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

Inception report

June 2012

Denzel Hankinson

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Appendices

1 Introduction

The Armenia Renewable Resources and Energy Efficiency Fund (R2E2) asked Denzel Hankinsonto conduct an economic and financial appraisal of the potential geothermal power plant at the Karkar geothermal site. This involves the development of a preliminary power plant concept (conceptual plant) for the site based on comprehensive field investigation works, and economic and financial viability analyses of the conceptual plant.

The results of the economic and financial appraisal will provide the basis for a recommendation on whether to proceed with exploratory drilling at the Karkar site. The economic appraisal will compare the economic cost of the plant to the other base-load power supply options available to Armenia, andthe financial appraisal will determine the financial viability of the conceptual plant under different cost profiles and financing structures. The role of the plant in Armenia's power sector expansion plans will also be evaluated based on Mr. Hankinson's prior knowledge and experience in this area.

Purpose of this report

The purpose of this inception report is as follows

- Describe the proposed methodology for the development of the preliminary power plant concept
- Describe the proposed methodology for the economic and financial appraisal of the conceptual plant
- Describe the proposed methodology for making a recommendation about proceeding with exploratory drilling at the Karkar site.

2 Approach and Methodology for Task 1: Development of Preliminary Power Plant Concept

The objective of Task 1 is to provide estimates on the technical and cost characteristics of a potential geothermal power plant at the Karkar site, based on a desktop analysis of available data. The primary subtasks are as follows:

- Estimation of geothermal fluid temperature, chemical properties and other key parameters
- Comparison of potential generation methods based on these parameters, and development of one or more preliminary power plant concepts for the site
- Estimation of the capacity, annual generation and costs of a conceptual plant using each generation method under a range of conditions.

2.1 Preliminary plant concept development methodology

R2E2 provided the findings of the previously completed technical field scouting works, MT sounding study, 3D MT sounding survey and an independent interpretation of the results of MT sounding study and 3D MT sounding survey. These data, information about the climatic conditionsat the Karkar site, and prior

experience estimating geothermal parameters and costs will be used as the basis for the technical analysis and the development of the preliminary plant concept.

2.1.1 Estimation of key geothermal parameters

Estimation of geothermal parameters will be based on a review of existing data for the site and used to estimate expected reservoir characteristics. Geothermal fluid properties such as temperature and chemical properties will be among the most important parameters used in the development of the conceptual plant.

2.1.2 Design of thermal cycle options

The accuracy of the geothermal information that will provide the basis for the design of the thermal cycle is unknown. In order to manage this uncertainty and accommodate a range of potential values of the key parameters, two conceptual plants will be designed, each with a different output and cost profile.

The thermal cycle process diagramsand analyses will be developed using in-house software. This software has been tested in existing binary cycle and flash cycle projects.

A layoutof mechanical and civil engineering works will be created at the appropriatelevel of detail for an AACE International Class IV cost estimate.[1]Estimatesof system maintenance and replacement requirements will also be made, in order to inform operating cost estimates.

2.2 Outputs of the Technical Analysis

Preliminary design of the conceptual plant will produce technical and economic parameters for the conceptual plant, which will serve as inputs to the economic and financial analysis. As mentioned above, a range of values for each of these parameters will be provided, based on the two process options evaluated in the technical analysis.

2.2.1 Generating capacity and annual generation estimates

A range of capacity and annual energy production values will be produced for each of the two process options based on the maximum likely key parameters of the resource. These will include estimates of maximum and minimum electricity generation potential, as well as estimates of annual plant running time and forced and planned outages.

The effect of ambient temperature on energy production from the conceptual plant will be estimated for three different conditions: cold, design and hot.Interpolation among these conditions will be used to estimate plant output under other conditions.

2.2.2 Cost estimates

Capital costs estimates will be presented as quarterly expenditures during the construction phase. Annual operating costs and decommissioning costs that would

[1] An ACEE International Class IV cost estimate is a cost estimate deemed suitable for a concept or feasibility study. For more information about the ACEE International cost-estimation classification system, see AACE International, “AACE International Recommended Practice No. 17R-97 Cost Estimation Classification System,” 2003. Accessed June 14, 2012, http://www.nsf.gov/about/contracting/rfqs/support_ant/docs/facility_manuals/palmer_mcm_and_southpole/costestimatingsystemaace-208a.pdf

be incurred at the end of the plant's service life will also be estimated and presented.

Stochastic cost estimating methods will be used to provide cost estimates for this project. This involves cost modeling based on known or inferred relationships between costs and the technical or programmatic characteristics of a project. Due to the fact that the resource assessment of the site is at an early stage and there is a high level of uncertainty about the resource potential, this method is most appropriate.

Deterministic methods such as obtaining budget quotes from producers or manufacturers are not cost-efficient until the resource has been confirmed with a successful production well. However, as necessary, internal cost databases will be used to estimate the cost of large equipment needed from international manufacturers.

3 Approach and Methodology for Task 2: Analysis of Economic and Financial Viability of the Project

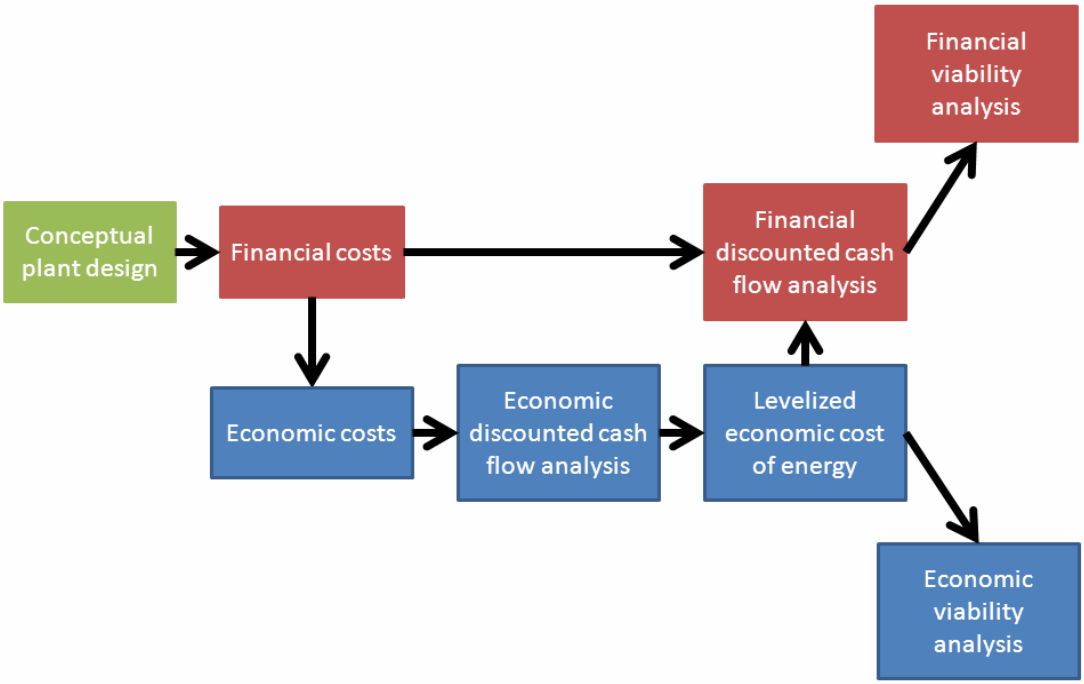
The objective of Task 2 is to evaluate whether or not exploratory drilling at the Karkar site is justified in economic and financial terms, given the technical and cost characteristics of the conceptual plant developed in Task 1. This will involve the development of discounted cash flow (DCF) models to estimate indicators of economic and financial viability. The economic and financial analyses will be developed out for a base case, as well as low and high cost scenarios to determine the effects of changes in various input variables on economic and financial viability.

This section outlines how the economic and financial viability analyses will be conducted, and how the recommendation about proceeding with exploratory drilling at the site will be made.

3.1 Interdependencies Between the Financial and Economic Analyses

The financial and economic analyses in the project are interdependent. The financial costs of the conceptual plant developed in Task 1 will serve as an input to both the economic analysis and the financial analysis. The levelized economic cost of energy (LEC) output of the economic analysis will serve as the basis for the economic viability analysis, in which the conceptual plant is compared with other supply options. The LEC will also be used as the tariff in the financial analysis. Figure 3.1presents a simple schematic of the interdependencies between the economic and financial analyses in order to clarify the flow of data between the two analyses.

Figure 3.1Interdependencies between the economic and financial analyses



3.2 Financial Assessment of the Conceptual Plant

The financial analysis will involve the preparation of a financial model to forecast the conceptual plant's cash outflows and inflows, and discount them to present-day dollars. The outputs of the financial analysis will be a set of indicators, which will be used to determine the financial viability of the project. Scenarioanalyses will be developed to determine the financial viability of the plant under different financial conditions.

3.2.1 Inputs to the financial analysis

The financial analysis will be conducted by specifying values for the following assumptions and using them to calculate key financial indicators for the conceptual plant.

Financial Costs

The total expected costs for a project are a function of its estimated capital works costs, operations and maintenance costs (both fixed and variable), and financing costs. Total expected costs are also influenced by assumed tax, depreciation, inflation and exchange rates. Assumptions about the following will be used in the financial analysis:

- **Capital costs.** Capital costs include exploration, drilling and plant construction costs, as well as price and physical contingencies. Not all capital costs will be incurred upfront, as drilling and construction is spread over months or years. Capital costs include the costof decommissioning at the end of the plant's life. A schedule of construction and other capital

expenditure over the life of the plant will be provided. The bullets below define the critical components of capital costs:

- Drilling costs. This refers to the cost of drilling exploration, production and make-up wells for the plant.
- Construction costs. Also sometime referred to as capital expenditure (CAPEX), this refers to the construction and equipment costs in building the plant.
- Working capital. Working capital defined from an accounting perspective is the difference between current assets and current liabilities. Working capital should allow a company to meet its short term liabilities or expenses with its current assets, including cash, accounts receivable and inventory. It includes expenses which are not considered direct capital expenditures such as salaries of construction workers, engineering studies, legal fees, etc. that are required to construct a project prior to the time it is completed and generating revenue.
- Residual value. Residual value is the remaining value of an asset after it has been fully depreciated.

- **Operating and maintenance (O&M) costs.** Operating and maintenance expenses refer to the ongoing costs of maintaining and operating the plant. For the conceptual plant, these will primarily take the form of fixed annual costs.
- **Financing costs.** Financing costs refer to the cost of debt or equity for a project. Financing costs depend on the following:
  - The sources of financing or funding used (loans, grants, user contributions or equity), and the amount of each source.
  - The opportunity cost of debt. The opportunity cost of debt is determined by the interest rate that lenders charge for a project.
  - The term of the loan. The term of the loan refers to the length of a payback period, and how disbursements of the loan are synchronized with the loan term. A loan repayment schedule will be provided for the conceptual plant.
  - The opportunity cost of equity. This is determined by the annual dividend payments that any investors in the conceptual plant would expect.
  - Interest during construction. For construction projects, loan disbursement begins during the construction period, but loan repayment does not begin until the project begins generating revenue, which is during or after the construction period has ended. As a result, interest accumulates during the construction period on the amount of money borrowed to finance construction. This is treated as an additional cost to the project.

The base case financing structure for the financial analysis will assume that the conceptual plant receives 100 percent debt financing from

government. At least one sensitivity analysis will be conducted in which the effect of an alternative financing structure on the conceptual plant's financial viability will be tested.

- **Tax rate.**Corporate taxes and VAT (to the extent that it is applicable) will be included in project costs.
- **Inflation and cost escalators.**The financial model will be developed in "real" or "constant dollar" terms (in other words, net of expected inflation).If costs are expected to escalate in real terms, then costs escalators will be applied to future costs.

Revenues

The expected annual revenue for the conceptual plant is a function of the amount of energy sold and the price at which it is sold, or the tariff. Several estimates for the annual generation of the conceptual plant will be produced in Task 1 and used as inputs to this calculation. The tariff in the base case financial analysis will be equal to the LEC estimated in the economic analysis. The tariff will be varied in the sensitivity analysis to evaluate the effect of different tariffson the financial viability of the project.

3.2.2 Calculation of financial metrics

A variety of financial indicatorswill be used to determine the financial viability of the conceptual plant. Of primary importance in this analysis will be the determination of whether the plant would be able to adequately service a loan and provide an acceptable return to equity investors.

The following financial indicatorswill be calculated:

- **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 FIRRis 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.

3.2.3 Scenarioanalysis

Scenario analysis will be conducted to determine the effects of changes to financial variables on the financial indicatorscalculated for the conceptual plant. Scenario analysis looks at the effects on a project's financial viability of changes in multiple input assumptions. Three scenarios will be developed to capture low, base and high

cost estimates for the cost of the conceptual plant. At least one scenario will include a commercial financing structure. This will help determine the conditions under which the conceptual plant will be financially viable, and provide information on the probability of the plant's financial viability under a wide range of scenarios. Three different scenarios will be evaluated, which will capture lower bound, base and upper bound estimates of the financial viability of the plant.

The scenario analyses will include combinations of the following variations in input variables to the financial analysis:[2]

- Capital cost variations due to higher or lower values than are used in the base case for the following parameters:
  - Well productivity
  - Drilling costs
  - Plant construction costs
- Variations in the size and energy output of the conceptual plant
- Use of alternative debt/equity ratios in financing
- Variations in the opportunity cost of capital, namely, the cost of debt financing and the return required by equity investors
- Tariff rates that are higher and lower than the base case tariff rate.

3.2.4 Assessment of the financial viability of the conceptual plant

The financial metrics listed above will be compared to commonly accepted benchmark values used for determining financial viability of a power project among lenders and equity investors in order to determine financial viability. Based on the results of the scenarioanalysis, the cost, productivity and financial structure conditions under which the plant is financially viablewill be discussed and an overall assessment of financial viability will be made.

3.3 Economic Assessment of the Conceptual Plant

The economic assessment will involve comparison of the costs of the conceptual plant to the costs of other base-load power supply options. This will involve the preparation of an economic model to calculate the LEC of the conceptual plant and the other base-load supply options available. This analysis will be similar to the financial analysis, except for the treatment of certain costs and assumptions.

3.3.1 Conversion of financial costs to economic costs

Financial costs and economic costs are fundamentally different.In order to conduct the economic analysis, financial costs must be converted to economic costs.

Financial costs are cost incurred by project developers and investors for goods and services necessary for completion and operation of a project. Economic costs are the cost of that project's development and operation to the entire economy. Taxes, duties and subsidies are financial costs because they must be paid by project developers. However, they are not costs to the economy as a whole because they

[2] Variations in the technical parameters to be used for the sensitivity analyses will be developed in Task 1

are simply transfers of resources from one entity to another.[3] Emissions of pollutants are economic costs because they have health effects, damage buildings and haveother negative effects on the economy as a whole. However, they do not typically impose a cost on project developers, so they are not financial costs.[4]

Generally, economic costs will be derived from financial costs by adding the cost of negative externalities associated with the project and subtracting financial transfers of resources and other costs that do not represent real costs to the economy.[5]

3.3.2 Converting financial prices to economic prices

Costs that are incurred in domestic prices have a different economic value than costs incurred at border prices. This is due to the fact that purchasers in domestic markets place different values on imported goods and services than on domestic goods and services. As a result, financial costs that are incurred in these two different domains must be brought to a common basis using appropriate conversion factors. This conversion will be part of the economic analysis.

3.3.3 Discounted cash flow analysis of economic costs

In addition to converting financial costs to economic costs, the economic analysis will differ from financial analysis in the following ways:

- The economic analysis will consider the conceptual plant's cash flows over the life of the asset rather than the term of the project (which may differ if investors intend to sell or turn-over the asset to government before the end of its useful life).
- The economic analysis will use a "social discount rate" for discounting the project's cash flows. A social discount rate is the minimum rate of return a project should generate for society as a whole in order to be viable.

3.3.4 Calculating the levelized economic cost of electricity (LEC)

The levelized economic cost of electricity (LEC) will be calculated in the economic DCFand will serve as the basis for the comparison of the conceptual plant and other base-load power supply options. The LEC will also serve as the tariff level in the financial analysis.

The LEC is useful 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 break even. The methodology for calculating LEC is shown below in Equation 3.1.

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[3] 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.

[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] In order to derive economic costs from financial costs, it is also often necessary to apply conversion factors to the financial costs. A conversion factor is the ratio between the economic price value and the financial value of various projects inputs (costs) and outputs (revenues). Conversion factors reflect the economic value of goods and services, for example, the opportunity cost of labor, or the implicit value placed on imported goods, that may not be reflected in the market price. Conversion factors are used to convert constant price financial values used in a project's financial viability analysis into their corresponding economic values.

Equation 3.1 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

3.3.5 Scenarioanalysis

Scenarioanalysis will be conducted to determine the effects of changes to the economic variables on the LEC of the conceptual plant and the other supply options. The comparisons between the LECs of the conceptual plant and the other supply options will be the basis for determining the plant's economic viability. The effect of the different scenarios on the differences between the LECs of the conceptual plant and the other supply options will help determine the conditionsunder which the conceptual plant will or will not be economically viable.Three different scenarios will be analyzed to capture low, base and high estimates of the economic costs of the plant.

The scenario analyses will include variations in the economic cost of the plantand will produce a range of tariff estimates.

3.3.6 Assessment of the economic viability of the conceptual plant

An assessment of the economic costs of the conceptual plant compared with those of alternative options is the basis of the economic viability analysis, and essential for making a recommendation about exploratory drilling at the Karkar site. The comparison of the conceptual plant with other base-load supply options will be based on the two following analyses:

- Comparison of the LEC of the conceptual plant and the LEC of each alternate base-load supply option
- Analysis of the conceptual plant in Mr. Hankinson's system dispatch model developed for Armenia

These comparisons will be presented for the base case analysis and the low and high case sensitivity analyses. This will provide the basis for a discussion of the conditions under which the conceptual plant will or will not be economically viable.

3.4 Recommendation on Exploratory Drilling

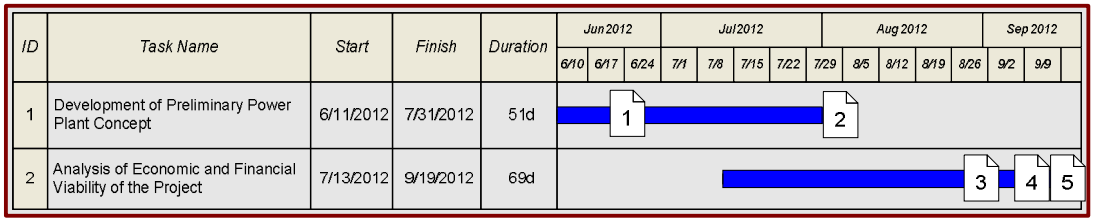
Based on the economic and financial viability of the conceptual plant, a recommendation to proceed or not proceed with exploratory drilling will be presented. This will include an identification of the most likely of the various economic and financial analyses.

The recommendation will also include a discussion of how the conceptual plant might fit into Armenia's power sector and its future generation expansion plans. This will be based on the analysis of the plant in Mr. Hankinson's system dispatch model developed for Armenia. Whether or not the conceptual plant could eliminate the need for, or affect the size of other base-load generation expansion options will be evaluated and discussed.

3.5 Work Plan

Figure 3.2 below shows the Work Plan for this project.

Figure 3.2 Work Plan



Date: Deliverable	
	1 Inception Report: 06/21/2012
	2 Interim Report 1: 07/31/2012
	3 Interim Report 2: 08/30/2012
	4 Draft Final Report: 09/09/2012
	5 Final Report: 09/19/2012

Appendix A: Terms of Reference and Scope of Services

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