ECONOMIC ANALYSIS

1. The economic analysis, which follows the *Guidelines for the Economic Analysis of Projects,*[1] considers the estimated economic costs and benefits at 2014 constant prices for a proposed transmission system rehabilitation project in Armenia. The analysis covers 25 years inclusive of a 5-year construction period based on the incremental benefits arising from the comparison of with- and without-project scenarios. All financial prices were converted to economic prices by applying the corresponding conversion factors.

2. The transmission system in Armenia is aging and has already exceeded its technical life-span. The reliability of the network is crucial to the economy in ensuring that the domestic economy continues to grow in accordance with the government's target of average annual real gross domestic product growth of 6.5% through 2025, as well as the continuation of regional trade with neighboring countries including Georgia and Iran. Rehabilitation of the transmission network therefore is a priority and since the late 1990s the government has requested development partner support in the form of concessionary loan and grant financing.[2]

3. The project comprises (i) rehabilitation of two substations in the transmission network; (ii) expansion of the supervisory control and data acquisition (SCADA) system and energy management system (EMS); and (iii) provision of support for institutional development and capacity building in both implementing agencies. As agreed with the government, Agarak-2, Ararat-2, Shinuhayr, and Yeghegnadzor were selected for the first phase of the substation rehabilitation program. Agarak-2 and Shinuhayr are included in the Asian Development Bank (ADB)-funded project, while the European Bank of Reconstruction and Development (EBRD) is expected to finance rehabilitation of Ararat-2 and Yeghegnadzor as a parallel cofinancier. The four substations have an average age of more than 40 years and had partial repair work in the late 1990s. They require major rehabilitation. The current SCADA system has limited functions. By expanding the existing system, the reliability and efficiency of the system can be increased and overall transmission losses reduced.

A. Demand Analysis

4. Armenia does not have a power shortage. Currently, the electricity system has 4,100 megawatts (MW) of installed capacity and 3,047 MW of available generation capacity. Figure 1 illustrates the three main generation sources.

5. Nuclear power accounts for about one-third of total generation. The sole nuclear power generation plant (NPP) Metsamor has been in operation since the 1970s and operates as a base-load electricity provider. Although the NPP has exceeded its technical lifespan, it is scheduled for decommissioning only in 2026 due to lack of an available replacement. This not only poses a danger to the country, but will also affect the balance of power supply and demand in Armenia and its surrounding region if the production ceases without replacement. In addition to the NPP, thermal generation accounts for approximately 41% of total generation. Natural gas is the main fuel source and is imported from the Russian Federation (about 80% of total gas import) and Iran. The remainder of the power generation is supplied by hydropower, wind, and biogas.

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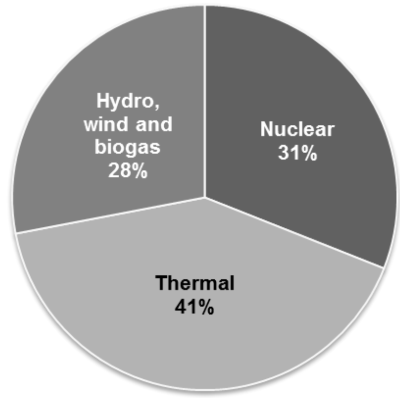
[1] Asian Development Bank. 1997. *Guidelines for the Economic Analysis of Projects*. Manila.

[2] Development partners include the Asian Development Bank, European Bank for Reconstruction and Development, Japan Bank for International Cooperation, KfW, United States Agency for International Development, and World Bank.

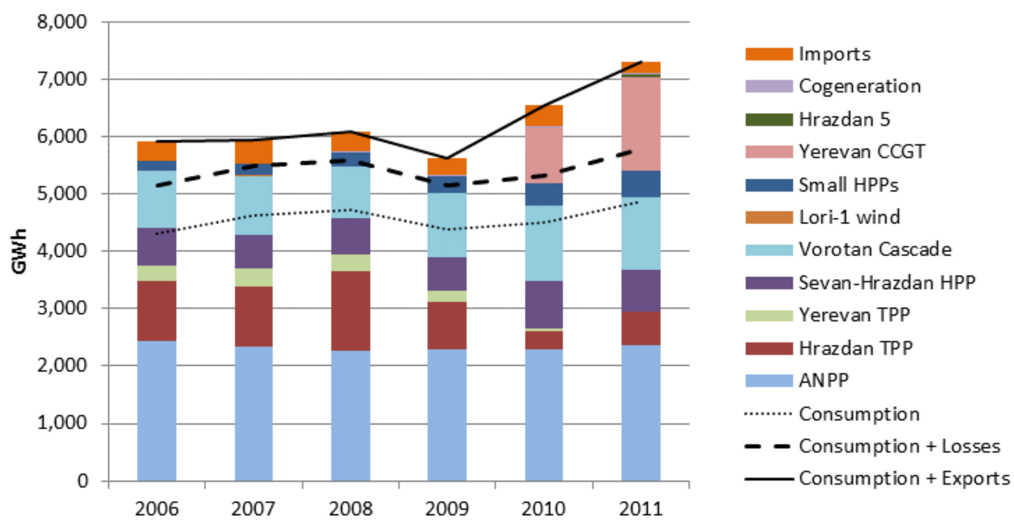
Figure 1: Sources of Power Generation



Source: Asian Development Bank estimates.

6. From 2004 to 2008, electricity consumption grew at 4.5% per annum. In 2009 due to the global financial crisis, consumption fell by 7.4%. However in 2010, consumption resurged at a growth rate of 2.9% and in 2011 by 8% (Figure 2). Assuming the same pace of growth until 2030, a gap of 360–650 MW between the installed capacity and peak demand will occur if the NPP ceases its operation in 2026 without replacement.

Figure 2: Net Generation and Consumption



Source: Public Services Regulatory Commission.

7. In addition to domestic consumption, Armenia exports electricity to neighboring countries. The power system of Armenia is connected to Turkey (220 kilovolts [kV] but not in operation), Georgia (110 kV and 220 kV island operation), and Iran (220 kV synchronous operation). Armenia only has a framework agreement in place with Georgia on the general exchange of power without specifying any MW or megawatt-hour values. It has signed two agreements with Iran. The first agreement provides for export of electricity to Iran in return for the import of natural gas.[3] The second agreement stipulates a zero balance power exchange whereby electricity is provided by Armenia to Iran in the summer to satisfy the increased need for

[3] The feasibility study noted that 3 kWh of electricity is exchanged for each cubic meter of natural gas.

electricity (for air conditioning); and an equal amount of power is supplied by Iran to Armenia in the winter for heating purposes. The government plans to expand the interconnections with Georgia and Iran in anticipation of an increase in the export of electricity with the commissioning of the power plants.

8. As a result, the stability of Armenia's high-voltage transmission network is of vital importance: (i) to maintain and enhance the stability of domestic power distribution, (ii) to maintain and/or support the increase in electricity export to neighboring countries, (iii) to support a potential need for a temporary increase in electricity import in the future, and (iv) to provide a reliable supply of power to the growing domestic demand.

B. Least-Cost Analysis

9. The project was compared with the only viable alternative, which is to construct new substations. Construction of new substations would require higher capital investment as a result of increased civil works and equipment, and the potential need for additional land acquisition, resettlement, rerouting of existing networks, and environment mitigations. Both the financial and economic costs are much higher than the project, while the new substations would not necessarily result in additional energy flow. The project therefore is considered the least-cost option to ensure a reliable supply of energy with minimal social and environment impact.

C. Project Benefits

10. The two substations under the analysis are instrumental to the steady supply of electricity in the transmission system. Both were built in the 1970s. Despite continuous maintenance carried out by HVEN over the last 45 years, the feasibility study reconfirms that full rehabilitation is required instead of general repair and/or partial rehabilitation. Table 1 shows the expected disruption in energy transmission in the system if the project is not implemented as provided under the without-project scenario.

Table 1: Energy Not Transmitted due to Aging of the Substations

	Current Energy	**Estimated Disruption in Energy Flow without the Project** (%)				
Substation	**Flow** (GWh)	**2017**	**2020**	**2025**	**2030**	**2035**
Agarak-2	1,585	158	475	792	792	1,585
Shinuhayr	1,732	173	520	866	1,732	1,732

GWh = gigawatt-hour.
Source: High Voltage Electric Networks company data and Asian Development Bank estimates.

11. In the without-project scenario, even with more frequent maintenance work, the number of outages are still expected to increase significantly commencing from the next few years as the existing equipment should be either retired and replaced. Therefore the estimated avoided power outages were used as the basis for the calculation of project benefits. No additional demand was projected for the valuation of incremental benefits.

12. As the two substations are part of the overall transmission system, the need to consider the potential impact of other aging assets was also considered. Of the 14 220 kV substations in the system, the feasibility study conducted under the project preparatory technical assistance identified 8 substations (Agarak-2, Ararat-2, Lichk, Marash, Shaumyan-2, Shinuhayr,

Yeghegnadzor, and Zovuni) as requiring major rehabilitation.[4] Four substations have completed full rehabilitation with financing from KfW; and two substations have undergone partial rehabilitation with World Bank financing. The government agreed to include four substations from the first category as phase one of the rehabilitation program. This project covers two of the four identified substations. In parallel, EBRD will provide financing for the rehabilitation of the other two substations. The government is expected to seek financing assistance for the rehabilitation of the remaining four substations as phase 2 of the program. The analysis considered the potential impact on the energy flow if the other assets are not rehabilitated therefore requiring rerouting of electricity. An approximately 2% per annum reduction in the energy flow is assumed as a result of the outages and/or stoppage of operation in substations in the system with no or partial rehabilitation.

13. To value the project benefit, three options were considered. The first option, willingness-to-pay (WTP), was determined to not be the most appropriate method for the project. As Armenia has a sufficient supply of energy, a WTP survey may not accurately reflect the cost. In addition, WTP is not usually considered suitable for a transmission project. The second option is foregone export tariff. Armenia exports electricity to Iran in exchange for electricity and gas. The price is considered highly sensitive and not solely based on commercial considerations. Lastly, the cost of unserved energy was considered. The short-run costs include product spoilage and damage to machinery, shutdown, and restart costs. The long-run costs reflect the costs of mitigating the effects of power outages by way of switching to standby generation facilities or self-generation (e.g., diesel generators). A wide range of value has been applied in the region from $0.02/kWh to $0.07/kWh depending on the country and consumer category. An estimated $0.02/kWh was applied to estimate the project's incremental benefits as a conservative measure.

14. Transmission losses may be reduced as a result of the upgraded SCADA system and EMS. New software and hardware will be installed, and additional communication equipment and optical ground wire put in place to enhance system reliability. Substation staffing is not expected to be reduced as, even with an expanded system, the operator will still need to carry out maintenance. Furthermore, as transmission losses are estimated by taking the entire transmission system into account, attributing a specific portion to an individual component in the system is difficult. Therefore estimated benefits that may arise from reduced transmission losses were not considered for this analysis. No other non-incremental benefit was assumed, as the project will rehabilitate substations to prevent outages and disruption in service delivery.

D. Project Costs

15. The total project costs comprise capital investment for the rehabilitation of the two substations,[5] the upgrading of the SCADA system and EMS, environmental mitigation measures mainly concerning waste disposal, incremental operation and maintenance cost, and physical contingencies. Taxes and duties are excluded from the calculation. Project costs are converted from financial prices to economic prices. A standard conversion factor (SCF) of 0.9 is used for non-tradable items and a shadow wage rate factor (SWRF) of 0.94 for unskilled domestic labor. The SCF and SWRF calculations are in accordance with ADB guidelines.[6] The SCF considers account value, elasticity, and tariff of exports and imports in the context of supply and demand.

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[4] ADB. 2012. *Technical Assistance for Preparing the Power Transmission Rehabilitation Project.* Manila (TA 8198-ARM approved on 22 October 2012).

[5] ADB financing will be provided for the rehabilitation of Agarak-2 and Shinuhayr substations. The rehabilitation of Yeghegnadzor and Ararat-2 substations will to be covered by EBRD financing on a parallel basis.

[6] ADB. 1997. *Guidelines for the Economic Analysis of Projects*. Manila.

The SWRF weighs the discount in local wages between international, local skilled, and local unskilled labor. A salvage value is estimated based on an average technical lifespan of 40 years.

16. Additional operation and maintenance cost associated with the rehabilitated substations and upgraded SCADA system and EMS is estimated to be 2% of the capital investment cost. As the project is not expected to meet electricity demand or number of consumers, only the environmental mitigation costs as part of the investment costs are considered. No additional land will be required as the rehabilitation and upgrading will be conducted in the existing substations and load center.

E. Economic Internal Rate of Return

17. The project's economic internal rate of return (EIRR) is 18.3% and exceeds the economic opportunity cost of capital of 12% (Table 2).

Table 2: Economic Internal Rate of Return Estimates (%)

Item	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**	**2035**	**2040**
Total benefits	0.0	0.0	0.0	1.1	1.1	4.4	4.4	11.0	11.0	22.0	22.0
Capital expenditure	(0.36)	(3.0)	(8.8)	(22.7)	(1.4)	(1.1)	0.0	0.0	0.0	0.0	15.1
Incremental costs	0.0	0.0	(0.2)	(0.2)	(0.7)	(0.7)	(0.7)	(0.7)	(0.7)	(0.7)	(0.7)
Net benefits	(0.36)	(3.0)	(9.0)	(21.8)	(1.0)	2.6	3.7	10.3	10.3	21.3	36.5
Economic Internal Rate of Return											**18.3%**
Economic Net Present Value @ 12% Discount Rate ($ million)											**20.1**

( ) = negative value.
Source: Asian Development Bank estimates.

F. Sensitivity Analysis

18. The project's EIRR is sufficiently robust under adverse conditions including under the scenario of reduced scope of the substation rehabilitation program to be carried out by HVEN in the event that EBRD funding does not materialize (i.e., the originally envisaged phase 1 rehabilitation program covering four substations is only partially implemented). Table 3 provides the EIRR of the combined project including all of the ADB- and EBRD-financed components, and under adverse conditions.

Table 3: Economic Results of Sensitivity Analysis of the Project

Item	**Economic Internal Rate of Return** (%)
Base case	18.3
Increase in capital cost by 10%	17.2
Increase in operation and maintenance cost by 10%	18.2
Decrease in revenues by 10%	17.0
Only 2 substations rehabilitated instead of 4	17.8
Cofinanced substations included as part of the project	19.8

Source: Asian Development Bank estimates.