



RESEARCH REPORT 16 • June 2008 • WWW.SASSU.ORG.UK

## Understanding Pakistan's Energy Security Needs and the Role of Nuclear Energy

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By Jack Boureston • Series Editor: Maria Sultan

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# Understanding Pakistan's Energy Security Needs and the Role of Nuclear Energy

Jack Boureston

June, 2008

## I. Introduction

Like most modern nations, Pakistan is coming to grips with its energy security needs. Their expected rise in energy consumption has created the necessity for the government to modernize the energy resources in the country. Increased pressure on domestic capabilities, diminishing reserves, and political and economic constraints all hinder further development of the energy industry. However, Pakistan created the 2005 Energy Security Plan (ESP) to gradually increase its energy production capability to eight times of the current 2005 standards. Nuclear energy will play a prominent role in the ESP. This paper will consider Pakistan's future energy needs based on the government's current capabilities and resources, as described in open sources. The report will also provide a series of objectives that may help Pakistan meet its energy goals for the future.

## Energy Security Plan (ESP)

In 2005, the Planning Commission of Pakistan joined with the Pakistan Atomic Energy Commission (PAEC) to formulate the Energy Security Plan (ESP).<sup>1</sup> The ESP addresses the country's growing demand for energy and predicts future needs based on current trends. It lays out a plan to produce 162,590MWe by 2030, 8,800MWe of which will be produced by nuclear reactors. According to 2006 figures, Pakistan currently produces only 19,540MWe.<sup>2</sup> The ESP proposes that nuclear energy will play a larger role in the future production of electricity in order to meet the country's energy demands.

Nuclear energy is clean, efficient and relatively cost effective.<sup>3</sup> The Pakistani government plans to dramatically invest in the development of this industry.<sup>4</sup> Reliance on nuclear power in Pakistan is currently relatively minor: Nuclear energy supplied approximately 2% of Pakistan's power production in 2006.<sup>5</sup> Pakistan's present annual nuclear power production capability is only 425MWe. It is generated from the country's two nuclear power plants, *The Karachi Nuclear Power Plant (KANUPP)* and *Chasma Nuclear Power Plant I (CHASNNUP I)*. To reach its 2030 goal of producing 8,800MWe annually from nuclear energy, Pakistan will need to produce

<sup>1</sup> "Energy Security Plan," Deputy Chairman of the Pakistan Planning Commission. February 15, 2005 [www.pakistan.gov.pk/.../presentations/Energy%20Security%20Plan%2015-02-05-Final.ppt](http://www.pakistan.gov.pk/.../presentations/Energy%20Security%20Plan%2015-02-05-Final.ppt)>

<sup>2</sup> "Pakistan to Develop Indigenous Nuclear Power Plants," *The Financial Times Limited*, June 21, 2007.

<sup>3</sup> Zia ul Hasan Siddiqui. "Nuclear Power Program in Pakistan," *World Nuclear Association*, 2006, <<http://www.world-nuclear.org/sym/2006/siddiqui.htm>>

<sup>4</sup> "Nuclear Energy To Assume Bigger Role In Pakistan," *The Financial Times*, May 20, 2007.

<sup>5</sup> "Pakistan: Power Reactor Information System," IAEA, <<http://www.iaea.org/programmes/a2/index.html>>

roughly an additional 600MWe each year through 2030. The government has developed a plan to build additional 300MWe, 600MWe, and 1000MWe reactors in the future.<sup>6</sup>

The ESP was formulated by the PAEC. This organization presides over research, training and promotion of peaceful nuclear energy development as well as national security projects.<sup>7</sup> The PAEC has established the Engineering Design Organization (EDO) to promote the indigenous development of nuclear power plants to satisfy the country's energy needs.<sup>8</sup>

### **Power Production Capabilities: Now and in the Future**

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Pakistan has two main civilian nuclear reactors and is in the process of constructing a third power plant.<sup>9</sup> According to Pakistan's 2005 ESP, in the long-term the Pakistani government must obtain two 600MWe reactors and seven 1000MWe reactors. While it is anticipated that the reactors will come from China, both countries have yet to solidify an agreement. In May of 2007 PAEC officials stated that the Commission will be constructing three 600MWe power plants at Karachi.<sup>10</sup> Balochistan is likely to be a site for one of the 600MWe plants.<sup>11</sup> It is thought that the remaining two sites will be established near the Karachi plant. According to PAEC officials, the PAEC has begun planning to construct six power plants at 1000MWe.<sup>12</sup> The PAEC has selected six sites for installation of more nuclear power plants (NPPs) that will likely become the hosts of the six 1000MWe reactors. The locations are as follows: Qadirabad-Bulloki link canal near Qadirabad headworks, Dera Ghazi Khan canal near Taunsa Barrage, Taunsa-Punjad canal near Multan, Nara canal near Sukkur, Pat Feeder canal near Guddu, and the Kabul river near Nowshera.<sup>13</sup> Based on this information it appears that Pakistan has changed its original 2005 plan and decided to add an additional 600MWe reactor and one less 1000MWe reactor.

### **Existing Nuclear Power Plants**

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*The Karachi Nuclear Power Plant (KANUPP)* - KANUPP is a Canadian-made deuterium uranium pressurized heavy water reactor.<sup>14</sup> It was established 1971 and is capable of producing 137MWe each year.<sup>15</sup> The Karachi plant has 2288 fuel assemblies with a cycle length of 1.4 months.<sup>16</sup> It operates on 12 tons of 0.7% enriched UO<sub>2</sub> per year.<sup>17</sup> The KANUPP reactor

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<sup>6</sup> "Energy Security Plan Deputy," Chairman of the Pakistan Planning Commission. February 15, 2005 [www.pakistan.gov.pk/.../presentations/Energy%20Security%20Plan%2015-02-05-Final.ppt](http://www.pakistan.gov.pk/.../presentations/Energy%20Security%20Plan%2015-02-05-Final.ppt)

<sup>7</sup> "History of PAEC," PAEC, <<http://www.paec.gov.pk/paec-hist.htm>>

<sup>8</sup> "Pakistan to Develop Indigenous Nuclear Power Plants," The Financial Times Limited, June 21, 2007.

<sup>9</sup> "Pakistan: Power Reactor Information System," IAEA, <<http://www.iaea.org/programmes/a2/index.html>>

<sup>10</sup> "Pakistan To Establish Three Nuclear Power Plants Near Karachi," The Financial Times, May 28, 2007.

<sup>11</sup> "Balochistan Freedom Fighters Attack Nuclear Establishment," South Asia Analysis Group, Paper No. 1801 May 17, 2006. <<http://www.saag.org/papers19/paper1801.html>>

<sup>12</sup> "8,800MW Nuclear Power Target Achievable by 2030 PAEC Chairman," The Financial Times, March 30, 2007.

<sup>13</sup> "Country's Nuclear Power Output Capacity Only 400 Megawatts," The Financial Times, May 20, 2007.

<sup>14</sup> "Information and Issue Briefs: India and Pakistan," World Nuclear Association, September 2003, <<http://world-nuclear.org/info/inf53.htm>>

<sup>15</sup> "Pakistan: Nuclear Power Reactor Details - KANUPP," IAEA, *Power Reactor Information System Database*, <<http://www.iaea.org/programmes/a2/index.html>>

<sup>16</sup> "Karachi Nuclear Power Plant (KANUPP): Plant Features and Data," PAEC <<http://www.paec.gov.pk/kanupp/pf.htm>>

<sup>17</sup> "Kanupp Unit # (125 MWe)," *World Nuclear Industry Handbook*, January 1997. <[http://www.insc.anl.gov/cgi-bin/rperl/sql\\_interface?view=newrx\\_data&qvar=oracle\\_id&qval=238](http://www.insc.anl.gov/cgi-bin/rperl/sql_interface?view=newrx_data&qvar=oracle_id&qval=238)>

completed its 30-year design life on December 5, 2002.<sup>18</sup> KANUPP is scheduled to retire in 2019.<sup>19</sup> The Pakistani government has made significant investments in the maintenance and life-extension of the reactor yet its energy output is comparatively low.<sup>20</sup> According to IAEA statistics in 2006, KANUPP's energy availability factor was a mere 27.46%. This figure represents the amount of energy produced after dividing out the amount of energy lost.<sup>21</sup> KANUPP provides less than 1% of the country's total energy needs.<sup>22</sup>

*Chashma Reactors* - China has provided Pakistan with two 300MWe nuclear reactors. Chashma-I was provided in 1992 and construction on Chashma II began in 2005. These reactors are modeled after the Qinshan Phase I plant.

*Chashma I (CHASNUP I)* - Chashma I is a pressurized water reactor.<sup>23</sup> The Chashma reactor, which went critical in May 2000, has a lifespan of 40 years and is capable of producing 325MWe a year.<sup>24</sup> The Chashma nuclear power plant has a 3 meter tall, 2.5 meter wide fuel core. It holds 36 tons of 3.4% enriched U235 fuel.<sup>25</sup> It requires 11 tons of new fuel per year to produce 300MWe annually.

*Chashma II (CHASNUP II)* - Chashma II is under construction. It is a joint Chinese-Pakistani program. China is supplying technical assistance and enriched fuel for the reactor. The Chinese supplier will reportedly supply the first five fuel loads to Pakistan for the reactor.<sup>26</sup> Like Chashma I, this 300MWe power reactor is modeled after the Chinese Qinshan Phase 1 plant.<sup>27</sup> Construction of the reactor began on April 8, 2005. It is scheduled to be completed by 2011.<sup>28</sup> It will be put under is under IAEA safeguards.<sup>29</sup>

According to *The Nation*, in April of 2006 Pakistani and Chinese officials participated in joint working group nuclear cooperation discussions. During those talks, China offered to construct two new Qinshan Phase II-modeled 600MWe reactors in Pakistan.<sup>30</sup> Each Qinshan-II unit is estimated to discharge approximately 27 tons of spent fuel per year.<sup>31</sup> Pakistan may purchase up

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<sup>18</sup> "Pakistan Nuclear Update 2003," The Risk Report Volume 9 Number 6 (November-December 2003) <<http://www.wisconsinproject.org/countries/pakistan/nuke2003.htm>>

<sup>19</sup> Muneer, T. and M. Asif. "Pakistan for Secure and Sustainable Electricity Supply for Pakistan," *Napier University, School of Engineering*, May 5, 2005.

<sup>20</sup> "Country's Nuclear Power Output Capacity Only 400 Megawatts," The Financial Times, May 20, 2007.

<sup>21</sup> "Kanupp: Pakistan," *IAEA Power Reactor Information System* <<http://www.iaea.org/programmes/a2/index.html>>

<sup>22</sup> "Country Nuclear Fuel Cycle Profiles," *IAEA*, Technical Reports Series No. 404. 2001 <[http://www-pub.iaea.org/MTCD/publications/PDF/TRS404\\_scr.pdf](http://www-pub.iaea.org/MTCD/publications/PDF/TRS404_scr.pdf)>

<sup>23</sup> "Information and Issue Briefs: India and Pakistan," World Nuclear Association, September 2003, <<http://world-nuclear.org/info/inf53.htm>>

<sup>24</sup> Mustafa, Khalid. "Six Sites Selected for Nuclear Power Plants 'in a Major Development,'" Open Source Document [SAP20061017033001] The News October 17, 2006

<sup>25</sup> "Pakistan: Chasnupp," *No Nukes Info Source*, <<http://www.ecology.at/nni/site.php?site=Chasnupp>>

<sup>26</sup> "Information and Issue Briefs: India and Pakistan," World Nuclear Association, September 2003, <<http://world-nuclear.org/info/inf53.htm>>

<sup>27</sup> "Chashma Nuclear Power Plant-1 (CHASNUPP-1)," *PAEC* <<http://www.paec.gov.pk/chasnupp1/index.htm>>

<sup>28</sup> "Chashma Nuclear Power Plant-1 (CHASNUPP-1)," *PAEC* <<http://www.paec.gov.pk/chasnupp1/index.htm>>

<sup>29</sup> Goraya, Rafiq. "Chasnup II Comes Under IAEA Safeguards," The Financial Times, February 24, 2007.

<sup>30</sup> Braun, Chaim. "Security Issues Related To Future Pakistani Nuclear Power Program," CISAC, Stanford, CA.

<sup>31</sup> Braun, Chaim. "The Pakistan Nuclear Power Program - Security and Safety Issues," NPEC Workshop on Pakistan's Nuclear Futures: Reigning in the Risks, Washington DC: April 27-28, 2006.

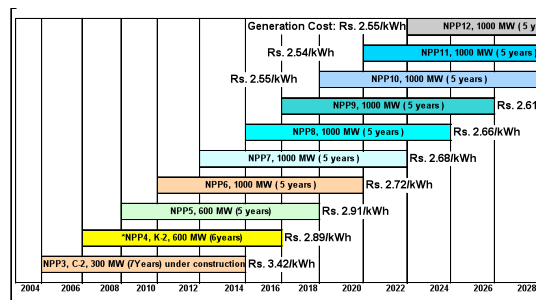
to eight 600 MWe from China before 2017. If Pakistan and China were to solidify their plans, they could provide 4,800MWe to Pakistan’s power grid.<sup>32</sup> However, the deal has reportedly stalled.<sup>33</sup> Therefore, Pakistan is now considering indigenous resources to design and construct nuclear power plants.<sup>34</sup> Pakistan will need to produce an average of an additional 600MWe per year to reach its energy goals.

**Figure 1: ESP Power Generation Goals**

<b>Current Production</b>	<b>425MWe/yr</b>
<b>Planned Expansion</b>	an additional 300MWe/yr reactor; (possible plans to construct 2 x 600MWe reactors <sup>35</sup> and 2-4 1000MWe from China) <sup>36</sup>
<b>Amount needed to meet overall energy plan</b>	8,800MW
<b>Meets/does not meet goals and by how much</b>	8,075MW

**Assessment:** In 2006 Pakistan produced only 425MWe based on its two reactors. Including the 300MWe reactor under construction, Pakistan has energy potential of producing 725MWe, which still falls well below ESP goals. Under the ESP it had been proposed that Pakistan begin construction of a 600MW nuclear reactor in 2006; as of the summer of 2007, construction had still not begun. As it stands, Pakistan will need to begin constructing two 600MW reactors by the end of 2008.

The graph below, provided by the PAEC, illustrates the timeline of the proposed construction of nuclear reactors. It illustrates how much energy needs to be produced in order to meet Pakistan’s target of 8,800MWe by 2030. Based on the information below, Pakistan aims to produce 737MW of electricity by 2014, 1,937MWe by 2018, 3,800MWe by 2022, and 5,800MWe by 2026 so as to reach its goal.



#### IV. Supporting Nuclear Fuel Cycle Infrastructure

<sup>32</sup> Niazi, Tarique. “Thunder in Sino-Pakistani Relations,” The Jamestown Foundation, China Brief: Vol. 6 No. 5 March 2, 2006. <[http://jamestown.org/publications\\_details.php?volume\\_id=415&&issue\\_id=3637](http://jamestown.org/publications_details.php?volume_id=415&&issue_id=3637)>

<sup>33</sup> “Pakistan to Develop Indigenous Nuclear Power Plants,” The Financial Times Limited, June 21, 2007.

<sup>34</sup> “Pakistan to Develop Indigenous Nuclear Power Plants,” The Financial Times Limited, June 21, 2007.

<sup>35</sup> Braun, Chaim. “The Pakistan Nuclear Power Program - Security and Safety Issues,” NPEC Workshop on Pakistan’s Nuclear Futures: Reigning in the Risks, Washington DC: April 27-28, 2006

<sup>36</sup> “Pakistan to Develop Indigenous Nuclear Power Plants,” The Financial Times Limited, June 21, 2007.

To meet 2030 ESP goals Pakistan will address each step in the fuel cycle. In order to manufacture the required reactor fuel, Pakistan will acquire uranium ore indigenously that will be into U3O8 and converted into UF6. UF6 is enriched and then used to make the fuel for nuclear reactors. The table below shows how much material is required from each step in the nuclear fuel cycle to make a sufficient amount of fuel to maintain nuclear reactors and fulfill Pakistan's energy goals. The table details each step that is required to produce the reactor fuel and illustrates how much the demand for fuel will increase over time based on Pakistan's anticipated acquisition of nuclear power reactors.

**Figure 2: ESP Fuel Requirements**

	2014	2018	2022	2026	2030
Tons of Uranium ore at 0.2%	117450/yr	218076/yr	346050/yr	512100/yr	761400/yr
Tons of U3O8	261/yr	484/yr	769/yr	1138/yr	1692/yr
Tons of UF6	340/yr	630/yr	1000/yr	1480/yr	2200/yr
Tons of fuel assemblies for reactors	34/yr	63/yr	100/yr	148/yr	220/yr
MW of electricity	737/yr	1937/yr	3800/yr	5800/yr	8800/yr

### **1. Mining, Milling & Uranium Exploration**

In March 2007 the Pakistani government created a budget of Rs600 million for the exploration and mining of uranium deposits. Mining of low grade ore is proposed to take place at the Bannu Basin, Suleman Range-3 and Suleman Range-4 in Dera Ghazi Khan.<sup>37</sup> The government has established the Pakistan Uranium Resource Evaluation (PURE) to assist with the identification of favorable rocks.<sup>38</sup>

In April 2007 the PAEC reported that it discovered 1,000 sites with uranium reserve potential. The areas were scanned using airborne gamma-spectrometric and foot radiometry surveys. The PAEC plans to unearth 6,000 tons of reasonably assured reserves of uranium by 2011, an amount that Pakistan claims will satisfy one third of ESP's fuel requirements.<sup>39</sup> To reach ESP's goals, Pakistan will need to unearth 117,450 tons of 0.2% uranium ore a year by 2014, 218,076 tons a year by 2018, 346,050 tons a year by 2022, 512,100 tons a year by 2026, and 761,400 tons a year by 2030.

#### **Mining**

*Qabul Khel, Taunsa & Baghalchur* - Qabul Khel is a region in Pakistan's North West Frontier Province that is rich with uranium deposits.<sup>40</sup> Based on Pakistan's Energy Security Report,

<sup>37</sup> Haque, Ihtasham ul. "Pakistan Said Prepares \$600 Million 'Extensive' Plan for Mining Uranium Deposits," Open Source Document [SAP20070301037003] Dawn, March 1, 2007.

<sup>38</sup> Zia ul Hasan Siddiqui. "Nuclear Power Program in Pakistan," *World Nuclear Association*, 2006, <<http://www.world-nuclear.org/sym/2006/siddiqui.htm>>

<sup>39</sup> "Pak Finds 1,000 Sites With Possible Uranium Reserves," The Press Trust of India, April 14, 2007.

<sup>40</sup> "Uranium Mining Said To Help Build Nuclear Program," Open Source Document [FTS19951023000013] Business Recorder, October 9, 1995 p. 3

Taunsa is also a uranium mining site. The Baghalchur mine located 50 km from the Dera Ghazi Khan milling site can produce 23 MT of uranium ore per year.<sup>41</sup> A new uranium mine has been reported at Tumman Leghani in southern Punjab.<sup>42</sup>

*Kakul Phosphate & Nangar Nai* - The Kakul Phosphate Mine is located 9km east of Abbotabad. The mine's dominant phosphate mineral is carbonate fluorapatite. Less often discovered are chlorapatite, calcite, dolomite, quartz, chert, feldspar, glauconite and pyrite. Rock samples from the deposit were found to contain uranium by using fission track analysis. The rocks contained uranium levels of up to 37 parts per million (ppm).<sup>43</sup> Uranium deposits have also been found in the Nangar Nai region and the Bannu range; in-situ leach mining technology has been applied at these locations.<sup>44</sup>

*Shanawah* – Uranium from the 2 kilometer wide, 17 meter deep Shanawah mine contains both carnotite and uraninite minerals. The average ore grade is 0.05% natural uranium.<sup>45</sup> A total of 32 boreholes to a 9,329-meter depth have been drilled. Ore fields as thick as 17 meters have been discovered.

*Manchar Formation at the Kirthar Range in Sindh* - Uranium deposits have been discovered at the Manchar Formation holding as much as 4.5% natural uranium. The size of the excavation is 200km and 25km long. The minerals present are carnotite, curienite, phurcalite and saleite. Anomaly sites are located at Sori, Kukrani, Gaji Kumb and Haleli in Wahi Pandi.<sup>46</sup>

*Kamlial Formation* - Uranium ore anomalies have been discovered in the Kamlial salt range. This mineralized zone reaches to the Kohat, Potwar, Azad Kashmir and Kallar Kahar areas of the range. Anomalous radioactivity and chemical uranium as well as organic and volcanic materials have been found in the sandstone. The existence of these mineral-rich areas gives a significant indication of the potential for uranium discovery in Pakistan. Uranium exploration has also been conducted in the Maraghzar area. The results indicate a high concentration of uranium.<sup>47</sup>

The *Nangar Nai*, *Khura-Murghan Zai*, and *Pitok-Sori Gorakh* areas have been excavated for uranium resources under a PAEC exploration program. This five year project began in June 1996. The project has yielded consistent results and identified numerous new deposits.

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<sup>41</sup> Koch, Andrew and Jennifer Topping. "Pakistan's Nuclear Related Facilities," Monitoring Proliferation Threats Project, *Center for Nonproliferation Studies Fact Sheet*, <<http://cns.miis.edu/pubs/reports/pdfs/9707paki.pdf>

<sup>42</sup> <Pakistan Nuclear Update: 2001," <<http://www.wisconsinproject.org/countries/pakistan/pakistan-nuclear-update.htm>>

<sup>43</sup> Qureshi, A.A., N.U. Khattak, and M. Sardar. "Determination of Uranium Contents in Rock Samples from Kakul Phosphate Deposit, Abbotabad (PAKistan), Using Fission-Track Technique," *Radiation Measurements* Vol. 34 (2001) p. 355-359. March 2, 2001.

<sup>44</sup> "Pakistan," The NEA Redbook 2001.

<sup>45</sup> "Pakistan: Uranium Deposits Found in Sindh Area," Open Source Document [SAP20020806000084] *The News* August 6, 2002.

<sup>46</sup> "Pakistan: Uranium Deposits Found in Sindh Area," Open Source Document [SAP20020806000084] *The News* August 6, 2002.

<sup>47</sup> "Pakistan," The NEA Redbook 2001.



**Figure 3: Mining Requirements to be achieved**

<b>Current Production</b>	23t of uranium ore
<b>Planned Expansion</b>	6,000t
<b>Amount needed to meet overall energy plan</b>	761,400t/yr
<b>Meets/does not meet goals and by how much</b>	755,377t/yr
<b>2014 goals</b>	117,450t/yr
<b>Remaining need based on 2014 goals</b>	111,427t/yr

**Assessment:** Pakistan it will continue to increase its uranium excavations to develop its indigenous supply of uranium. The government has increased its mining and exploration budget to Rs600 million to reach its 2008/2009 goal of producing 6,000 tons of uranium annually. They will attempt to produce at least 117,450 tons of uranium ore annually by 2014 to meet ESP goals.

**Figure 4: Mines & Deposits**

<b>Mines</b>	<b>Location</b>	<b>Materials</b>	<b>Capacity</b>	<b>Method</b>
Kakul Phosphate	9km east of Abbotabad	Carbonate fluorapatite	Uranium levels of 37ppm	
Nangar Nai			UNK	In-situ leach
Bannu Range			UNK	In-situ leach
Qabul Khel	NW frontier		UNK	
Taunsa			UNK	
Baghalchur	50km from DGK		25t U/yr	
Tumman Leghani	Southern Punjab		UNK	
<b>Deposits</b>			UNK	
Nangar Nai			UNK	PAEC Phase V
Khura-Murghan Zai			UNK	PAEC Phase V
Pitok-Sori Gorakh			UNK	PAEC Phase V
Shanawah		Carnotite and uraninite	.05% natural uranium	32 boreholes
Manchar Formation	Kirthar Range in Sindh	Uranium	4.5% natural uranium	
Kamlial Formation	Kohat, Potwar, Azad Kashmir & Kallar Kahar	Anomalous radioactivity & chemical uranium	High concentration of uranium	

## **2. Milling**

The PAEC aims to produce 350 tons of U308 by the year 2015. Pakistan will need to produce 1692 tons of U308 a year by 2030 to fulfill its stated goals.

*Dera Ghazi Khan* The Atomic Energy Minerals Center controls the Pakistani Uranium Extraction Plant and uranium and nuclear mineral resource development in Lahore. It produces

reactor fuel and holds a pilot-scale uranium mill.<sup>48</sup> The mill at Dera Ghazi Khan produces 55 tons of yellowcake (U-308) per year.<sup>49</sup> In the Minawali district there is a proposed uranium mill at Issa Khel. Qabul Khel houses a uranium mine near Lakki in the North West Frontier Province.<sup>50</sup> The Qabul Khel pilot-scale uranium mill can produce approximately one ton of U308 per year.<sup>51</sup>

**Figure 6: Required U308 to be achieved**

<b>Current Production</b>	55t/yr
<b>Planned Expansion</b>	350t/yr
<b>Amount needed to meet overall energy plan</b>	1692t/yr

**Assessment:** The government’s target is to produce 350 tons of U308 per year by 2015. This is one third of its ESP goals. Pakistan’s capacity may increase to 261 tons a year (t/yr) of U308 by 2014, 484 t/yr by 2018, 769t/yr by 2022, 1138t/yr by 2026, and 1692t/yr by 2030.

### 3. Conversion

The PAEC in collaboration with the Central Development Working Party is establishing the *Chemical Processing Plant (CPP)* - a uranium conversion facility – for an estimated 28 billion rupees.<sup>52</sup> In February 2007, Pakistan’s ESP initiated the development of the plant as a part of the *Pakistan Nuclear Power Fuel Complex* to manufacture nuclear fuel for pressurized water reactors. The CPP will have lines to convert U308 to natural UF6 gas, enriched UF6 gas into UO2 powder, convert depleted UF6 into depleted uranium metal and manufacture zircon ore into Zr-4 ingots. Each year, this CPP will produce 400 tons of natural UF6 gas, 40 tons of enriched UO2 powder, and 30 Zr-4 ingots.<sup>53</sup>

*Dera Ghazi Khan* – The Dera Ghazi Khan uranium conversion plant has a maximum production capacity of 220 tons of uranium hexafluoride (UF6) per year. This plant was supplied by CES Kalthof G.m.b.H of Freiburg, Germany. It began operating outside of IAEA safeguards.<sup>54</sup>

*Islamabad* - The Islamabad conversion facility converts U308 into UO2.<sup>55</sup> Production capability is not known.

<sup>48</sup> Koch, Andrew and Jennifer Topping. “Pakistan’s Nuclear Related Facilities,” Monitoring Proliferation Threats Project, *Center for Nonproliferation Studies Fact Sheet*, <<http://cns.miis.edu/pubs/reports/pdfs/9707paki.pdf>>

<sup>49</sup> “Country Nuclear Fuel Cycle Profiles,” IAEA, Technical Reports Series No. 404. 2001 <[http://www-pub.iaea.org/MTCD/publications/PDF/TRS404\\_scr](http://www-pub.iaea.org/MTCD/publications/PDF/TRS404_scr)>

<sup>50</sup> Koch, Andrew and Jennifer Topping. “Pakistan’s Nuclear Related Facilities,” Monitoring Proliferation Threats Project, *Center for Nonproliferation Studies Fact Sheet*, <<http://cns.miis.edu/pubs/reports/pdfs/9707paki.pdf>>

<sup>51</sup> “Country Nuclear Fuel Cycle Profiles,” IAEA, Technical Reports Series No. 404. 2001 <[http://www-pub.iaea.org/MTCD/publications/PDF/TRS404\\_scr.pdf](http://www-pub.iaea.org/MTCD/publications/PDF/TRS404_scr.pdf)>

<sup>52</sup> Ghumman, Musht AQ. “Nuclear Fuel Enrichment Plant To Be Set Up Cost Estimated At RS 13708 Billion,” *The Financial Times*, June 20, 2007.

<sup>53</sup> “Pakistan To Develop Indigenous Nuclear Fuel Manufacturing Capability,” Open Source Document [SAP20070221081001] *Dawn* February 21, 2007.

<sup>54</sup> Spector, Leonard. *Nuclear Ambitions*. Carnegie Endowment, Westview Press: Boulder 1990. p.114.

<sup>55</sup> “Country Nuclear Fuel Cycle Profiles,” IAEA, Technical Reports Series No. 404. 2001 <[http://www-pub.iaea.org/MTCD/publications/PDF/TRS404\\_scr.pdf](http://www-pub.iaea.org/MTCD/publications/PDF/TRS404_scr.pdf)>

**Figure 7: Required conversion capabilities to be achieved in terms of tons of UF6**

<b>Current Production</b>	220t of UF6 per year
<b>Planned Expansion</b>	400t/yr
<b>Amount needed to meet overall energy plan</b>	2200t/yr
<b>Meets/does not meet goals and by how much</b>	~1580t/yr

**Assessment:** To meet ESP goals the Pakistani government will produce 2200 tons of UF6 by 2030. It is working to produce up to 340 tons a year by 2014, 630 tons a year 2018, 1000 tons a year by 2022, and 1480 tons a year by 2026. According to the current production of UF6 compared to Pakistan’s ESP goals, the country is on track to meet its ESP goals.

#### 4. Enrichment

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*Khan Research Laboratories (KRL)* - KRL in Kahuta is an ultracentrifuge enrichment plant that produces 110 pounds, around 50 kg or low enriched uranium per year. It was established in 1984 without safeguards.<sup>56</sup> Kahuta produces 15,000 SWU per year operating with approximately 3,000 centrifuges.<sup>57</sup> This facility also has a uranium metals laboratory which may be used for the machining of special metals.<sup>58</sup>

*Sihala*- Sihala opened in 1979.<sup>59</sup> It is a pilot-scale centrifuge based uranium enrichment plant. It contains 54 centrifuges and is not under IAEA safeguards.<sup>60</sup>

*Golra* - Golra is an ultracentrifuge plant established in December 1987 without safeguards.<sup>61</sup> Golra Sharif is located 15 km from Islamabad. Its facilities are larger than those at the Kahuta enrichment plant.<sup>62</sup>

**Assessment:** Pakistan’s current enrichment capabilities are not sufficient to support its planned expansion of nuclear power reactors. In August 2007, the PAEC announced that they will be constructing a new enrichment facility that is larger than the Kahuta facility. This new plant is expected to be able to support Pakistan’s planned nuclear power developments.

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<sup>56</sup> Spector, Leonard. *Nuclear Ambitions*. Carnegie Endowment, Westview Press: Boulder 1990. p.114.

<sup>57</sup> Koch, Andrew and Jennifer Topping. “Pakistan’s Nuclear Related Facilities,” Monitoring Proliferation Threats Project, *Center for Nonproliferation Studies Fact Sheet*, <<http://cns.miis.edu/pubs/reports/pdfs/9707paki.pdf>>

<sup>58</sup> “Pakistan’s Nuclear History- Separating Myth From Reality,” *Pakistan Defense Forum*, June 19, 2006. <<http://www.pakistanidefenceforum.com/lofiversion/index.php/t56317.html>>

<sup>59</sup> Spector, Leonard. *Nuclear Ambitions*. Carnegie Endowment, Westview Press: Boulder 1990. p.114.

<sup>60</sup> Koch, Andrew and Jennifer Topping. “Pakistan’s Nuclear Related Facilities,” Monitoring Proliferation Threats Project, *Center for Nonproliferation Studies Fact Sheet*, <<http://cns.miis.edu/pubs/reports/pdfs/9707paki.pdf>>

<sup>61</sup> Spector, Leonard. *Nuclear Ambitions*. Carnegie Endowment, Westview Press: Boulder 1990. p.114.

<sup>62</sup> Koch, Andrew and Jennifer Topping. “Pakistan’s Nuclear Related Facilities,” Monitoring Proliferation Threats Project, *Center for Nonproliferation Studies Fact Sheet*, <<http://cns.miis.edu/pubs/reports/pdfs/9707paki.pdf>>

## 5. Fuel Fabrication

Pakistan has had a fuel fabrication capability since the 1980s. It was established for the purpose of supplying fuel to its Canadian-imported light water reactor in Karachi. However, Pakistan currently does rely on foreign imported fuel to supply its other reactors.

*Kundian Fuel Fabrication Plant* –This facility was established in 1980 without safeguards with the assistance of Canada.<sup>63</sup> It can produce 24MT of natural uranium fuel per year.<sup>64</sup> The plant currently produces nuclear fuel for the KANUPP reactor.<sup>65</sup> However, Pakistan also relies on Chinese imports of fuel elements for its nuclear power reactors.<sup>66</sup> Pakistan’s 2030 goal is to have the capacity to produce 220 tons of UO<sub>2</sub> fuel per year.

*Chashma Fuel Fabrication* - According to the IAEA, the fuel fabrication plant at Chashma has a capacity of producing 20 tons of HM per year.<sup>67</sup>

**Figure 8: Fuel Requirements to be achieved**

<b>Current Production</b>	44t/yr
<b>Planned Expansion</b>	none stated
<b>Amount needed to meet overall energy plan</b>	220t/yr
<b>Meets/does not meet goals and by how much</b>	176t/yr

**Assessment:** To produce 8,800MW of electricity, Pakistan will need to acquire an additional 20 tons of uranium fuel each year to reach 220 tons per year in 2030. Pakistan’s goal is to produce approximately 34t/yr of fuel by 2014, 63t/yr by 2018, 100t/yr by 2022, 148t/yr by 2026, and 220t/yr by 2030. No fuel fabrication expansion plans are available in open-sources.

## 6. Spent Fuel & Waste Management

Pakistan’s nuclear waste management capacity is relatively small but sufficient at this time. Currently nuclear waste is stored at the reactor sites. The PAEC is currently working to find new methods to manage its spent fuel.<sup>68</sup> Pakistan’s current reprocessing plant, New Labs, is reported to process spent fuel from the Khushab heavy water research reactor. According to open-sources Pakistan may be constructing a second, larger plant near the Chasma 1 reactor. This facility could be used to manage spent fuel from the CHASNUPP reactors and future reactors.<sup>69</sup>

<sup>63</sup> Spector, Leonard. *Nuclear Ambitions*. Carnegie Endowment, Westview Press: Boulder 1990. p.114.

<sup>64</sup> Koch, Andrew and Jennifer Topping. “Pakistan’s Nuclear Related Facilities,” Monitoring Proliferation Threats Project, *Center for Nonproliferation Studies Fact Sheet*, <<http://cns.miis.edu/pubs/reports/pdfs/9707paki.pdf>>

<sup>65</sup> “Pakistan: Chasnupp,” *No Nukes Info Source*, <<http://www.ecology.at/nni/site.php?site=Chasnupp>><http://www.ecology.at/nni/site.php?site=Chasnupp>

<sup>66</sup> “Nuclear Power in Pakistan,” *World Nuclear Association*, March 2007, <<http://www.world-nuclear.org/info/inf108.html>>

<sup>67</sup> “Country Nuclear Fuel Cycle Profiles,” *IAEA*, Technical Reports Series No. 404. 2001 <[http://www-pub.iaea.org/MTCD/publications/PDF/TRS404\\_scr.pdf](http://www-pub.iaea.org/MTCD/publications/PDF/TRS404_scr.pdf)>

<sup>68</sup> Zia ul Hasan Siddiqui. “Nuclear Power Program in Pakistan,” *World Nuclear Association*, 2006, <<http://www.world-nuclear.org/sym/2006/siddiqui.htm>>

<sup>69</sup> Albright, David and Paul Brannan. “Chasma, Nuclear Site in Pakistan with Possible Reprocessing Plant,” *the Institute for Science and International Security*, January 18, 2007, <<http://www.isis-online.org/publications/southasia/chashma.pdf>>

PAEC websites report that it has an established infrastructure to manage liquid and solid radioactive waste. The PAEC manages radioactive waste for both the public and private sectors.<sup>70</sup>

**Assessment:** It is difficult to determine Pakistan's nuclear waste management capabilities. To ensure future expansion of the nuclear power industry, Pakistan will continue to consider ways to properly handling of nuclear waste disposal.

## 7. Research and Universities

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In its efforts to increase its nuclear infrastructure, the Pakistani government has developed a robust research and training program. The following is a selection of research centers and universities that have nuclear related (engineering, chemistry, and physics) programs.

*Institute of Nuclear Power (INUP):* INUP carries out studies related to pressurized water reactors (PWRs). The institute provides technical support to Chashma in-core fuel management, operational core analysis and safety analysis. In 2003, INUP signed a memorandum of understanding with the Karachi Nuclear Power Complex for joint technical activities for the continued safe operation of KANUPP.<sup>71</sup>

*KANNUP Institute of Nuclear Power Engineering (KINPOE):* KINPOE was established by the PAEC to develop qualified manpower for its nuclear power program. It was formerly called the Karachi Nuclear Power Training Centre (KNPTC). KINPOE collaborates with the Nadirshaw Edulji Dinshaw (NED) University of Engineering and Technology in Karachi to award masters of engineering degrees in nuclear power. It offers three academic programs: Masters of engineering in nuclear power, a post graduate training program, and a post diploma training program. It houses a health physics and radiation detection laboratory, nuclear instrumentation laboratory, mechanical engineering laboratory, electrical engineering laboratory, electronics and applications laboratory, analytical engineering Laboratory, and Chemistry Laboratory.<sup>72</sup>

*NED University of Engineering and Technology:* Established in 1922, NED University of Engineering & Technology is the oldest degree-level engineering institution in Pakistan. It offers bachelors degree programs in ten engineering disciplines, as well as several master's degree programs and one faculty development doctorate degree program. Departments in NED include civil engineering, mechanical engineering, industrial & manufacturing engineering, electrical engineering, computer and information systems engineering, electronics engineering, mathematics and basic sciences, and bio-medical engineering.<sup>73</sup>

*NED University of Engineering and Technology Department of Mathematics & Basic Sciences:* The department was established primarily to fulfill the needs of mathematics, physics and chemistry for undergraduate degree programs. More recently, it has expanded to support the post

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<sup>70</sup> "Health Physics Division," PAEC, <<http://www.paec.gov.pk/pinstech/organization/hpd.htm>>

<sup>71</sup> "Annual Report 2003-2004," Pakistan Atomic Energy Commission.

<sup>72</sup> KINPOE Website, <<http://www.kinpoe.org.pk/index.asp>>.

<sup>73</sup> NED Website, <<http://www.neduet.edu.pk/departments/academichtml>>.

graduate programs in engineering, as well. The department provides laboratory facilities for physics and chemistry for undergraduate programs. The *NED* library holds 96087 volumes and 89 current periodicals.<sup>74</sup>

*North West Frontier Province University of Engineering and Technology*: This university was established in 1980 at Peshawar. It regularly accommodates up to 1600 students and employs 145 instructors. Relevant departments include chemical engineering, electrical engineering and mining.<sup>75</sup> Graduates of the Department of Mining Engineering program are employed by the Directorate General of Mines and Minerals at the PAEC, as well as other private organizations. The department has a mineral processing laboratory, surveying laboratory, rock mechanics laboratory, geology laboratory, and a ventilation, environment and safety laboratory.<sup>76</sup>

*Pakistan Institute of Nuclear Science & Technology (PINSTECH)*: The PAEC established PINSTECH as a first major step in addressing Pakistan's lack of appropriately trained nuclear manpower and a viable scientific and industrial infrastructure. In 1965, the institute's reactor building and ancillary facilities were completed. In 1974, the second stage was completed. It comprised the various laboratories, a workshop, library and auditorium. PINSTECH was established to keep pace with the expanding nuclear field through research; serve as PAEC's technological development for peaceful applications of nuclear energy; produce radioisotopes and radiopharmaceuticals, promote applications of radiation and isotope technology, provide training, undertake limited production of sophisticated equipment and nuclear materials, and work on other important non-nuclear fields. PINSTECH facilities include the following: irradiation laboratories, analytical laboratories, radiation and radioisotope applications, corrosion testing, vibration analysis, charged particle accelerator, polymers processing, vacuum technology laboratory, scientific glass blowing, lasers, and radioactive waste management.<sup>77</sup> The institute has published 1100 research papers in numerous scientific journals. In 2002, it was awarded a cash prize of \$100,000 by the Islamic Development Bank (IDB).<sup>78</sup>

*Pakistan Institute of Engineering and Applied Sciences (PIEAS)*: In 1968, this institute was established as the Centre for Nuclear Studies. It conducts graduate and doctorate degrees and certificate programs for scientists, engineers, medical doctors and technicians in the fields of nuclear engineering, system engineering and nuclear medicines. Post-graduate research and development work is published in international and national journals. PIEAS also draws on the expertise of scientists and engineers of PAEC and its research and development facilities.<sup>79</sup> Since its inception, it has had close collaboration with Quaid-i-Azam University.<sup>80</sup>

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<sup>74</sup> *World of Learning*, 2003, p.1235.

<sup>75</sup> *World of Learning*, 2003, p.1242.

<sup>76</sup> *NWFP University of Engineering and Technology Website*, <<http://nwfpuet.edu.pk>>.

<sup>77</sup> *PINSTECH Website*, <<http://www.paec.gov.pk/pinstech/htm>>.

<sup>78</sup> "Internal Auditing for Quality Control of Nuclear Analytical Techniques," *PakAtom – Newsletter of the Pakistan Atomic Energy Commission*, March-April 2003.

<sup>79</sup> "Youth Urged to Concentrate on National Development," *PakAtom – Newsletter of the Pakistan Atomic Energy Commission*, June-August 2001.

<sup>80</sup> "Development of Human Resource and S&T Essential for National Uplift," *PakAtom – Newsletter of the Pakistan Atomic Energy Commission*, March-April, 2003.

*University of Balochistan:* The University of Balochistan was founded in 1970. It is controlled by the state and instruction is conducted in both English and Urdu. The university has a physics department, a mathematics department, and a center of excellence in mineralogy. The center publishes the *Acta Mineralogica Pakistanica* twice a year.<sup>81</sup>

*Centre of Excellence in Mineralogy and Postgraduate Studies:* The Centre was established in 1973 and is funded by the Ministry of Education. It offers M.Phil and Ph.D Programs in Mineral Science.<sup>82</sup>

*University of Engineering and Technology (UET):* Established in 1961, UET is the most renowned engineering university of Pakistan. It has a student body of 6,000 and offers bachelors, masters, and doctoral degrees. Relevant disciplines include chemical, mineral and metallurgical engineering. Throughout the past 40 years, the university has enabled over 250 students to pursue postgraduate studies abroad. Research projects conducted in the Advanced Physics Laboratory include laser induced plasma, laser induced material modification, fabrication of laser, pulse laser deposition, image capturing of plasma by CCD, and ion induced material modifications. Graduates of this laboratory typically pursue careers at fusion reactors. The Advanced Engineering Materials Lab houses metallographic examination facilities, an emission spectrometer, hardness and micro-hardness testers, and controlled heat treatment facilities. The Advanced Analytical Facilities Lab houses an electron microscope that is used in studies of applied physics, metallurgy and materials engineering, and solid state physics.<sup>83</sup>

*University of Karachi:* The University of Karachi was established in 1951. It is controlled by the state and instruction is in both Urdu and English. There are 12,500 students enrolled and 479 professors. The Faculty of Science includes a Department of Physics, Department of Chemistry, as well as the Pure and Applied Physics Research Centre. The university publishes the *Journal of Science* twice a year.<sup>84</sup>

*University of Peshawar (UOP):* UOP was founded in 1950. It is also controlled by the state. Instruction is conducted in Urdu, Pashto, English, Persian and Arabic. The university enrolls 17,000 students and has 583 instructors on its faculty. The university publishes *Geological Bulletin* once a year.<sup>85</sup>

*University of Peshawar (UOP) Department of Chemistry:* The department was established in 1955. It accepts international students annually and is one of the largest postgraduate departments of UOP.<sup>86</sup>

*University of Peshawar (UOP) Department of Geology:* The department was established in 1959. It offers a three year Bachelor of Science degree program. It has played a significant role in the economic development of Pakistan by providing skilled geo-scientific manpower.<sup>87</sup>

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<sup>81</sup> *University of Balochistan Website*, <<http://www.uob.edu.pk>>.

<sup>82</sup> *Ibid.*

<sup>83</sup> *University of Engineering and Technology, Lahore*, <<http://www.uet.edu.pk>>.

<sup>84</sup> *World of Learning*, 2003. p.1240.

<sup>85</sup> *World of Learning*, 2003. p.1242.

<sup>86</sup> *UOP Website*, <<http://www.upesh.edu>>.

<sup>87</sup> *UOP Website*, <<http://www.upesh.edu>>.

*University of Peshawar (UOP) Department of Physics:* The Department of Physics was established in 1955. It offers master of science programs in nuclear physics, solid state physics, and electronics.<sup>88</sup>

## **V. Concluding Assessment**

Pakistan appears to have a clear goal of increasing its future use of nuclear energy and is currently expanding its infrastructure to fulfill those aims. To successfully meet its stated goals, the Pakistani government will invest more in its research and development programs, and the commercialize its related infrastructure. To realize its ambitious energy plans, the Pakistani government will need to annually produce 1692 tons of yellowcake, 2200 tons of UF<sub>6</sub>, 220 tons of reactor fuel as well as obtain 761,400 tons of uranium ore in order to sustain the magnitude of its 8,800MW electricity output goal. Across Pakistan, deposits rich in uranium and other useful minerals have been discovered. It is investing greatly in its capabilities to take advantage of these resources. As the country constructs and begins to operate more nuclear power reactors, it will also increase its ability to mine, convert, enrich and fabricate fuel, and manage its spent fuel.

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<sup>88</sup> *UOP Website*, <<http://www.upesh.edu>>.





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For more information visit [www.sassu.org.uk](http://www.sassu.org.uk)

Email: [info@sassu.org.uk](mailto:info@sassu.org.uk)

36 Alie Street

Aldgate

London, E1 8DA

Phone: + 44 (0) 845 003 0864

Fax: +44 (0) 127.434.7295



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Production and Design: Nick Robson - SASSI

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South Asian Strategic Stability Institute

36 Alie Street, London. E1 8DA

Phone: +44 (0) 845.003.0864

Fax: +44 (0) 127.434.7295

Email: [info@sassi.org.uk](mailto:info@sassi.org.uk)

<http://www.sassi.org.uk>



