energy Information Administration.

35. *Ibid*.