3.3 Nuclear Power Generation

This section of the report is concerned with the nuclear power contribution to the least-cost plan. To meet the objectives, a brief assessment was made of the existing and planned nuclear projects that are considered to be suitable for inclusion in such a plan. As specified in the terms of reference, the studies were based, for the most part, on existing information and information received from references.

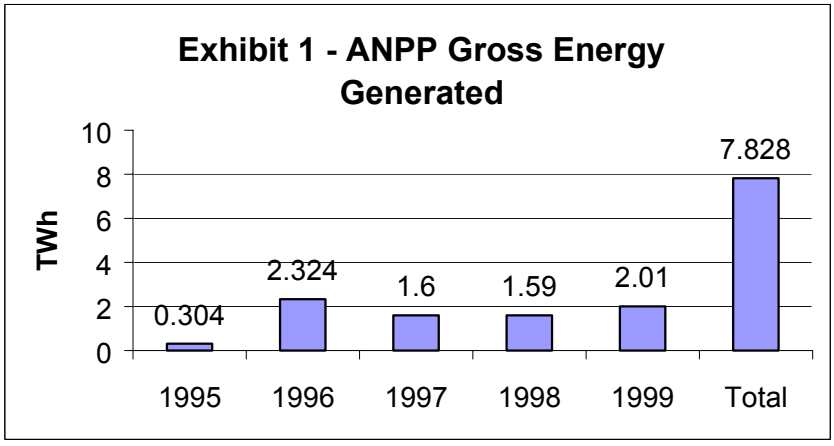
3.3.1 Existing Nuclear Power Summary

3.3.1.1 *Existing Unit 2 at ANPP*

Units 1 and 2 of the Armenian Nuclear Power Plant (ANPP) were commissioned in 1976 and 1979, respectively. Each unit is a Soviet VVER 440-230 design with two generators (220 MW capacity each).

Both units were in operation before, during, and after the December 1988 earthquake. The units continued in operation until March 1989 and then were shut down. Unit 2 was back on line on November 5, 1995 after a safety assessment by Armenian and Russian specialists. ANPP has not recorded or reported any reactor-related accidents during the operating period [1].

Western countries have been providing significant financial support at ANPP for safety improvements. The support is limited to safety issues only, and is not directly related to usual O&M issues. The government has made a commitment to shut down ANPP in 2004, assuming that alternatives for power generation are in place at that time. Historical generation levels reported by MoE since Unit 2 startup in November 1995 are presented in Exhibit 1.



More detailed description of the power plant and related technical and safety issues can be found in Hagler Bailly's Report entitled "Operating and Maintenance (O&M) Requirements Study for the Armenian Electric Sector", prepared for USAID in November 1999.

3.3.1.2 Current Issues

Since ANPP is currently generating about 30% of all energy in Armenia, its importance to the system can not be underestimated. Nuclear power in general being relatively clean energy source has a lot of benefits. However, safety concerns of nuclear power should be considered. A commitment to shut down ANPP by 2004 was provided by Government of Armenia to the international community. For all practical purposes of the long-term least-cost generation plan, the date will be assumed to be beginning of 2005, after yearly system peak that is normally observed in January.

At the same time, the physical life of the nuclear unit is supposed to be technically depleted in 30 years (i.e., in 2010). Armenian technical experts are also discussing the possibility of excluding 5 years (while unit was stopped in 1989-95), from its useful life calculation and, therefore looking at the decommissioning of ANPP Unit 2 in year 2015.

All three dates of 2005, 2010, and 2015 for unit shutdown were reviewed in this LCGP analysis. The study base case will assume shutdown in 2005 based on the commitment mentioned earlier.

It should be noted that ANPP operation practices, safety upgrades, and nuclear policy issues are outside of scope of this study.

3.3.1.3 Decommissioning Cost

Since detailed cost estimates for ANPP decommissioning was outside of the scope of this study and this task is being currently performed by other research groups, an initial estimate for the decommissioning cost of $225 million (Y2000) is proposed for this task. More detailed analysis will verify the cost in the future. The proposed cost is based on the typical Western estimates for such a project.

In order to get LCGP non-distorted investment requirements, ANPP decommissioning cost is simply added to the derived investment cash flow. Proposed cost is considered to be constant for all decommissioning scenarios (i.e., does not account for possible decommissioning technology improvements). The decommissioning cost is free of any financing charges, interest requirements, or taxes.

3.3.2 Assessment of Proposed Nuclear Projects

3.3.2.1 Background

Since Republic of Armenia has extensive experience in construction and operation of nuclear plants, it is logical to assume new nuclear generation expansion option for study time horizon of 2000-2015.

The rehabilitation of unit #1 of the Armenian Nuclear Power Plan has been considered. However, due to numerous reasons of a political, economic and technical nature, this option was rejected during the prescreening analysis as not viable for further consideration in the screening analysis and modeling.

Current nuclear plants in the world include Western reactors and Russian reactors. Both options are analyzed within this generation development plan. The primary focus of current report is on the economic solutions for Armenian energy sector. Most of the analysis in this report is related to new economic (i.e., least-cost) generation sources. However, several sensitivities look at energy security issues and fuel (generation) diversification.

3.3.2.2 New Technologies

Several new Russian reactors are being designed now. These primarily include two VVER (PWR equivalent) units of 640 (see Exhibit 2) and 1500 MW size. Addition of VVER-640 unit is planned for Kola and Sosnovy Bor NPPs in Russia during 2006-2010 period [2]. The future of VVER-1500 unit is not clear at this point from a design prospective.

The design of VVER-640 unit is based on the experience from design, construction, and operation of existing VVER-440 and VVER-1000 reactor plants. Most of the process design and components are proven technology from those projects. For safety systems, new innovations with passive features will be used. Much analysis and experimental work have been carried out to verify safety and other technical features of the design. Works at the large-scale experimental facilities in the Scientific and Industrial Center NITI in Sosnovy Bor are still continuing, with the final experiments being scheduled for 2000-2001. In 1996 the nuclear regulatory body Gosatomnadzor (GAN) of Russian Federation (RF) gave construction permits for both of the proposed projects.

The analyzed projects are the first power plants of VVER-640 type. Taking into account present conditions of economy and industry in Russia, it is estimated that construction will take 5-7 years. The economic analysis based on the cost estimates of the design organization and on the assumptions agreed to be used in this project did not indicate the proposed projects to be very attractive from an economic point of view. The economic life of 50 years for VVER-640 is also questionable. In addition to economic indicators (see Chapter 8) derived in screening analysis, there are of course social, political, and other aspects that influence the decisions on

implementation of VVER-640 project.

In principle, the following type of projects could influence the generation plan for Armenia with nuclear options:

- Safety upgrades
- Nuclear power upgrading and upgrading for life extension
- New NPP projects

As mentioned above, safety improvement programs are under implementation at ANPP. Several Russian and Western organizations are involved in those programs; there exist already necessary mechanisms for identification of the needs and development of new projects. No new safety upgrading projects were reviewed in this study.

In general, various options for increasing power could be considered for the existing VVER-440 reactor. However, at the moment, there are no serious proposals for the ANPP, so that this option is excluded from the present study.

There is no finalized proposal for life extension of ANPP unit. Also, Government of Armenia made a commitment to shutdown ANPP by 2004. Alternative dates of shutdown in 2010 and 2015 are treated as sensitivities in this study.

Evaluation of new nuclear projects is presented below.

3.3.2.3 Evaluation of New Nuclear Options

The new Russian nuclear power option is based on the VVER-640 nuclear power plant concept. This concept with the V-407 reactor has been developed in accordance with the Russian Federal Program "Environmentally Clean Power". The main goal of development was to design a competitive, medium-sized nuclear power plant with enhanced safety features. The design is based on more than 30 years of experience in the construction of nuclear power plants with pressurized water reactors (PWRs) in Russia and abroad. In general, technologies and systems proven during design, construction, and operation of the proceeding NPP are used. The safety systems are comprised of both traditional systems, such as the sprinkler systems and systems of forced circulation with emergency power supply from diesel generators, and passive systems of residual heat removal to ultimate heat sink, thus allowing design accidents without external power supply. The main design parameters of VVER-640 are given in Exhibit 2.

Exhibit 2 – VVER-640 Design Parameters

Reactor Type	V-407 (PWR)
Thermal rated power, MW	1,800
Number of Loops	4
Pressure in the reactor at outlet of the core, Mpa	15.7
Temperature of coolant in the reactor, °C - at outlet - at inlet	 323.3 293.7
Fuel loading, tons of U	68.64
Average enrichment of fresh fuel, %	3.45
Average discharge burn-up, MW day/kgU	39.6
Average specific energy density of the core, KW/l	64.5
Steam Generator Type	Horizontal
Steam Generation, tons/hr	3,576
Steam Pressure in the steam generator, MPa	7.06

Exhibit 2 – VVER-640 Design Parameters (continued)

Turbine Type	K-600-6.9/50 (LMZ)
Number of turbines per unit	1
Rated power of the turbine, MW	645
Rotation frequency, rpm	3,000
Parameters of Steam upstream of the turbine 24 pressure, MPa - temperature, °C - degree of dryness	6.9 284.5 0.995
Pressure in the condenser, kPa	4.9
Generator	TZV-630-2UZ
Unit net efficiency, %	33.3
Design lifetime, years	50

The project of a unit with VVER-640 is being developed in accordance with Russian regulatory requirements that are currently in force. The major safety documents of GAN of Russian Federation are unconditionally observed; all deviations from these documents are substantiated and defended in GAN RF. The main regulatory documents that define safety criteria at the design of VVER-640 are:

- "General Rules for the Safety of NPPs (OPB-88),"
- "Rule of Nuclear Safety for the Reactors of NPPs", PBA RU AC-89.

In addition to the national regulatory documentation listed in the "List of Main Regulations and Norms in Force in the Area of Atomic Power under GAN RF's Responsibility" (P-01-01-92),

international standards and IAEA materials related to the design of NPPs were considered such as: "Regulations for the Safety of NPPs"; "Design of NPPs. N50-C-D (rev. 1)"; IAEA Safety Guidelines N50-CG-D1…D14; Main Principles of the Safety of Atomic Power Stations N75-INSAG-3; and "The Safety of Nuclear Power," INSAG-5 (draft).

Radiological safety of the environment is based on the regulations currently in force in Russia (OPB-88, NRB-76/87, SPAS-88, OSP-72/87, PNAE G-03-33-93) and ICRP publications.

A summary of cost estimate is provided in Exhibit 3.

Exhibit 3 – Construction and O&M Costs[1]

	VVER-640 Unit	
	Million US$ (2000)	US$/kWe
Overnight Construction Cost	935	1,460
First Fuel Load Per Unit	53.5	83
Fixed non-fuel O&M costs/year	17.9	27.9

These and other parameters are listed in Chapter 8 of this report. Western NPP technology is also presented for contrast in the same chapter.

[1] This cost estimate is based on the Sosnovy Bor NPP proposal in Russia. The proposal is for 2xVVER-640 arrangement and is dated 1998. This is the best estimate available. After several consultations with Russian Authorities, the estimate was verified to be current and applicable to ANPP conceptual study.

References:

[1] *Operating and Maintenance (O&M) Requirements Study for the Armenian Electric Sector*, prepared by Hagler Bailly for USAID, November 1999.

[2] Russia: *Northwest Region Power Investment Plan*, prepared by Burns and Roe Enterprises, Inc. for USAID/EBRD, September 1998