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## EXECUTIVE SUMMARY

The Government of Armenia is in the midst of a reform effort for the power sector. As this work progresses, a strategic power production plan will be developed to ensure integrity of the power production system as well as the ability to deliver fuel to the power stations. This reform effort must recognize the current and future fuel resources required for operation of the power stations whether their source is domestic or imported. Within the strategic planning exercise, it is important to consider the value of strategic domestic fuel resources such that the country has some insurance against external political issues that could disrupt fuel deliveries.

Since 1995, the Ministry of Energy (MoE), with the assistance of USAID has been examining coal resources within Armenia that could be used as an alternative energy source. In 1998, a coal-fired power station was conceptualized; a comparative alternate-source power-generation study is being prepared to examine the economic feasibility of such a plant. Knowledge of Armenian coal suggests the power station be a fluidized bed design because of its tolerance for low calorific value, high ash and sulfur content. Work efforts to evaluate coal resources in Armenia have resulted thus far in enhanced definition of the coal fields, identification of significantly more resource, and a small-scale mining economic study for recently discovered coal. The goal of this effort is to provide Armenia with a significant degree of energy security.

This report is part of the evaluation of coal potential for large-scale generation use. This evaluation does not take into account any other possible coal applications (e.g. small scale, end-use).

### ES.1 CONDENSED SUMMARY OF RECOMMENDATIONS

Based on this review, the following actions are recommended:

1. Abandon any further exploration efforts on the Jajur, Nor-Arevik, Jermanis, Antaramut, and Shamut coal deposits as a potential source for power generation.
2. Continue exploration on the Ijevan coal deposit as the only promising source for large-scale economic production.
3. A likely delivered cost of Ijevan coal cannot be determined at this time due to inadequate definition about the coal reserve and its location. As a design characteristic for domestic coal, employ a free-on-board (FOB)-rail Hrazdan price range of \$25 to \$57 per metric tonne for an as-received basis 4,100 kcal/kg, 50% ash, 5% moisture, 3% sulfur, and dry-ash-free basis 25% volatile matter product.

Analyze a range of delivered prices to establish economic criteria to compare against other power generation alternatives.

4. Recognize that the exploration program, if continued, will embark on even more marginal solid fuel resources. Economic guidelines should be established to allow rational decisions concerning Armenia's ability to support an expensive energy security policy by setting financial limits dependent on Armenia's capability, donor tolerance, and likely private financial interest. This exercise should establish how non-economic or expensive mining ventures would be financed and/or subsidized on an annual basis in order to support the economics of the coal-fired power station.
5. Continue the Armenian Coal Exploration and Resource Assessment Program for Power Generation by establishing maximum fluidized bed fuel characteristics for marginal fuels, such as those with over 50% ash, along with acceptable economic guidelines. Employ these guidelines to conduct a preliminary evaluation of future marginal fuel resources, such as the Dilijan oil shale, to determine if projects meet minimum guidelines established by item number 4 above before commissioning exploration work.
6. Initiate a new research program parallel to any domestic exploration effort to define potential coal producers and coal deposits in the countries bordering Armenia in an effort to develop a mutually dependent relationship that can provide a solid fuel resource to support a mine-mouth or Armenian-sited power plant.
7. Investigate the potential of the Tkibuli coal mine in Georgia as a viable option to generate an alternative solid fuel supply source that can attain energy security goals. It is very important to recognize that this is the only specific solid-fuel energy option currently identified in neighboring countries. Evaluate the option to construct a mine-mouth power station in Georgia and wheel power to Armenia as well as locating a power plant in Armenia with rail haulage of coal. Assess these options in detail to establish a concrete option as a basis of measuring other solid-fuel power generation alternatives. Present this option to the Government of Armenia as a formal energy security option against which all other future options can be compared.
8. Upon successful completion of #4, begin action to create attractive incentives for foreign mining companies and investors by reviewing and establishing new mining industry policies, mining regulations, and environmental guidelines.

## **ES-2 DISCUSSION OF RECOMMENDATIONS**

The Armenian Coal Exploration and Resource Assessment Program to date has only found about one million tonnes of coal (Antaramut) that could be considered as potentially mineable and

economical. To support a 50 MW power station for 35 years, it is expected that about 9.5 million tonnes of proven coal reserve is required. The U.S.G.S. recommends that three of the deposits evaluated - Jajur, Nor Arevik, and Jermanis - receive no further attention. These resources contain no significant quantities of economic reserves and it appears appropriate to abandon any further action on these deposits.

The Shamut coal deposit should be better described as a carbonaceous shale deposit with a very low quality resource. Current information suggests that the average heat value of mineable seams is 2,100 kcal/kg, which is extremely low. The seams are erratic, thin, and deposited in such a fashion that it appears it would be very difficult to mine all the individual layers, provide a product with a good heat value, and economically mine the deposit. The potential power station fuel reserve volume requirement, given the low heat value, appears to be high in relationship to the available resource. The resource will likely be greatly discounted as feasible surface mining methods are considered, because the deposit is so thin and vertically fragmented. The variable and thin nature of the carbonaceous shale deposit seams does not appear to be feasible for an underground mining method. Thus, we recommend not pursuing the Shamut deposit any further.

The other deposit, Antaramut, has been fully explored and determined to be capable of providing about one million tonnes of acceptable quality economic coal.

The last deposit - Ijevan - may have potential. Here we find a much thicker seam with a measured section of up to 23 meters. Sample data suggest an in-situ heat content average for the seam in the order of 4,400 kcal/kg (7,920 btu/lb.) and an average for an internal mineable section of 5,500 kcal/kg (9,900 btu/lb.). The deposit is contained within a complex geologic structure dipping down from 45 to 70°. The complex geology and the need for a labor-intensive underground mining method, such as the breast and pillar technique, are negative aspects concerning potential development of the deposit. On the positive side, the deposit is located near local infrastructure, water, and rail. The field has not been explored and the U.S.G.S. is of the opinion that additional resources may well exist. Of all the coal deposits identified in Armenia, Ijevan appears to present the best opportunity to locate mineable reserves. It also appears to be the last identified opportunity for good coal quality and volume at this point in time.

The efforts of the Armenian Coal Exploration and Resource Assessment Program have appropriately focused to date upon locating the best available coal reserves in Armenia. As mentioned above, one candidate, Ijevan, appears to hold promise of a decent quality coal with adequate reserves. Other known remaining domestic solid-fuel resources include the Dilijan oil shale deposit located northeast of the Sevan Lake near the town of Dilijan. Analyzing low-grade fuel deposits any further will require investigating fuel resources with ash content greater than 50%. Ash content greater than this magnitude will likely dictate a mine mouth power station and a much more meaningful ash management plan if ventures are to be economic. We recommend that a maximum technical capability description be prepared for a fluidized-bed power station to guide explorers in evaluating solid-fuel options, such as those with ash greater than 50%, prior to

expenditure of further funds for these type projects. Because it will be necessary to evaluate more marginal domestic fuel reserves now, guidelines should also be developed to guide decisions related to economic analysis of fuel resources and power station feasibility. Capital and operating costs for a 50 MW fluidized bed power station given varied ash contents, calorific values, and price assumptions were evaluated at the feasibility level in 1998 and should be updated to allow explorers the capability to evaluate a fuel reserve and to predict likely economic performance of a specific deposit. In this way, likely economics can be reviewed to determine if it is reasonable to pursue further exploration efforts.

The information provided in this report and any subsequent economic analysis relative to a coal-fired power station should be employed to analyze the likely cost of developing a fuel resource. This analysis should be used to determine how expensive or non-economic ventures would be financed and subsidized on an annual basis. This exercise should allow rational decisions concerning Armenia's ability to support an expensive energy security policy by setting financial limits dependent on Armenia's capability, donor tolerance, and private bank interest. Guidelines should be developed for this project to ensure precious donor funds are not poorly employed.

In continuing the Armenian Coal Exploration and Resource Assessment Program from a domestic perspective after Ijevan, it is necessary to evaluate lower marginal fuel resources. It is recommended that a parallel program be implemented to attempt to source better quality solid fuel resources beyond Armenian borders. These resources might provide more energy independence through mutual reliance upon economic goals with Armenia's neighboring countries. Although this alternative is not as desirable as having domestic coal reserves, it is a viable alternative to the current situation with a single source of natural gas. A program of researching information on potential coal suppliers and coal resources in the countries bordering Armenia wherein mutual international economic benefit could result, is recommended. Opportunities to develop a source of supply from a coal deposit or to procure power from a power plant that could be constructed at a foreign coal deposit should be investigated.

The Tkibuli mine in Georgia is a viable option because a mine exists, reserves have been identified, and the Government of Georgia desires to improve the economy in the Tkibuli region. In addition, a transportation system is in place and a situation would exist where dependent reliance between supplier and buyer would act as a long-term cohesive agent. This alternative should be fully investigated, developed, prepared as a formal option, and presented to the Government of Armenia as a viable alternative.

The coal resources identified during the coal exploration program were reviewed to determine a mining cost could be estimated, that is reasonable for the type of domestic reserves identified and appropriate for use in economic analyses for a coal-fired power station. Because adequate information concerning economic coal reserves is not available, this task can not be accomplished with any degree of certainty. Nonetheless, as all reserves identified so far appear to be amenable to a contour-haulback mining method, the costs developed by the U.S.G.S. were

used as a reasonable estimate of the likely lower limit of mining costs. We then estimated a range of likely delivered coal prices by using current unit bulk cargo rates for rail.

There is inadequate information to generate reliable cost and fuel quality estimates for confident economic analyses of a 50 MW coal-fired power station. We recommend that a delivered cost, FOB-rail range from \$25 to \$57 per metric tonne be employed as a cost estimate for domestic coal delivered to a power station at Hrazdan. Because of the lack of sufficient information, a range of mining costs will have to be employed to analyze coal-fired power generation economics against other generation alternatives. Similarly, a theoretical calorific value of 4,100 kcal/kg, an ash content of 50%, a sulfur content of 3.0%, moisture content of 5%, and a DAF\* volatile matter content of 25% are suggested as the domestic design fuel quality characteristics for a coal-fired power station.

There is a need to qualify exploration programs before they are executed. The analysis of the Shamut and Antaramut deposits are examples that show a mining professional is required to analyze deposits or exploration targets prior to venturing into a project. It is also necessary to have a coal professional evaluate the supply options of providing foreign coal to Armenia and searching for existing producers. It will be of advantage to require an independent mining/power professional to develop new guidelines, analyze new exploration prospects and evaluate solid fuel supply options for the power stations in order to ensure optimization of donor resources.

To date, the focus of this work program has been on the power sector. If solid fuel resources are found in Armenia, it will be necessary to attract foreign investment and satisfy foreign donors. Discussions with foreign mining professionals working in the industry indicate that little has been done to make the mining sector attractive to foreign capital sources or mining companies. In fact, it is difficult to even receive a letter of credit to purchase supplies that must be obtained from foreign sources. Immediate preparation of acceptable regulations and policies for the mining industry is recommended so that foreign mining companies and their financiers can be attracted to Armenia while appropriate environmental safeguards are provided. This work requirement can be made as a condition for continued exploration funding by USAID or any other international donor agency, while the opportunity is present.

### **ES-3 RECOMMENDED STEPS**

A number of next steps are recommended. These include:

1. Request the U.S.G.S. to collect and document all known information available about the Ijevan coal deposit. They should also generate a set of assumptions and conclusions regarding the status of this information and the potential for locating

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\* DAF - Dry Ash Free. This is a method of testing a coal sample wherein all the moisture and ash content have been removed before the sample is tested.

- additional coal resources at Ijevan. Use this information to develop an exploration plan.
2. Request a scope of work and cost proposal from the U.S.G.S. to evaluate Ijevan and have the work program and background material reviewed by an independent mining professional. Negotiate the work program, involve the mining professional, and commission the work.
  3. Within the Power Generation Alternative Case Evaluation being performed, incorporate a series of alternate coal-fired cases representing the range of mining costs concluded herein to provide a full spectrum of the economic analysis for a series of delivered coal prices.
  4. The current Least Cost Generation Plan (LCGP) team should define the maximum coal quality parameters that can be employed in the fluidized bed so that marginal solid fuel deposits, including coal, can be evaluated prior to exploration expenditures. Request an economic model be prepared along with guidelines so explorers can evaluate standard and more marginal solid-fuel reserves.
  5. Commission work to establish what economic limits are acceptable relative to pursuing an alternate energy supply. Formally determine what donor and private financing limits are acceptable as well as the capability of the Armenian Government to subsidize the mine and or the power station. Relate this study to the future of the power sector and establish an appropriate set of guidelines.
  6. Based on #5, revise any existing solid fuel power generation option as a base case to compare other potential future options against, by fully investigating the potential of using the Tkibuli, Georgia coal mine and deposit as a coal supply source. Evaluate both a mine-mouth and an Armenian sited power station and prepare a formal summary for presentation to the Government of Armenia. If adequate support exists, prepare a formal package for submittal to the Government of Georgia and private investors.
  7. Within any international regional assistance efforts, initiate a new parallel solid-fuel resource investigation program by researching the potential of identified mining and coal deposit resources in neighboring countries.
  8. Initiate action to revise Armenian mining policies and regulations and to review and revise their environmental standards in the mining sector. Ensure policies, regulations, and standards meet international donor specifications to help improve the likelihood of attracting foreign mining companies and their financiers.