Economic and Financial Appraisal of the Potential Geothermal Power Plant at Karkar

Task 2 Report

September 2012

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Table of Contents

Appendices

Tables

Figures

Appendix Tables

1 Introduction

The Armenia Renewable Resources and Energy Efficiency Fund (R2E2) asked Denzel Hankinson to conduct an economic and financial appraisal of apotential geothermal power plant at the Karkar geothermal site (the Karkar site). This work involves the development of a preliminary power plant concept (conceptual plant) for the site based on previous field investigation studies, and an analysis of the economic and financial viability of the conceptual plant.

The conceptual plant was developed in the Interim Task 1 Report, presented to R2E2 on July 31st, 2012. Two binary cycle designs were created for the initial estimates of resource temperature at the Karkar site, which were 110°C and 130°C. A Kalex cycle design was specified for the 110°C temperature estimate and an Organic Rankine Cycle (ORC) design was specified for the 130°C temperature estimate. Subsequently, a Flash cycle design was developed for a potential 300°C resource temperature estimate, which was not considered in the original Task 1 report.

The purpose of this Task 2 Reportis to present the economic and financial viability analysis of thethree conceptual plant designs created for the Karkar site in this project. The final economic and financial analysis includes five sub-tasks, which are as follows:

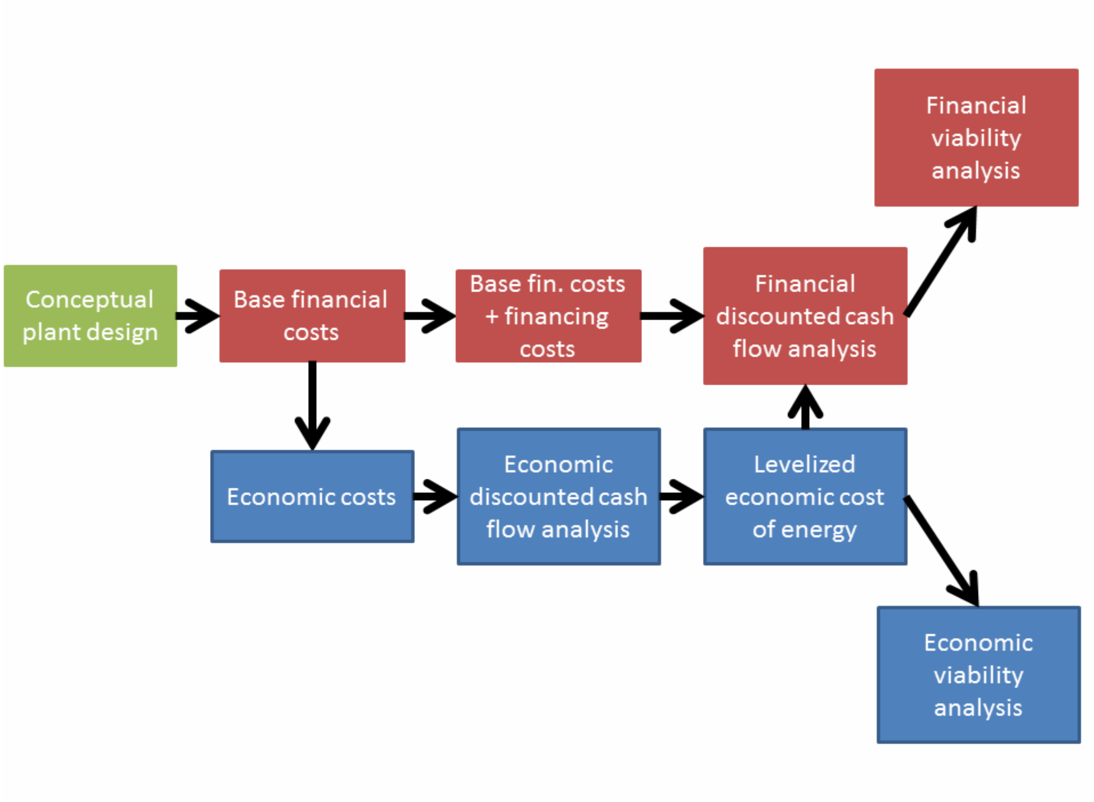
- Assess of the economic viability of the project. An assessment of the project's economic viability requires an estimate of the levelized economic cost (LEC) of the conceptual plant.
- Comparethe LEC of the conceptual plant with the costs of other generation expansion options in Armenia (the other supply options).These options are discussed in the Armenia Energy Sector Issues Note (October 2011), prepared by the World Bank (the 2011 Issues Note).
- Assess the financial viability of the conceptual plant, assuming a base-case electricity tariff equal to the levelized economic cost of the plant.
- Conduct sensitivity analyses to estimate the effect of changes to the inputs to the economic and financial analysis on the estimated economic and financial viability of the project.
- Discusswhether exploratory drilling at the Karkar site is justified by the economic and financial analyses.

1.1 Economic and Financial Analysis Methodology

In order to complete tasks above, we developed discounted cash flow (DCF) models, balance sheets and income statements to produce indicators of economic and financial viabilityfor the conceptual plant. Using these models, we conducted economic and financial analyses of theconceptual plant in five scenarios: three base cases (one for each plant design), a least favorable and a most favorable case. In the economic analysis, we compare the LEC of the conceptual plant to the LECs of the other supply options and the cost of energy not served to determine economic viability in each scenario. In the financial analysis, we compare various financial metrics to benchmark values to determine the financial viability of the conceptual plant under two tariff regimes and two sets of financing assumptions.

The financial and economic analyses in this project are interdependent. The financial costs of the conceptual plant we developed in Task 1 serve as an input to both the economic analysis and the financial analysis. The LEC calculations serve as the basis for the economic viability analysis, in which the conceptual plant is compared with the other supply options. The LEC is also used as the tariff in one set of scenarios evaluated in the financial analysis. Figure 1.1 presents a simple schematic of the interdependencies between the economic and financial analyses in order to clarify the flow of data between them.

Figure 1.1 Interdependencies Between the Economic and Financial Analyses



1.2 Overview of the Conclusions of this Report

We find that the conceptual plant at the Karkar site is only likely to be economically and financially viable if a hightemperature and high enthalpy resource is assumed (300°C), and aFlash cycle design is used. If lower resource temperatures and enthalpies are available (110°C -130°C) and the binary cycle designs presented here must be used, the conceptual plant is not likely to be economically viable because it has an LEC that is higher than the LECs of almost all of the other supply options. If one of the binary designs is used, the conceptual plant is only financially viable if very favorable financing terms are available and the plant is able to receive a very high tariff.

1.2.1 Economic Viability

We find that if a geothermal resourcewith a temperature of 300°C exists at the Karkar site, a geothermal power plant built there could indeed be an economically viable power supply option for Armenia. The LECs of the conceptual plant designs created to utilize a resource at this temperature are below the LECs of most other supply options evaluated in this report. However, in the more likely scenario that resource temperatures at the site are in the 110-130°C range, we find that a geothermal power plant at the Karkar site is not likely to be economically viable when compared with the other supply options. When resource temperatures in this lower range are assumed, the LEC of the conceptual plant is significantly higher than the LEC of almost every other supply option evaluated in this report.

1.2.2 Financial Viability

The conceptual plant is only financially viable if a high resource temperature, high enthalpy andfavorable financing terms are available, or if low resource temperatures, low enthalpy, favorable financing terms and very high tariff rates are available. If a high resource temperature is available, then the conceptual plant can meet our minimum financial viability criteria as long as low-cost (public) financing is available and the tariff received is at least US$50/MWh.[1] However, if the resource temperature is low, then the conceptual plant will only meet our minimum financial viability criteria if low-cost financing is available and the tariff received is at least US$140/MWh.

Public financing with very low interest rates might be available for the plant, but we assume that tariff ratesat or above US$140/MWh are unrealistic.This levelis much higher thanthe highest renewable energy feed-in tariff (REFIT) rate available for in Armenia, which is approximately US$90/MWh.[2]As a result, we find that the conceptual plant is not likely to be financially viable if resource temperatures are in the 110-130°C range.

1.3 Structure of the Report

The remainder of the report is structured as follows:

- Section 2 presents the basic financial costs for the conceptual power plant, which are a result of the Task 1 report, as well as additional analysisconducted for this report.
- Section 3 presents the results of the economic analysis of the conceptual plant and compares the conceptual plant to Armenia's other supply options.
- Section 4 presents the results of the financial analysis of the conceptual plant and compares the results of this analysis to common benchmarks of financial viability for power projects.

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[1] "Public" financing assumptions are based the World Bank's stated financing terms for long-term loans as of July 2012. These are described in greater detail in Section 4.

[2] This is the feed-in tariff rate for electricity generated from biomass in Armenia. See R2E2, "Tariffs," http://r2e2.am/en/2011/06/tariffs/

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2 Base Financial Costs of the Conceptual Plant

As discussed in Section 1.1, the financial costs of the conceptual plant serve as the basis for both the economic and financial analysis. These consist of the capital costs of plant construction and the cost of plant operations and maintenance. In the economic analysis these costs are converted into economic costs by adjusting for the shadow cost of foreign exchange. In the financial analysis, financing costs are added to these base financial costs. Because these base costs are used in both the economic and financial analyses, they are presented separately in this section.

The base financial capital costs of the conceptual plant range from US$3,475 to US$18,424 per kW on a net basis. This wide range of capital costs reflects the different costs of different plant designs as well as the wide range in the estimated number of wells that would be required for the conceptual plant, which depends on the resource temperature and mass flow.

This section presents the base financial costs of the conceptual plant as well as the financial costs of the other supply options.

2.1 Capital Costs of the Conceptual Plant

We created three designs of the conceptual plant: a Kalex cycle design, an Organic Ranking Cycle (ORC) design and a Flash cycle design. For each design, we developed upper and lower bound capital cost estimates. Variation in the upper and lower bound estimates of the Kalex cycle and ORC plants is dependent on the number of wells required to support an 8 MW gross power plant at the Karkar site. For the Flash cycle design, variation is dependent on the number of wells required to support a 30 MW gross power plant.

In each case, the cost of design, project management, procurement and supervision is estimated at 20 percent of power plant and substation costs. A cost contingency of 20 percent of the same is also added to the total cost in each case. Due to the fact that different proportions of the total cost of each design result from well and power plant and substation costs, the percentage of the total cost of each design that is attributable to engineering differs among designs. For instance, well costs are a higher proportion of costs for the Kalex cycle and ORC designs than for the Flash cycle design. As a result, engineering is a lower proportion of the total cost for the Kalex cycle and ORC plants than for the Flash plant.

The cost of the transmission line from the conceptual plant to the grid is added to the costs developed for each design. The cost of the transmission line was calculated assuming the project will interconnect at a substation approximately 30 km from the Karkar site. It is assumed a 110 kV transmission line with a cost of US$90,000 per km will be required to connect the conceptual plant to the grid.[3]

The total capital cost ranges for each design are shown below in Table 2.1.

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[3] This is based on an estimate for a similar line from Ameria, "Jermaghbyur Geothermal Project Feasibility Study Final Report No TF 05/CS-07," 2006.

Table 2.1: Capital Cost Estimates for the Conceptual Plant

Item	KALEX 110°C (Million US$)	ORC 130°C (Million US$)	FLASH 300°C (Million US$)
Surveying	0.5	0.5	0.5
Wells	43-75	29-52	25-39
Power Plant	27	22	48
Substation	0.5	0.5	2
Transmission line to grid	2.7	2.7	2.7
Access Road	0.5	0.5	0.5
Equipment transport costs	0.27-0.41	0.21-0.31	0.34-0.49
Engineering	5.6	4.5	10
Contingency	5.6	4.5	10
TOTAL	**85.67-117.91**	**64.41-87.51**	**99.04-113.19**

2.2 Operating Costs of the Conceptual Plant

Operating costs for the conceptual plant are as follows:

- General overhead costs
- Supervision of machinery
- Materials for operation
- Additional drilling to maintain steam supply
- Maintenance, both work and material
- Monitoring of the geothermal field

The total annual operating costs of the conceptual plant estimated in the Task 1 report are US$1 million for the ORC design, US$1.3 million for the Kalex design and US$2 million for the Flash design. This equals a fixed operating cost of US$203 per kW-yr for the ORC and Kalex cycle design plants, and US$70 per kW-yr for the Flash cycle design plants.

Treatment of Land Rental Payments and Pollution Charges

Other operating costs that are not identified in the Task 1 reportare the cost of land rental for the project and fees due to the Armenian government for the emission of certain pollutants.

Land rental payments were assumed to be so small compared to the other operating costs of the conceptual plant that they would not have any appreciable effect on the plant's economic or financial viability,and these costs are not included in the economic or financial analysis of the geothermal project.

Binarycycle geothermal plants typically do not produce carbon dioxide and other air pollutant emissions. It is assumed that for the binary cycle designs, there areno pollutant emissions, and these plantswill not be subject to any pollution fees. Air emissions from the Flash cycle plant and associated fees are estimated and their costs are included in the financial analysis.

3 Economic Analysis

We find that the conceptual plant is not likely to be economically viable unless resource temperatures are high and a Flash cycle plant can be built. In three of the four scenarios developed to evaluate the plant, the conceptual plant's LEC is significantly higher than almost all the other supply options available to Armenia, except for solar PV. The Flash cycle plant's LEC is low enough that it is economically viable when compared with some other supply options for Armenia: it is found to be cheaper than all other options except for small hydro and the levelized cost of the ANPP life extension.

This section presents the results of the economic analysis of the conceptual plant by comparing its cost to the cost of the other base-load and renewable power supply options available to Armenia, and to the cost of energy not served. The base financial costs for each supply option are converted to economic costs and anLEC is calculated for each option, assuming an economic discount rate. Scenario analyses are performed on the conceptual plant to determine the effect of changes in assumptions on the conceptual plant's LEC. The LEC of the conceptual plant in each scenario is then compared with the LECs of the other supply options to make conclusions about the conceptual plant's economic viability.

3.1 Characteristics of Other Supply Options in Armenia

The capital and operating costs as well as other relevant characteristics of the other supply options that are compared to the conceptual plant are presented in financial terms in Table 3.1. In Section 3.2 we describe how adjustments are made to these costs to reflect their economic costs before calculating and comparing LECs of each option.

Table 3.1: Characteristics of Other Supply Options in Armenia

Supply Option	Gross Capacity (MW)	Assumed Capacity Factor (%)	Capital Cost ($/kW)	O&M (fixed and variable, including fuel) ($/kWh)	Asset Life (yrs)
Conceptual Geothermal Plant at Karkar site	6.4 or 28.5*	85-92	3,475-18,424	0.008-0.02	30
New Gas Plant (CCGT)[a]	1,100	85	1,175	0.0392	30
New Nuclear Plant[a]	1,100	85	5,500	0.00020	50
ANPP Life Extension[a]	385	85	550	0	5
Small HPPs[a]	152	33	1,000	0.02	40
Wind[a]	175	30	1,500	0.02	25
Solar PV[b]	8	19	4,000	0.02	25
Biomass[c]	20	85	3,000	0.11	25

Sources:

[a]Ani Balabanyan, Arthur Kochnakyan, Gevorg Sargsyan, Denzel Hankinson, Lauren Pierce, "Republic of Armenia Energy Sector Note, Charged Decisions: Difficult Choices in Armenia's Energy Sector," World Bank,October 2011.

[b] Tetra Tech ES, Inc., "Overview on Solar Electric Power in Buildings with Applications in Armenia," United States Agency for International Development, July 2011.

[c] Based on the average capital and non-fuel O&M cost of biomass stoker boilers, CFBs, BFBs and gasifiers, and fuel costs for agricultural residues reported in International Renewable Energy Agency, "Biomass for Power Generation," Renewable Energy Technologies: Cost Analysis Series, Volume 1: Power Sector Issue 1/5, June 2012.

*Note: An6.4-6.5 MW net plant size is assumed for the Kalex cycle and ORC designs, while a 28.5 MW net plant size is assumed for the Flash cycle design.

3.2 Development of Economic Costs

Economic costs are the cost of a project to the entire economy. Financial costs, in contrast, are the cost of a project to its developers and financiers and do not include the costs incurred by the entire economy. . Economic costs often include costs that are not directly incurred during project development and operations. These include the economic cost of externalities, such as environmental pollution.[4] Economic analysis also excludes certain costs such as taxes, duties and subsidies.[5] These costs must be paid by project developers but are not costs to the economy as a whole, as they simply represent a transfer or resources within the same economy.[6]

[4] When financial penalties are incurred because of emissions of pollutants, or when pollution credits must be purchased in order to emit pollutants, a financial cost is incurred by developers.

[5] Taxes and subsidies that exist to correct for an externality, such as pollution, are indeed economic costs and will be included in the economic analysis.

[6] World Bank, "Economic versus financial analysis: differences and interaction," http://rru.worldbank.org/documents/toolkits/highways/3_public/33/3333.htm

In order to develop the economic costs of the conceptual plant and the other supply options, we make two adjustments:

- Transfer payments, such as financing costs and taxes are excluded because they do not represent costs to society, but rather transfers of payments from one entity to another in the same society.
- The economic costs of environmental externalities are added, in order to account for the economic cost of environmental pollution to society.

Details of how these adjustments are made can be found inAppendix A.

3.3 Assessing the Economic Viability of the Conceptual Plant

The LECs of the conceptual plant, the other supply options and the estimated long-run supply costfor Armenia provide the basis for assessing the conceptual plant's economic viability. The LEC is a useful metric for comparing different power projects because it provides a single per kilowatt-hour metric for each project, which accounts for differences in capital, operating costs and energy output levels over the economic lives of each project. The LEC is calculated as the levelized average lifetime cost of a power project that would enable a theoretical investor with a given discount rate to just break even.

We calculate LECs in economic discounted cash flow (DCF) models, assuming a 10 percent social discount rate. We chose this discount ratebecause it is a commonly used discount rate for the economic analysis of infrastructure projects in Armenia by international financial institutions.[7] The DCF models calculate the LECs of the conceptual plant and each of the other supply options using the formula shown in Equation 3.1.

[7] Examples of other power sector projects in Armenia in which the same discount rate is used are World Bank, "Project Appraisal Document on a Proposed Grant from the Global Environment Facility Trust Fund in the Amount of US$1.82 Million to the Republic of Armenia for an Energy Efficiency Project," March 1, 2012 and World Bank, "Project Appraisal Document on a Proposed Loan in the Amount of US$39 Million to the Republic of Armenia for the Electricity Supply Reliability Project," May 4, 2011.

Equation 3.1 Calculation of Levelized Economic Cost of Electricity

$$LEC = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Where

- I_t= Investment expenditures in year t
- M_t= Operations and maintenance expenditures in year t
- F_t = Fuel expenditures in year t
- E_t= Electricity generation in year t
- r = Discount rate
- n = Life of the system

3.3.1 Scenario Analysis

We calculate the LEC of the conceptual plant in for four different scenarios: Basecase – Kalex design, Base case – ORC design, Base case – Flash design, Most Favorable and Least Favorable. These scenarios provide a range of estimates of the conceptual plant's LEC.

Variation in the LEC of the conceptual plant across scenarios is caused by differences in resource temperature and mass flow assumptions. Resource temperature determines which plant design is used, and temperature and mass flow determine the electricity output of that design.

A resource temperature of 110°C suggests a Kalex cycle design, while a resource temperature of 130°C suggests an ORC design. If a high resource temperature—around 300°C—is available, then a Flash cycle design is assumed. Each design has a different capacity factor and capital cost. Well mass flow determines how many wells must be drilled, whichfurther influencesthe capital cost of the conceptual plant. Lower well mass flow means more wells must be drilled and capital costs are higher and higher well mass flow means fewer wells must be drilled, and capital costs will be lower.

It is important to note that the resource temperatures and enthalpies presented here are not the only resource temperatures and enthalpies that could result from geothermal exploration at the Karkar site. Resource temperatures around 250°C have been discussed as a potential resource temperature at the Karkar site in previous studies. If this were the case, the geothermal resource would likely have a lower enthalpy than the 300°C case presented in this study, and therefore a higher cost.

Table 3.2 shows the different temperatures, plant types in each scenario, as well as the resulting LECs for each scenario.

Table 3.2: Characteristics of the Conceptual Plant in Each Scenario

Scenario	Resource Temperature (Degrees C)	Plant Type	Plant Size (Net MW)	Capital Cost ($/kW)	LEC (US$/MWh)
Base Case – Kalex	110	Kalex Cycle	6.4	16,193	265
Base Case – ORC	130	ORC	6.5	11,898	200
Base Case – Flash	300	Flash Cycle	28.5	3,790	66
Most Favorable	300	Flash Cycle	28.5	3,538	63
Least Favorable	110	Kalex Cycle	6.4	18,755	304

Base CaseScenario – Kalex Cycle Design

This scenario assumes a resource temperature of 110°C, for which the Kalex cycle design is appropriate. This scenario also assumes a medium level of well mass flow, and total well costs of US$60 million.Total plant costs (in economic terms) are estimated at US$103.6 million, or US$16,193/kW (net basis). The LEC calculated for the conceptual plant in this scenario is US$265/MWh.

Base Case Scenario – ORC Design

This scenario assumes a resource temperature of 130°C, for which the ORC design is appropriate. Similar to the Kalex cycle base case scenario, a medium level of well mass flow is assumed, and therefore well costs are in the middle of the estimated range, at US$41.2 million. Total plant costs are estimated at US$77.3 million, or US$11,898/kW (net basis). The LEC calculated for the conceptual plant in this scenario is US$200/MWh.

Base Case Scenario – Flash Cycle Design

This scenario assumes a resource temperature of 300°C, for which the Flash cycle design is appropriate. This design would likely have a significantly larger capacity than the Kalex cycle and ORC designs. The plant is assumed to have a gross capacity of 30 MW and a net capacity of 28.5 MW. The base case Flash cycle design scenario assumes a medium level of well mass flow (for a high temperature resource) and total well costs of US$32.6 million. Total plant costs are estimated at US$108 million, or US$3,790/kW (net basis). The LEC calculated for the conceptual plant in this scenario is US$66/MWh.

Most Favorable Scenario – Flash Cycle Design

This scenario is developed to determine the lowest potential LEC for the conceptual plant, based on the parameters developed for this study by assuming the highest temperature and well mass flow characteristics.In this scenario, the 300°C resource temperature and high well mass flow are assumed,and the Flash cycle design is used. Well costs are estimated at US$25.45 million and total plant costs are estimated at US$100 million, or US$3,538/kW (net basis). The LEC calculated for the conceptual plant in this scenario is US$63/MWh.

Least Favorable Scenario

This scenario determines the highest possible LEC for the conceptual plant based on the parameters developedfor this study by assuming the lowest temperature and well mass flow characteristics. In this scenario, the resource temperature is assumed to be 110°C, so the Kalex cycle design is used. Well mass flow is assumed to be at the low end of the range estimated for this resource temperature and plant cycle design. Well costs are estimated at US$76.3 million and total plant costs are estimated at US$120 million, or US$18,755/kW (net basis). The LEC calculated for the conceptual plant in this scenario is US$304/MWh.

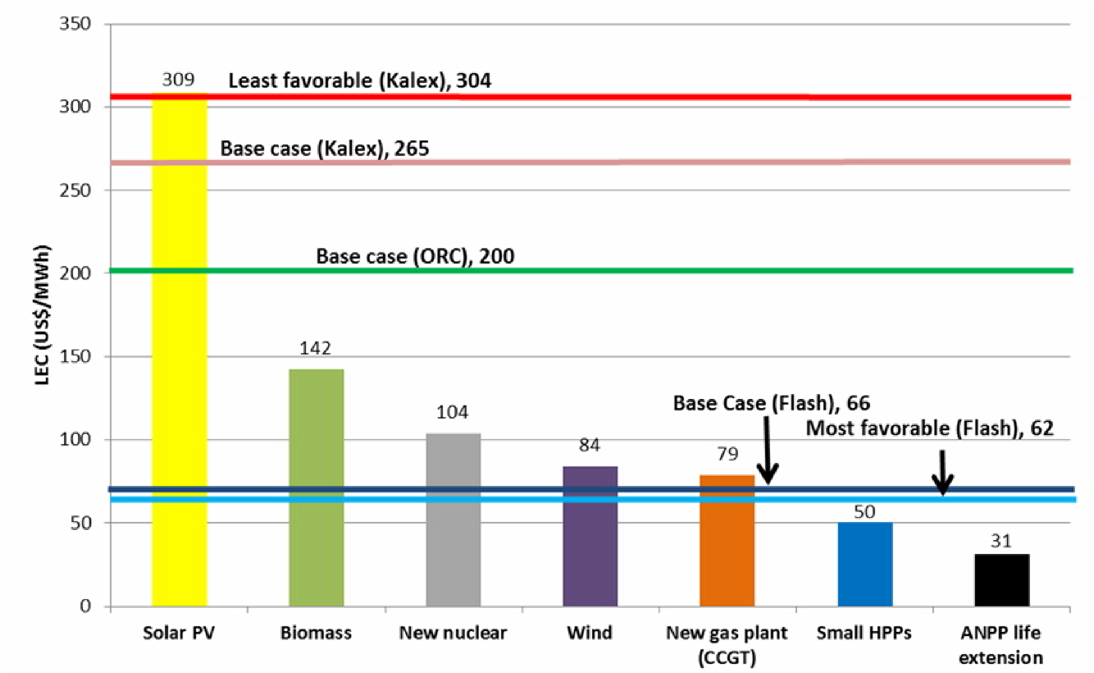
3.3.2 Comparing the Conceptual Plant to Other Supply Options

In every scenario where the ORC or Kalex cycle design is assumed, we find that the LEC of the conceptual plant is higher than the LEC of the every other supply option except for solar PV. Solar PV is higher cost than the conceptual plant in all scenarios. Figure 3.1compares the LEC of each of the other supply options to those of the conceptual plant in each scenario.[8]This demonstrates that a low temperature and low mass flow resource would most likely result in a plant with a relatively high LEC, and which would not be economically viable assuming other supply options are available to Armenia.

If a hightemperature, high mass flowgeothermal resource does indeed exist at the site, thenthe conceptual plant could be economically viable compared with the other supply options available to Armenia. In both the Base Case Flash cycle scenario and the Most Favorable scenario (in which a Flash cycle design is assumed) theconceptual plant has a lower LEC than all base-load supply options except for the nuclear plant life extension. In these scenarios, the conceptual plant also has an LEC lower thanthose of all other renewable energy options expect for small HPPs.

[8]A “capacity penalty” is added to the LECs of wind, solar and small hydro to reflect the fact that these resources are non-dispatchable and must be “backed up” with firm capacity. It is assumed that a gas CCGT would be used to back up non-dispatchable resources. The capacity penalty is calculated by multiplying the fixed cost of a gas CCGT by 1 minus the ratio of the capacity factor of each non-dispatchable resource to the capacity factor of the gas CCGT. For a further explanation of this methodology and its justification, see Frontier Economics, “Cost Benefit Analysis of Renewable Energy in Croatia,” May 2003, http://siteresources.worldbank.org/EXTRENENERGYTK/Resources/5138246-1237906527727/Cost0Benefit0A10and0World0Bank0GEF0.pdf

Figure 3.1: LECs of the Conceptual Plant and Other Supply Options



4 Financial Analysis

Similar to the results of the economic viability analysis, we find that the conceptual plant is only financially viable if a high temperature resource is available and a Flash cycle plant can be built. When a Flash cycle design is assumed, the plant is financially viable under a public financing scheme and a reasonable tariff ofat least US$0.05. We assume that this is a reasonable tariff, as it is below the REFIT received by biomass generators in Armenia. The Kalex cycle and ORC designs are financially viable when a public financing scheme is assumed and the tariffs received are equal to the economic LECs of these plants. However, this suggests a tariff that is 2-3 times higher than the highest REFIT available in Armenia and we assume that that is an unrealistically high level to assume.

In the remainder of this section we provide further detail on the financial viability analysis. We develop financial costs by adding certain taxes, financing and pollution costs to the base financial costs presented in Section 2. We then calculate financial metrics for the conceptual plant in multiple scenarios to determine whether or not it would be financially viable under a range of plant design, financing and tariff rate assumptions.

An overview of the results of the scenario analysis is presented in Table 4.1. The detailed characteristics of each scenario presented in this table are described in Section 4.2.

Table 4.1: Summary of Financial Viability Analysis Results

	Publicly Financed		Commercially Financed	
	Tariff = LEC	**Tariff = US$0.09/kWh**	**Tariff = LEC**	**Tariff = US$0.09/kWh**
Base Case – Kalex	*Viable*	Not Viable	Not Viable	Not Viable
Base Case – ORC	*Viable*	Not Viable	Not Viable	Not Viable
Base Case – Flash	*Viable*	*Viable*	Not Viable	Not Viable
Most Favorable – Flash	*Viable*	*Viable*	Not Viable	Not Viable
Least Favorable – Kalex	*Viable*	Not Viable	Not Viable	Not Viable

4.1 Development of Financial Costs

Financial costs quantify the cost of a project to the project's investors. In contrast with economic costs, financial costs exclude the costs imposed by a project on society, unless those costs are directly incurred by the project's investors. This means that in the financial analysis we do not consider the economic premium on foreign exchange and the economic costs of pollution, which we considered in the economic analysis in Section 3.

Financial costs considered here are the base financial costs of the project (described in Section 2), applicable taxes, duties and subsidies, as well as financing costs. Costs are allocated over the life of the project according to a depreciation schedule. Costs and revenues are discounted to present value terms using a discount rate that is equal to the weighted average cost of debt and equity (the weighted average cost of capital).

This section describes the use of depreciation and the taxes and financing costs considered in the financial analysis.

4.1.1 Depreciation

In order to properly calculate annual income, which is the basis for the calculation of income tax, we make adjustments for depreciation using the straight-line method.

4.1.2 Income Tax and VAT

The taxes included in this analysis are income taxes and VAT. An income tax of 20 percent is applied to income. A VAT rate of 20 percent is applied to all imported goods. VAT is calculated using the credit-invoice method. In this method, VAT that is paid to suppliers is collected by charging VAT to customers. The VAT paid to the government is only the difference between VAT paid to suppliers and VAT collected from customers.[9]

4.1.3 Financing Costs

The financing costs included in this analysis are interest during construction (IDC), debt service and equity shareholder dividends. IDC is treated as an additional capital cost calculated as the monthly interest on construction loan disbursements over the duration of the construction period. Debt service consists of principal and interest payments over the course of the loan period, which is assumed to be 20 years in every scenario. Interest rate and debt level assumptions are different in the public and commercial financing schemes and these are presented in Table 4.2. Shareholder dividends are calculated in scenarios where it is assumed that private investors take an equity stake in the project. Dividends are assumed to be disbursed after all tax and debt service obligations are satisfied.

4.2 Scenario Analysis

We evaluate the same four scenarios evaluated in the economic analysis (see Section 0) under two tariff regimes and two sets of financing assumptions. This results in 16 separate analyses of financial viability. Varying the conceptual plant's performance as well as the financing assumptions and tariff assumptions enables us to determine the conceptual plant's financial viability under a range of different conditions.

In this analysis, we consider the two following tariff regimes:

- **Tariff regime 1:** we assume that the tariff received by the conceptual plant in each scenario is equal to the LEC calculated for that plant.

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[9] Information and Assistance Center for Armenian and Turkish Entrepreneurs, "Value Added Tax," Available: http://armturkbusiness.org/?p=legal&sc=3&cat=25&l=en

- **Tariff regime 2:** we assume that the tariff received by the conceptual plant is the highest REFIT rate in effect in Armenia to date. This rate is US$0.09 per kWh.[10]

We consider both public and commercial financing schemes. The public financing terms are based on the lending practices of the World Bank.The commercial financing assumptions are the same as those used to evaluate Armenia's energy supply options in the 2011 Issues Note. The financing assumptions used in each case are presented inTable 4.2.

Table 4.2: Financing Assumptions

	Public Financing	Commercial Financing
Debt percentage	100	70
Cost of debt (%)	3	10.39
Debt repayment term (years)	20	20
Cost of equity (%)	Not applicable	18
Weighted Average Cost of Capital (WACC)	3	12.67

4.2.1 Determining Financial Viability

For each scenario we calculate the following financial metrics for the conceptual plant under each tariff regime and financing scheme:

- Net present value
- Project internal rate of return
- Equity internal rate of return (where applicable)
- Average debt service coverage ratio

In order to determine the financial viability of each scenario, we assess whether or not all of the applicable metrics calculated for the conceptual plant meet our financial viability criteria. These criteria are summarized in Table 4.3. In order to be considered financially viable, the conceptual plant must meet all of these criteria. If the conceptual plant does not meet at least one of these criteria in the scenario in which it is analyzed, then we determine that the conceptual plant is not financially viable.These financial metrics are described in detail in Appendix B.

Table 4.3: Summary of Financial Viability Metrics

Metric	Minimum Criteria for Financial Viability
Net present value (NPV)	Positive

[10] This is the feed-in tariff rate for electricity generated from biomass in Armenia. See R2E2, "Tariffs," http://r2e2.am/en/2011/06/tariffs/

Financial IRR (FIRR)	Greater than the WACC
Debt service coverage ratio (DSCR)	At least 1.5 average over project life
Equity IRR (when applicable) (EIRR)	At least equal to desired equity return

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The following sections discuss the resultsof the financial viability analyses. For each set of scenarios analyzed under various financing and tariff assumptions, a table shows which plants, if any, meet the financial viability criteria we have developed, and whether or not each plant can be considered financially viable. The detailed results of these analyses, including the values for each metric, can be found inAppendix C.

4.2.2 Public Financing and Tariff Regime 1 Results

When we assume a public financing structure and a tariff rate equal to the economic LEC of the conceptual plant (tariff regime 1), the conceptual plant is financially viable in each of the fivescenarios.In each case, the conceptual plant meets our minimum financial viability thresholds for each financial metric. Table 4.4shows the results of this analysis.

Table 4.4: Scenario Analysis Results – Public Financing, Tariff Regime 1

	Financial Viability Criteria			
Scenario	Net Present Value is Positive	Internal Rate of Return > WACC	Average Debt Service Coverage Ratio>= 1.5	Financial Viability
Base Case – Kalex	✓	✓	✓	*Viable*
Base Case – ORC	✓	✓	✓	*Viable*
Base Case – Flash	✓	✓	✓	*Viable*
Most Favorable – Flash	✓	✓	✓	*Viable*
Least Favorable – Kalex	✓	✓	✓	*Viable*

Note that we determined in the economic analysis that in three of the five scenarios that the LECs of the conceptual plant are very high compared with the LECs of the other supply options in Armenia, and therefore the conceptual plant is not economically viable in these scenarios. This suggests that even though the financial viability analysis shows that a tariff equal to the LEC of the conceptual plant would make it financially viable under public financing terms, paying such a high tariff rate would not be an economically efficient use of resources. According to the economic analysis other, lower-cost supply options are available and should be considered before considering a Kalex cycle or ORC design of the conceptual plant.

On the other hand, if high resource temperature and high mass flow conditions are available and a Flash cycle plant can be built, the LEC of the conceptual plant would be lower than the LECs of many other supply options. Unlike the Kalex cycle and ORC designs, it appears that the Flash cycle plant could be both economically and financially viable under a public financing scheme.

4.2.3 Public Financing and Tariff Regime 2 Results

When we assume a public financing structure and tariff regime 2, the conceptual plant is only financially viable in the Flash cycle design scenarios. In every other scenario,the tariff rate of US$90/MWh is far too low for the conceptual plant to be financially viable. Table 4.5shows the results of this analysis.

Table 4.5: Scenario Analysis Results – Public Financing, Tariff Regime 2

	Financial Viability Criteria			
Scenario	Net Present Value is Positive	Internal Rate of Return > WACC	Average Debt Service Coverage Ratio >= 1.5	Financial Viability
Base Case – Kalex	✕	✕	✕	Not viable
Base Case – ORC	✕	✕	✕	Not viable
Base Case – Flash	✓	✓	✓	*Viable*
Most Favorable – Flash	✓	✓	✓	*Viable*
Least Favorable – Kalex	✕	✕	✕	Not viable

4.2.4 Commercial Financing and Tariff Regime 1 Results

When we assume a commercial financing structure and tariff regime 1, the conceptual plant is not financially viable in any scenario.While in every scenario the plant has a positive IRR and EIRR, they are below the weighted average cost of capital and the required equity return. In every scenario, the NPV of the conceptual plant is negative and the DSCR of the conceptual plant is below the minimum threshold for financial viability. Table 4.6shows the results of the scenario analysis assuming commercial financing terms and tariff regime 1.

Table 4.6: Scenario Analysis Results – Commercial Financing, Tariff Regime 1

	Financial Viability Criteria				
Scenario	Net Present Value is Positive	Internal Rate of Return > WACC	Average Debt Service Coverage Ratio >= 1.5	Equity IRR >=18%	Financial Viability
Base Case – Kalex	✕	✕	✕	✕	Not viable
Base Case – ORC	✕	✕	✕	✕	Not viable
Base Case – Flash	✕	✕	✕	✕	Not viable
Most Favorable – Flash	✕	✕	✕	✕	Not viable
Least Favorable – Kalex	✕	✕	✕	✕	Not viable

4.2.5 Commercial Financing and Tariff Regime 2 Results

Under commercial financing terms andtariff regime 2, the Flash cycle scenarios come close to meeting all of our financial viability criteria. The plants in these scenarios meet our net present value, internal rate of return and average DSCR criteria. However, the equity IRRs of the conceptual plant in these scenarios are below the assumed required equity return levels. These results demonstrate that if a tariff of US$90/MWh and equity financing with a required rate of return around 14-16 percent were available, a Flash plant might be financially viable under a commercial financing scheme and tariff regime 2.

For every Kalex cycle and ORC scenario, the financial metrics of the conceptual plant are significantly below the levels required for financial viability under this financing scheme and tariff regime. These plants would not likely be financially viable in these conditions.

Table 4.7shows the results of the scenario analysis assuming commercial financing terms and tariff regime 2.

Table 4.7: Scenario Analysis Results – Commercial Financing, Tariff Regime 2

	Financial Viability Criteria				
Scenario	Net Present Value is Positive	Internal Rate of Return > WACC	Average Debt Service Coverage Ratio >= 1.5	Equity IRR >=18%	Financial Viability
Base Case – Kalex	✗	✗	✗	✗	Not viable
Base Case – ORC	✗	✗	✗	✗	Not viable
Base Case – Flash	✗	✓	✓	✗	Not viable
Most Favorable – Flash	✗	✓	✓	✗	Not viable
Least Favorable – Kalex	✗	✗	✗	✗	Not viable

4.3 Comparison of the Conceptual Plant to the Long-Run Average Supply Cost for Armenia

We compare the conceptual plant with the forecast average cost of electricity supply in Armenia in the future. This provides an analysis of how competitive the conceptual plant could be with the entire power supply in addition to the analysis of its competitiveness with other individual supply options presented in Section 3.3.2. The cost of supply in Armenia is calculated in financial terms, so we compare it to the financial cost of the conceptual plant. We make this comparison for the scenarios and financing assumptions under which the conceptual plant was found to be financially viable.

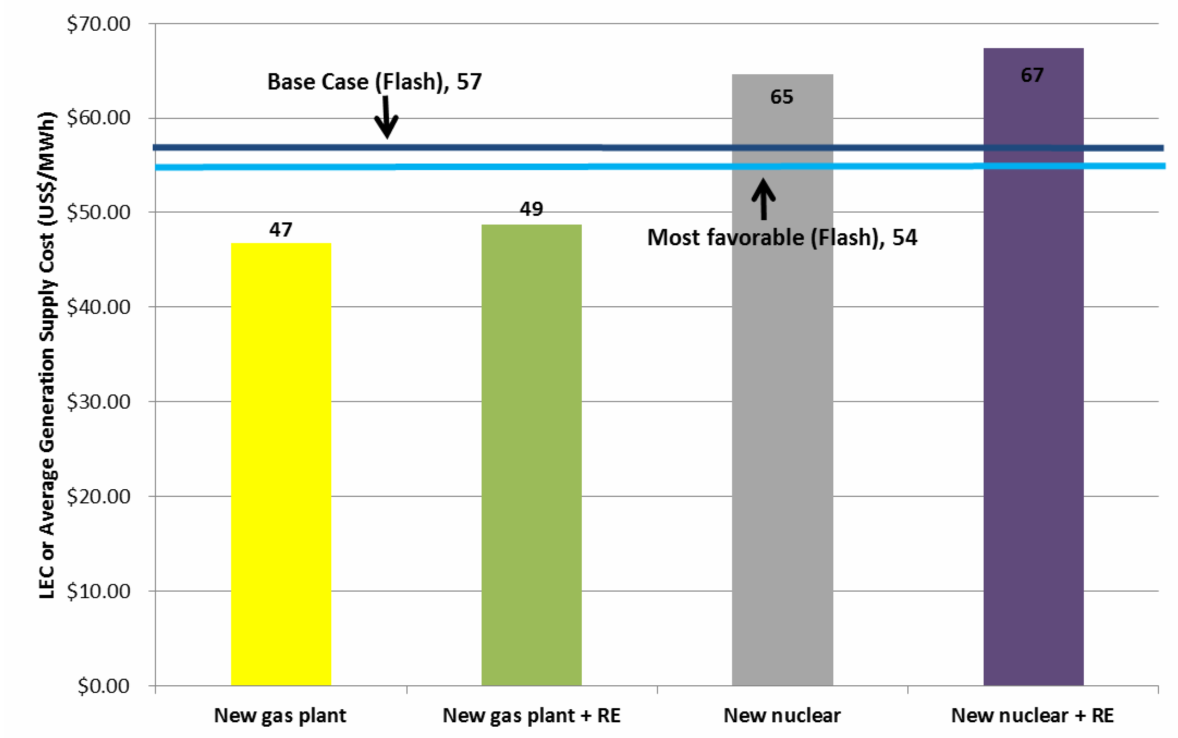
Average Long-Run Supply Cost of Electricity

Estimates of the average long-run supply cost of electricity in Armeniaare derived from data from an Armenia electricity sector tariff study for the World Bank, which is currently in progress. This study provides the generation component of the average cost of electricity supply in Armenia until 2030 for four different scenarios, which were developed for the 2011 issues note and used in the tariff study. These supply scenarios are follows:

- **New Gas Plant:** assumes a new, 800 MW gas plant comes online in 2021.
- **New Gas Plant + RE:** assumes a new, 800 MW gas plant comes online in 2021, a 175 MW wind plant comes online in 2017, and 152 MW of small hydropower plants are built and come online starting in 2012.
- **New Nuclear:** assumes that a new, 1,100 MW nuclear plant comes online in 2021.
- **New Nuclear + RE:** a 175 MW wind plant comes online in 2017, and 152 MW of small hydropower plants are built and come online starting in 2012.

Figure 4.1 compares the financial LECs of the Flash cycle designs of the conceptual plant to the forecast generation component of the average electricity supply cost in Armenia. Forecast electricity supply costs are presented as the average per MWh cost of supply from 2016 to 2030, assuming public financing terms. Electricity supply costs are averaged starting in 2016 because this is the earliest date that the conceptual plant would be expected to come online. The average cost of electricity supply is forecast to rise in the future, so if electricity supply costs were averaged starting at a later date, they would be higher. We calculate the cost of conceptual plant such that all of our financial viability metrics presented in Section 4.2.1 are satisfied.

Figure 4.1: LEC of the Conceptual Plant and Average Electricity Supply Cost for Armenia



This analysis shows that the Flash cycle designs are only less expensive than the average electricity supply cost in the scenarios wherein a new nuclear plant is built. However, this does not mean that the plant could not be a viable part of a future electricity supply for Armenia in the other two scenarios. Although it is more expensive under these two scenarios, the conceptual plant could provide improved energy security by increasing Armenia's reliance on domestic resources for power generation.

Appendix A: Adjustments made to convert financial costs to economic costs

This appendix describes in detail the adjustments made to convert the financial costs to economic costs for the economic analysis in this report.

A.1 Shadow Exchange Rate Factor Adjustments

In the economic analysis, the financial prices of each supply option from Section 2 are adjusted to reflect the premium on foreign exchange. This is done by multiplying the financial priceof the tradable portion of each plant's costs by a Shadow Exchange Rate Factor (SERF) of 1.03.[11] For the conceptual plant, we assume that 60 percent of well, power plant, substation, transmission line, cost contingency and O&M costs are tradable.[12] All other costs are assumed to consist of non-tradable goods (primarily labor) and are not adjusted using the SERF.

For the other supply options analyzed in this report, we derive estimates of the tradable portion of each option's costs from an analysis of different plant type costs by the US National Renewable Energy Laboratory.[13] We then apply the SERF to the percentage of the total financial capital and operating costs that are tradable.The percent of each supply option's costs assumed to be tradable are presented inAppendix Table A.1.

Appendix Table A.1: Tradable Percentage of Capital Costs for Each Supply Option

Supply Option	Percentage of Capital and Operating Costs That are Tradable
Geothermal (all designs)	60
New Gas Plant (CCGT)	85
New Nuclear Plant	70
ANPP Life Extension	70
Small HPPs	70
Wind	90
Solar PV	90
Biomass	70

Source: Rick Tidball, Joel Bluestein, Nick Rodriguez and Stu Knoke, "Cost and Performance Assumptions for Modeling Electricity Generation Technologies," National Renewable Energy Laboratory, November 2010.

[11] The SERF and SWRF used are based on the factors used in Padeco Co., Ltd. "Armenia: Preparing the North-South Road Corridor Development Project," Asian Development Bank, May 2010, http://www2.adb.org/documents/reports/consultant/arm/42145/42145-01-arm-tacr.pdf.

[12] Based on previous experience with similar projects and the estimated non-labor portion of capital costs for geothermal plants provided in Rick Tidball, Joel Bluestein, Nick Rodriguez and Stu Knoke, "Cost and Performance Assumptions for Modeling Electricity Generation Technologies," National Renewable Energy Laboratory, November 2010.

[13] Rick Tidball, Joel Bluestein, Nick Rodriguez and Stu Knoke, "Cost and Performance Assumptions for Modeling Electricity Generation Technologies," National Renewable Energy Laboratory, November 2010.

A.1.1 Shadow Wage Rate Factor Adjustments

It is common practice in economic analysis to adjust the financial cost of unskilled labor to reflect its economic cost. The financial prices of unskilled labor are typically adjusted using a Shadow Wage Rate Factor (SWRF), when appropriate. The SWRF reflects the opportunity cost of using labor in the project under evaluation. This is applied when the wage rates for unskilled labor in a project are either higher or lower than the value of that labor to another use.[14]

We did not adjust the financial cost of unskilled labor in our economic analysis because we were unable to obtain adequate data on the percentage of skilled and unskilled labor that would be required for the construction of each of the plants evaluated in this report.

A.1.2 Exclusion of Transfer Payments

Income taxes, VAT, import duties and financing costs are excluded from the economic analysis. These costs represent transfers of resources from one entity to another within the same economy, are not considered economic costs, and are not considered in the economic analysis.

A.1.3 Costs of Environmental Externalities

Three supply options have pollutant emissions: the natural gas CCGT, the biomass plant and the Flash cycle geothermal plant. When applicable, the economic costs of the emission of carbon dioxide, particulate matter, nitrogen oxides and sulfur oxides from these plants are included as economic costs for these plants.

Estimates of the economic cost of carbon dioxide emissions are based on an International Energy Agency carbon price forecast.[15] Estimates of the economic cost of particulate matter, nitrogen oxides, sulfur dioxides are taken from an analysis done in the Jermaghbyur Geothermal Project Feasibility Study in 2006.[16] The economic cost of carbon monoxide emissions was assumed to be equal to the government-imposed fee for the emissions of this pollutant in Armenia.[17]

The economic cost of emissions of these pollutants for each of these supply options are shown in Appendix Table A.2.

Appendix Table A.2: Economic Costs of Emissions from CCGT and Biomass Plants

		Emissions Contribution to LEC per MWh (US$)		
Pollutant	Economic Cost per kg Emitted (US$)	Biomass Plant[b]	CCGT[c]	Flash Cycle Geothermal Plant
Carbon dioxide	0.08-0.45[a]	0	11.62	1.68
Carbon	0.057	0.03	0.001	NA

[14] J. Price Gittinger, "Economic Analysis of Agricultural Projects," World Bank, 1984, http://www.stanford.edu/group/FRI/indonesia/documents/gittinger/gittinger.pdf

[15] International Energy Agency, "World Energy Outlook 2011," November 9, 2011.

[16] Ameria, "Jermaghbyur Geothermal Project Feasibility Study Final Report No TF 05/CS-07," 2006

[17] Tax Service of Republic of Armenia, "Nature Protection Payments," 2012, http://www.taxservice.am/Content.aspx?itn=TINatureProtectionPayments

monoxide				
Particulate matter	5	2.36	0.31	NA
Nitrogen oxides	1	0.55	0.095	NA
Sulfur dioxides	0.15	0.005	0.0003	NA
	TOTAL	**3**	**12**	**1.68**

[a]Economic cost of carbon dioxide is provided as a range because a forecast is used, in which prices for CO_2 increase over time.

[b]Emissions factors for stand-alone biomass power plants from John R. Shelly, "Biomass Conversion to Electricity: Stand Alone Power Plants, Co-Generation, and Combined Heat and Power (CHP)," UC Berkeley, 2010, http://ucanr.org/sites/WoodyBiomass/files/79012.pdf

[c] Emissions factors from natural gas CCGTs from Pamela L. Smath and Margaret K. Mann, "Life-Cycle Assessment of a Natural Gas Combined-Cycle Power Generation System," NREL, 2000, http://www.nrel.gov/docs/fy00osti/27715.pdf

Appendix B: Details of financial viability metrics used in this report

This appendix explains the financial viability metrics used in the financial viability analysis in this report.

B.1 Assessing the Financial Viability of the Conceptual Plant

We calculate the following financial metrics to determine the financial viability of the conceptual plant:

- **Net present value (NPV).** The NPV is the sum of the present values of the expected incremental positive and negative net cash flows over the conceptual plant's anticipated lifetime.
- **Financial internal rate of return (FIRR).** The FIRR is the financial return of the conceptual plant. It is the discount rate that results in an NPV of zero, or the rate at which the present value of benefits is equal to the present value of costs.
- **Debt service coverage ratio (DSCR).** This identifies the number of times the cash flows available to meet debt service obligations can cover these obligations. This is a ratio lenders commonly used to determine the attractiveness of an investment.
- **Return on equity (equity IRR).** This is the return earned by equity investors who receive dividends on an investment. This will be calculated in the sensitivity in which a commercial financing structure is assumed. The equity IRR will determine the viability of this financial structure for the conceptual plant.

We compare these metrics to various benchmarks in order to determine financial viability. These comparisons are discussed in the next section.

B.1.1 Using Metrics of Financial Viability

After calculating the metrics described above for the conceptual plant, we determine whether or not all of the applicable metrics calculated for the conceptual plant meet the criteria described below. If the metrics calculated for the conceptual plant meet these criteria, we determine that the conceptual plant is financially viable. If the conceptual plant does not meet at least one of these criteria in the scenario in which it is analyzed, then we determine that the conceptual plant is not financially viable. Appendix Table B.1summarizes the metrics and minimum thresholds used for each to determine financial viability under each scenario.

Appendix Table B.1: Summary of Financial Viability Metrics

Metric	Minimum Criteria for Financial Viability
Net present value (NPV)	Positive
Financial IRR (FIRR)	Greater than the WACC
Debt service coverage ratio (DSCR)	At least 1.5 average over project life
Equity IRR (when applicable) (EIRR)	At least equal to desired equity return

NPV

The NPV calculation takes into account all costs and revenues from a plant, as well as its financing structure. A positive NPV suggests that a plant will be financially viable given the financing assumptions used in the analysis. In this analysis, we assume that a positive NPV is necessary for the conceptual plant to be financially viable.

FIRR

An FIRR in excess of the cost of financing demonstrates that the return on the investments in the plant will be sufficient to pay back all investors at to their expected rates of return. This is an indicator of financial viability because financing is generally only provided to projects for which it can be reasonably assumed that investors will earn a sufficient return. The higher the FIRR, the more attractive the project is to investors. We assume that an FIRR above the weighted average cost of capital is necessary for the conceptual plant to be financially viable. For instance, if the FIRR of the conceptual plant is 10 percent, and the weighted average cost of capital (WACC) is 8 percent, then the conceptual plant has met the FIRR criterion for that scenario.

DSCR

We assume that an average DSCR of at least 1.5 over a project's lifetime is generally necessary to receive financing for a project.[18] As a result, we assume that an average DSCR at or above 1.5 is necessary for us to consider the conceptual plant financially viable in this analysis.

EIRR

For projects that receive equity financing, an EIRR at or above the required equity return demonstrates that the equity shareholders in a plant will receive a return sufficient to justify their investment in the plant. For the scenarios in which commercial financing terms are used, we assume that an EIRR above equity return is necessary for the conceptual plant to be financially viable.

[18] This was taken as an average value that is viewed as the minimum acceptable value for this metric in the project finance communities after reviewing the following reports: Ministry of Energy of Armenia and USAID, "Evaluation of Power Projects in Armenia for Development and Financing by the Private Sector," 1996, http://pdf.usaid.gov/pdf_docs/PNACB383.pdf; J. Pater Salmon et al, "Guidebook to Geothermal Power Finance," NREL, 2011, http://www.nrel.gov/docs/fy11osti/49391.pdf

Appendix C: Detailed results of the financial viability analysis

This appendix provides detailed results of the financial viability analysis carried out for each scenario in this report under each financing scheme and tariff regime.

Appendix Table C.1: Scenario Analysis Results – Public Financing, Tariff Regime 1

Scenario	Economic LEC, Used as Tariff Received (US$/MWh)	Net Present Value (Million US$)	Internal Rate of Return (%)	Average Debt Service Coverage Ratio
Base Case – Kalex	265	61	7.1	1.6
Base Case – ORC	200	45	7.1	1.6
Base Case – Flash	66	82	7.7	1.8
Most Favorable – Flash	63	77	7.6	1.8
Least Favorable – Kalex	304	63	6.7	1.6

Appendix Table C.2: Scenario Analysis Results – Public Financing, Tariff Regime 2

Scenario	Tariff Received (US$/MWh)	Net Present Value (Million US$)	Internal Rate of Return (%)	Average Debt Service Coverage Ratio
Base Case – Kalex	90	-48	-1.1	0.4
Base Case – ORC	90	-22	0.6	0.6
Base Case – Flash	90	148	10.8	2.5
Most Favorable – Flash	90	153	11.5	2.7
Least Favorable	90	-66	-2.4	0.35

Appendix Table C.3: Scenario Analysis Results –Commercial Financing, Tariff Regime 1

Scenario	Tariff Received (US$/MWh)	Net Present Value (Million US$)	Internal Rate of Return (%)	Average Debt Service Coverage Ratio	Equity IRR (%)
Base Case – Kalex	265	-34	7.5	1.2	4.8
Base Case – ORC	200	-25	7.5	1.2	4.7
Base Case – Flash	66	-38	7.8	1.3	5.9
Most Favorable – Flash	63	-36	7.9	1.3	6
Least Favorable – Kalex	304	-43	7	1.2	3.6

Appendix Table C.4: Scenario Analysis Results – Commercial Financing, Tariff Regime 2

Scenario	Tariff Received (US$/MWh)	Net Present Value (Million US$)	Internal Rate of Return (%)	Average Debt Service Coverage Ratio	Equity IRR (%)
Base Case – Kalex	90	-79	-1.4	0.3	-10.7
Base Case – ORC	90	-54	0.4	0.42	-7.9
Base Case – Flash	90	-13	11.1	1.8	14.3
Most Favorable – Flash	90	-6.8	11.8	1.9	16.2
Least Favorable – Kalex	90	-95	-2.7	0.3	-13.6

Appendix D: Terms of Reference

Introduction

The Government of Armenia requested the World Bank to support with comprehensive field investigation works of Gridzor (located on the Gegham mountain plateau along the Western shore of Lake Sevan) and Karkar (located on the Syunik plateau in the South Eastern part of Armenia) geothermal sites. The US$1.8 million GeoFund 2: Armenia Geothermal Project (US$1.5 million grant from the technical assistance window of the GEF supported GeoFund program and US$0.3 million of Government co-financing) finances comprehensive field investigation works at the two of the above sites. The project development objective is to assess the feasibility of exploratory drilling of the geothermal site with the estimated highest geothermal potential.

The field investigation works at Karkar and Gridzor geothermal sites were carried out in two phases. Based on the Phase 1 results, it was decided that the Karkar site is the most prospective of the two sites. Therefore, Phase II field investigation works were continued only for Karkar site. Specifically, the Phase II technical investigation works included: (i) 3D MT study and (ii) interpretation of the results of 3D MT study. Economic and financial appraisal of the potential geothermal power plant should be completed to allow the Government to make a final decision whether to proceed with exploratory drilling.

Objective

The objective of the assignment is to conduct economic and financial appraisal of the potential geothermal power plant at Karkar site based on the findings of technical field scouting works, MT sounding study, 3D MT sounding survey as well as independent interpretation of results of MT and 3D MT study.

Scope of Work

Task 1: Development of preliminary power plant concept: The Consultant is required to:

- Estimate the temperature and other key parameters of the Karkar site, which are essential for assessment of potential electricity generation. As part of this activity, the Consultant should use data from other geothermal projects on deviation of actual well productivity from estimates based on surface studies.
- Identify the thermal cycle options based on the fluid parameters with maximum likelihood (enthalpy, well head pressure, well deliverability curve, minimum fluid separation pressure, etc.). The thermal plant cycle options might include single or double flash condensing steam cycles, binary fluid organic ranking cycles, etc.

- Estimate the annual potential of the geothermal well(s) and maximum and minimum electricity generation per year based on the maximum likely key parameters of the resource potential.
- Assess the total capital and O&M cost (fixed and variable; major plant overhaul costs, make up well costs) of the potential geothermal power plant. The estimate of capital costs should include: (a) construction of well-pads and access roads; (b) drilling and testing of production and reinjection wells; (c) power plant facilities, including all civil works; (d) costs required for connection to the power grid and other may cost items.

Task 2: Analysis of economic and financial viability of the project: As part of this task, the Consultant is expected to:

- Assess economic viability of the project. As part of this activity, the Consultant should estimate the levelized economic cost of the proposed geothermal power plant and determine how the estimated levelized cost compares with other base-load plant options for generation expansion in Armenia (including new nuclear and CCGTs). The economic assessment should be conducted taking into account the estimated average supply cost for the base-load type plants as discussed in the Armenia Energy Sector Issues Note (October 2011), prepared by the World Bank. The Consultant should convert the financial costs, estimated under Task 2, to economic costs to be used for economic analysis. Assessment of economic viability of the project should be conducted assuming the positive environmental impacts it will generate measured by avoided GHG emissions valued at CER prices.
- Assess financial viability of the project. The Consultant should assess the financial viability of the project based on the estimated financial costs and benefits. Financial analysis should be conducted assuming a base-case electricity tariff equal to the levelized economic cost, estimated under previous activity, and a base-case WACC assuming a public project with 100% debt financing.
- Conduct sensitivity analysis to estimate the impact of changes in key variables/inputs (including but not limited to well productivity, capital costs, tariffs) on the estimated economic and financial viability of the project.
- Prepare a justification whether exploratory drilling at the Karkar site is feasible given the results of economic and financial appraisal.

Deliverables

Deliverable 1.Inception Report
Duration: 10 days since the Contract signing
Inception Report: Inception Report shall include approach and methodology of assigned work.

Deliverable 2. Interim Report 1
Duration: 50 days since the Contract signing
Interim Report 1: Interim Report 1 shall include Task 1: Development of preliminary power plant concept.

Deliverable 3. Interim Report 2
Duration: 80 days since the Contract signing.

Interim Report 2: Interim Report 2 shall include Task 2: Analysis of economic and financial viability of the project.

Deliverable 3.Draft Final Report
Draft Final Report: DraftFinal Report shall include draft outcomes of economic and financial appraisal of the potential geothermal power plant at Karkar site.
Duration: 90 days since the Contract signing.
Draft Final Report: DraftFinal Report shall include draft outcomes of economic and financial appraisal of the potential geothermal power plant at Karkar site.

Deliverable 4.Final Report
Final Report: Final Report shall include final outcomes of economic and financial appraisal of the potential geothermal power plant at Karkar site.
Duration: 100 days since the Contract signing.
Final Report: Final Report shall include draft final outcomes of economic and financial appraisal of the potential geothermal power plant at Karkar site.

Reports	Deadline
Inception report	Contract signing + 10 days
Interim Report 1 (Task 1)	Contract signing + 50 days
Interim Report 2 (Task 2)	Contract signing + 80 days
Draft final report	Contract signing + 90 days
Final report	Contract signing + 100 days