

Document of
The World Bank
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Report No: ICR00004780

IMPLEMENTATION COMPLETION AND RESULTS REPORT

TF-A0544

ON A

GRANT

IN THE AMOUNT OF US\$8.55 MILLION

TO THE

REPUBLIC OF ARMENIA

FOR THE

GEOTHERMAL EXPLORATORY DRILLING PROJECT

December 2, 2019

Energy & Extractives Global Practice
Europe And Central Asia Region

CURRENCY EQUIVALENTS

(Exchange Rate Effective Aug 23, 2019)

Currency Unit = Armenian Dram
(AMD)

AMD 468.9 = US\$1

US\$1.5 = SDR 1

FISCAL YEAR

July 1 - June 30

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ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
APSPN	Armenia Power Sector Policy Note
CPF	Country Partnership Framework
CPS	Country Partnership Strategy
CSR	Corporate Social Responsibility
DSC	Drilling Service Contractor
EBRD	European Bank for Reconstruction and Development
E&FA	Economic and Financial Analysis
EMP	Environmental Management Plan
ENA	Electric Networks of Armenia
ESMAP	Energy Sector Management Assistance Program
ESC	Considering the Energy Security Concept for Armenia
FiT	Feed-in tariff
GDP	Gross Domestic Product
GGDP	Global Geothermal Development Plan
HVEN	High Voltage Electric Networks
IBRD	International Bank for Reconstruction and Development
ICR	Implementation Completion Report
IFC	International Finance Corporation
IP (SREP IP)	SREP Investment Plan
ISR	Implementation Status & Results Report
LCP	Least-Cost Plan
LEC	Levelized Economic Cost
M&E	Monitoring and Evaluation
MIGA	Multilateral Investment Guarantee Agency
MENR	Ministry of Energy and Natural Resources
MoEINR	Ministry of Energy Infrastructures and Natural Resources
MT	Magneto-telluric
O&M	Operation and Maintenance
PAD	Project Appraisal Document
PDO	Project Development Objective
PPIAF	Public – Private Infrastructure Advisory Facility
PPP	Public-Private Partnership
PSRC	Public Services Regulatory Commission
SCF	Strategic Climate Fund
SHPP	Small Hydropower Plant
SORT	Systematic Operations Risk-Rating Tool
SREP	Scaling-up Renewable Energy Program
TSSC	Technical Supervision and Support Consultant
YTPC	Yerevan Thermal Power Centre

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FINANCING

	Original Amount (US\$)	Revised Amount (US\$)	Actual Disbursed (US\$)
World Bank Financing			
TF-A0544	8,550,000	6,296,250	6,296,250
Total	8,550,000	6,296,250	6,296,250
Non-World Bank Financing			
Borrower/Recipient	2,130,000	2,130,000	1,570,000
Total	2,130,000	2,130,000	1,570,000
Total Project Cost	10,680,000	8,426,250	7,866,250

KEY DATES

Approval	Effectiveness	MTR Review	Original Closing	Actual Closing
08-Jun-2015	25-Aug-2015		31-May-2019	31-May-2019

RESTRUCTURING AND/OR ADDITIONAL FINANCING

Date(s)	Amount Disbursed (US\$M)	Key Revisions

KEY RATINGS

Outcome	Bank Performance	M&E Quality
Satisfactory	Satisfactory	Substantial

RATINGS OF PROJECT PERFORMANCE IN ISRs

No.	Date ISR Archived	DO Rating	IP Rating	Actual Disbursements (US\$M)
01	24-Sep-2015	Satisfactory	Satisfactory	.13
02	02-May-2016	Satisfactory	Satisfactory	2.46
03	10-Nov-2016	Moderately Satisfactory	Moderately Satisfactory	4.85



04	31-May-2017	Moderately Satisfactory	Moderately Satisfactory	6.79
05	17-Jan-2018	Moderately Satisfactory	Moderately Satisfactory	6.98
06	01-Aug-2018	Moderately Satisfactory	Moderately Satisfactory	7.00
07	19-Feb-2019	Satisfactory	Satisfactory	7.00

SECTORS AND THEMES

Sectors

Major Sector/Sector (%)

Energy and Extractives 100

Renewable Energy Biomass	25
Renewable Energy Geothermal	25
Renewable Energy Solar	25
Renewable Energy Wind	25

Themes

Major Theme/ Theme (Level 2)/ Theme (Level 3) (%)

Private Sector Development 40

Jobs	30
Job Creation	30
Public Private Partnerships	10

Urban and Rural Development 60

Urban Development	30
Urban Infrastructure and Service Delivery	30
Rural Development	30
Rural Infrastructure and service delivery	30

Environment and Natural Resource Management 10

Climate change	10
Mitigation	10



ADM STAFF

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I. PROJECT CONTEXT AND DEVELOPMENT OBJECTIVES

A. CONTEXT AT APPRAISAL

Context

1. **Country context.** At the time of project appraisal in 2015, Armenia’s Gross Domestic Product (GDP) slowed down, from 7.2 percent in 2012, to 3.5 percent in 2013 and 2.6 percent in 2014. Growth in the agriculture sector remained strong, but metallic mining output had declined, as well as activity in the construction sector. The service sector, with financing, telecommunications and real state were the highest contributors to growth. In addition, despite the economic recovery following the 2009 crisis, poverty rates were still high, with about 32 percent of Armenians living in poverty in 2013, mostly due to the slowdown in the construction sector.



Source: World Development Indicators and NSS for national poverty rates.

2. **Sector context.** The first phase of power sector reforms implemented in the 1990s and early 2000s had led to remarkable results, including 100 percent bill collection, elimination of subsidies, establishment of a competent and independent regulatory agency, and a regulatory framework conducive to private investment, including in renewable energy. However, at the time of appraisal, the power sector still faced several major challenges that would be addressed in a second phase of reforms, including supply adequacy and reliability, affordability of energy tariffs, financial viability of state-owned power companies, and transparency.
3. In terms of supply adequacy, in 2014 it was estimated that, to guarantee the medium to long-term supply, the country needed around 500 MW of new gas-fired generation as well as development of renewable energy projects which were already part of the least-cost supply plan, including geothermal. As for supply reliability, the average interruption frequency per line for 110 and 220 kV overhead transmission lines was 2.5 times higher than the comparator well-performing utilities, mostly due to the lack of rehabilitation and upgrades of old infrastructure. Regarding affordability, residential electricity tariffs had increased by 40 percent and gas tariffs by 19 percent in 2013-2014, which had led poor households to spend over 13 percent



of their disposable income in energy. Despite the tariff increases, the financial viability of state-owned companies was still jeopardized by the Government's intervention in tariff filings to limit the impact of increasing costs on end-user tariffs and by large short-term borrowings by the state-owned companies for non-core business activities. Finally, the transparency of the sector had deteriorated since 2011, which was manifested through reduced public disclosure of information related to energy sector issues and challenges.

4. The Government had already taken steps to support the development of indigenous renewable energy resources, especially to promote the development of small hydropower plants, and remained committed to further increase the share of renewable energy in the generation mix by promoting development of renewable energy technologies with large potential for scale-up with limited impact on end-user tariffs. The Government was thus committed to develop the country's geothermal resources as they could become an affordable source of base-load electricity generated from indigenous resources. Of the known areas in the country, the Karkar field has been assessed to be the most promising site. Development of the Karkar geothermal site was thus one of the projects included in the Scaling-up Renewable Energy for Low-Income Countries Program (SREP¹) Investment Plan (IP) developed by the Government with support from development partners and approved by the SREP Sub-committee on June 26, 2014. The SREP IP identified geothermal power, utility-scale solar PV, and solar heating as priority areas for support and future scale-up.
5. **Rationale for Bank support.** At the time of approval of SREP IP, Bank financing for geothermal, as well as that of other donors, had been historically focused on the downstream phases of project development (i.e. construction of power plants and associated infrastructure). However, the World Bank, through the Energy Sector Management Assistance Program (ESMAP) Global Geothermal Development Plan (GGDP) in partnership with the Climate Investment Funds among others, had become a leader in advocating that donor (and public sector in general) support for the sector should focus on the riskier exploratory and production drilling stages, as evidence showed that private developers and commercial financiers generally enter projects only at more mature development phases when the resource risk has been significantly reduced. In the case of Armenia, the risk was even higher given that this would be the first deep exploratory drilling carried out in the country and that the result from the prior extensive surface exploration work financed by the Global Environmental Facility (GEF) through the GeoFund 2 projects (P114409 and P112408) indicated that a viable geothermal resource might be found at Karkar. Although the likelihood of finding a low temperature geothermal field was considered higher than the likelihood of finding a high temperature one according by technical experts², finding a resource that would result in generation of base-load electricity at a competitive Levelized Energy Cost (LEC) was a reasonable possibility that the Government was keen to explore through exploration drilling given its efforts to prioritize the increased use of indigenous renewable resources to ensure supply adequacy and improve energy security. If resources were confirmed through SREP-financed exploration drilling and thus the high resource risk reduced, this was expected to catalyze additional financing from public (including IBRD) and private resources for further development of the geothermal field and construction of a power plant.

¹ SREP is one of the Strategic Climate Funds of the Climate Investment Funds and has the objective of supporting low income countries move toward low carbon development by adopting renewable energy technologies.

² ISOR Memorandum, dated 8/3/2012.



Theory of Change (Results Chain)

6. The Project consisted of investments in: a) exploratory drilling to assess whether the inferred geothermal resource at Karkar would be suitable for power generation; and b) geothermal development capacity building activities to support the exploratory drilling activities and potential transaction advisory activities. If the power generation potential were confirmed through exploratory drilling, then the Project would support the Government to involve the private sector in the development of a geothermal power plant. Higher level objectives of the Project included contributing to the reduction of the power supply gap, improving energy security, and reducing greenhouse gas emissions by offsetting investments in gas-fired power generation. The Project, as per the Project Appraisal Document (PAD) also intended to contribute to the reduction of poverty and promotion of shared prosperity through reducing the rate of expected tariff increases.
7. The Project was designed with a phased approach due to the inherent level of uncertainty of any geothermal exploratory drilling project, but also to ensure that the limited SREP grant resources would be used in an efficient manner, given that the interpretation of the results from the surface exploration studies was not unequivocally optimistic about the presence of a geothermal resource in Karkar. The first phase consisted of building necessary infrastructure and drilling of one or two slim exploration wells to about 1,200 m depth to assess whether the observed subsurface electrical resistivity was related to a high-temperature geothermal reservoir. If the slim well(s) drilled during the first phase confirmed this interpretation of the resistivity data, the Project would then move to the second phase: drilling of a production-size exploration well to confirm the geothermal resource and test the productivity of the geothermal reservoir. Depending on the success of the full-size well, the Project would also finance transaction advisory to help the Government engage a private-sector developer to fully develop the field and install a power plant.
8. During project preparation, three possible scenarios regarding the nature of the geothermal resource were identified in order to help determine whether to proceed to Phase II based on the findings of Phase I.
 - a. **Scenario 1**- the exploratory drilling indicating reservoir temperatures below 90°C. If this would be the result, the Project would be terminated because such low temperatures are not suitable for commercial power generation.
 - b. **Scenario 2** - the slim wells indicating the presence of a high temperature geothermal reservoir with temperatures in excess of 200°C, suitable for a flash power plant. The Project would then proceed to Phase II and the Government could initiate preparations for construction of a flash cycle power plant in partnership with private investors.
 - c. **Scenario 3** - temperatures lower than required for a flash cycle power plant but higher than the minimum threshold for a binary plant suitable for commercial exploitation. In this case, the Government would decide whether to build a binary geothermal power plant based on associated energy costs and interpretation of the drilling results by the Technical Supervision and Support Consultant (TSSC).
9. The SREP Grant Agreement signed between the Republic of Armenia and IBRD provided that If the government decided to proceed it would have to prepare a detailed justification request to be approved by the World Bank.
10. The Project PDO and results indicators reflected the conservative phased-approach to project design, with a commitment to provide evidence to the Government on whether the geothermal resource at Karkar was suitable for power generation and, if the resource was confirmed, competitively award the development of



the power plant to a private sector developer through a PPP schemes (see paragraphs below). These were the results that could be directly attributable to the project activities. However, at the time of project preparation, SREP required that the SREP results referred to the “SREP-leveraged project”, that is, the results achieved if a geothermal power plant at Karkar had eventually been built. Since construction of this power plant was not within the scope of the project, the team and management considered that the results framework for the project could not formally commit to the leveraged SREP results included in the SREP-Annex of the PAD (i.e. annual electricity output, public and private finance leveraged, CO2 emission reductions), as they were outside of the control of the project.

Project Development Objectives (PDOs)

11. The PDO was to confirm whether the geothermal resource at the project site was suitable for power generation and, if confirmed, to involve the private sector in the development of the geothermal power plant.

Key Expected Outcomes and Outcome Indicators

12. The Project had two direct outcomes with causal linkages: (i) assessment of the availability of exploitable geothermal resources at the Karkar site; and (ii) if geothermal potential were identified, engagement of a private developer for the construction and exploitation of the power plant. The specific indicators for the measurement of the Project outcomes included the following:
Indicator 1: Evidence provided to the Government for its decision on whether or not to construct a geothermal power plant at the Karkar geothermal site. (Yes/No)
Indicator 2: If geothermal resource is confirmed, power plant development is competitively awarded to qualified private developer(s). (Yes/No)

Components

13. The Project was financed by a US\$ 8.55 million grant from SREP, and by US\$ 2.13 million contribution by the Republic of Armenia. The SREP allocation for this Project was endorsed by the SREP Subcommittee on June 26, 2014, including a US\$ 0.3 million Project Preparation Grant.
14. **Component A: Phase I exploratory drilling program.** The slim well exploratory drilling program (US\$ 5,375,000, including US\$ 4,300,000 SREP grant) had two sub-components.
15. **Sub-Component A.1:** *Construction of access road and drilling of one or two slim exploratory wells* (US\$ 5,025,000, including US\$ 4,020,000 SREP grant). This sub-component was designed to finance: (a) the construction of an access road and other associated infrastructure; and (b) the drilling of up to two slim exploratory wells. The construction of the access road and other associated infrastructure included: (i) construction of a gravel road with sufficient length and width to allow for safe transportation of equipment and other materials to the site; (ii) preparation of small rig pads; and (iii) installation of equipment and minor works at the water source.
16. **Sub-Component A.2:** *Technical assistance for assessment of the geothermal resource potential and technical supervision* (US\$ 350,000, including US\$ 280,000 SREP grant). This sub-component was designed to finance: (i) well logging and well testing, including analysis of borehole cuttings, well temperature, and pressure



- measurements; (ii) a Technical Supervision and Support Consultant to support R2E2³ in technical supervision of the drilling, producing a Technical Report interpreting the results and findings, and other technical advice and support; and (iii) Project audit and operating costs, including incremental operating costs of R2E2's implementation of Phase I, salaries of Project staff (except civil servants), and Project audits.
17. The Project would only proceed to Component B (Phase II) if the results from drilling the exploratory well(s) during Component A justified it.
 18. **Component B: Phase II exploratory drilling program and transaction advisory.** The results obtained from Phase I would determine whether to proceed with Phase II of the Project (US\$ 5,312,500, including US\$ 4,250,000 SREP grant). Component B had two sub-components.
 19. **Sub-Component B.1: Construction of water infrastructure and rig pads and drilling of a full size exploratory well** (US\$ 4,175,000, including US\$ 3,340,000 SREP grant). This sub-component was designed to finance: (i) construction of water infrastructure and rig pads, including supplying water from a nearby well to ensure continuous water supply for the drilling operation and preparing rig pads where the rig and other associated equipment would be placed; and (ii) drilling of a production-size exploratory well.
 20. **Sub-component B.2: TA for assessment of the geothermal resource and technical supervision** (US\$ 1,137,500, including US\$ 910,000 SREP grant). This sub-component was designed to finance: (i) well logging, mud logging, and well testing, including analysis of cuttings from the borehole, well temperature, and pressure measurements; (ii) feasibility study for a potential geothermal plant, including assessment of the possible power output, enthalpy, economic and financial viability, and the legal and institutional framework, among others; (iii) Technical Supervision and Support Consultant, including supporting R2E2 in technical supervision of the production-size well drilling and reviewing results and findings; (iv) transaction advisory (to be co-financed, if necessary, with additional resources from SREP, PPIAF, ESMAP, or other sources), including provision of transaction advisory services to the Government in order to design a PPP scheme; and (v) Project audit and operating costs, including R2E2's incremental operating costs related to implementing Phase II and Project audits.
 21. The Project was designed as a four-year operation in order to ensure that all the necessary activities could be completed given the limitations on site accessibility caused by weather conditions and also given the time needed to complete the PPP transaction for the power plant. Given that the "window of opportunity" for accessing the site is generally from late spring to early-mid fall, at least two seasons would be needed to complete the two phases of drilling (i.e. the slim wells in Phase I and the full-size well in Phase II). However, drilling might be completed in only one season if the results from Phase I suggests that the resource is not suitable for power generation.

³ R2E2, Armenia Renewable Resources and Energy Efficiency Fund was established by the Government of Armenia as an independent non-governmental organization following the provisions of the Law on Energy Efficiency and Renewable Energy. The mission of the Fund is to facilitate investments in energy efficiency and renewable energy in Armenia.



B. SIGNIFICANT CHANGES DURING IMPLEMENTATION (IF APPLICABLE)

Revised PDOs and Outcome Targets

22. PDO and Outcome targets were not revised.

Revised PDO Indicators

23. PDO indicators were not changed during the implementation of the Project.

Revised Components

24. Component A was not revised. Construction of the access road and other associated infrastructure, drilling to two slim wells, and relevant TA for assessment of the geothermal resource potential and technical supervision were carried out with minor deviations from the original plan.
25. Component B was not implemented nor revised. Phase II of the Project exploratory drilling program and transaction advisory was designed to be implemented only if warranted by positive results of Component A.

Other Changes

26. Phase I was implemented largely according to the plan. There were no significant changes to the scope or scale of the Project. The minor changes in the implementation and arrangements of the Project had limited influence on the schedule of the activities.
27. The Project originally envisioned one or two slim wells to be drilled to 1,200 m in Phase I to test the hypothesis that the low resistivity layer found between 500 and 1,000 m depth represented the clay cap of a high temperature geothermal reservoir. Although not explicitly stated in the PAD, the well(s) drilled in Phase I were envisioned to be drilled using coring technology that requires less circulation water than drilling with a conventional tri-bit drill cone. During preparation of the bidding documents for Phase I drilling, R2E2, with support of its expert consultants, concluded that slim wells could be drilled more efficiently with a small conventional rig using tri-cone bit. Such rigs can safely drill to greater depths than coring rigs and, as a result, the design of the slim wells was altered to reach to 1,500 m depth to provide more information about the properties of the geothermal resource.
28. The only deviation in the Project's original timeline was caused by delays in the construction of the access road to the Karkar site and rig pads, required for transportation of the equipment and facilities for drilling the slim well(s). The road was only 95 percent completed in the 2015 season, as works had to stop in November 2015 as weather conditions worsened earlier than expected. The contractor resumed its work as soon as the site became accessible again in spring 2016, but this delayed by about a month the start of the drilling activities. Drilling of the first slim well started on July 15, 2016, after the access road was completed. The original plan had been to start the drilling in June. The well was finalized on September 21, 2016 and well tests were completed on September 29, 2016.



Rationale for Changes and Their Implication on the Original Theory of Change

29. The minor deviations from the planned activities did not affect the original theory of change.

II. OUTCOME

30. The extent to which the objective of the Project is achieved is **Satisfactory**. The Phase I exploratory drilling gathered the necessary evidence to conclude that the geothermal resource at the project site was not suitable for power generation. The Government thus decided not to proceed with Phase II Component B of the project.

A. RELEVANCE OF PDOs

Assessment of Relevance of PDOs and Rating

Rating: **Substantial**

31. The PDO has remained consistent with country engagement priorities. Particularly, the Project's outcomes have provided evidence-based information on the strategic issue of power supply options for Armenia. The Project, as planned, was consistent with the Country Partnership Strategy (CPS) for Armenia, specifically since it is centered on engagement area 1.3 of the CPS (improved access, quality and sustainability of key infrastructure) to eliminate constraints to competitiveness and job creation through selective energy sector investments.
32. The Project did not contribute to the higher-level objectives of economic growth, job creation and GHG emission reduction due to the fact that a geothermal plant was found not to be feasible at the site. However, the Project contributed to local capacity building for possible future geothermal projects—the local construction and drilling service contractor (DSC) engaged new technologies and machinery, and the interested municipalities, public entities, and civil society learned about the necessary arrangements for developing such projects.

B. ACHIEVEMENT OF PDOs (EFFICACY)

Rating: **Substantial**

33. The PDO consist of two parts. The first was confirmation whether the geothermal resource at the project site was suitable for power generation and, the second, if the resource were confirmed, to involve the private sector in the development of a geothermal power plant. The first part of the PDO was reached by concluding that the geothermal resource at Karkar was not suitable for power production and the second part was, thus, rendered irrelevant.



Assessment of Achievement of Each Objective/Outcome

34. **Outcome (i)** *Confirm whether the geothermal resources at the Karkar site were suitable for power generation.*
The target for the indicator “Evidence provided to the Government for its decision on whether to construct a geothermal power plant at the Karkar geothermal site” has been achieved. High-quality technical, economic, environmental, and social studies were completed to gather evidence on the potential for development of a geothermal power plant at Karkar.
35. The first slim well (B-1) was drilled to 1,497 m depth and the bottom hole temperature was determined to be 120°C. During drilling of B-1 it became clear that the resistivity pattern was due to the stratigraphic transition rather than to a hydrothermal alteration resulting from a high-temperature hydrothermal system. Also, no permeability (i.e. geothermal flow) was found in B-1. However, due to the relatively steep thermal gradient found near the bottom of the well and taking into account the location of tectonic faults observed by site geologists, R2E2 Fund’s Technical Supervision and Support Consultant (TSSC) recommended that the second slim well (B-2) be drilled about 500 m to the southwest of B-1 to 1,800 m depth to assess whether a geothermal reservoir of 140–160°C could be found.
36. Well B-2 had been drilled to 1,684 m depth in November 2016 when drilling operations had to be stopped due to onset of winter at the project site with heavy snowfall and extremely low ambient temperatures that rendered the water supply system unusable. The unstabilized temperature measured at 1,600 m depth was 124°C, indicating a formation temperature in the range of 130 to 135°C. Circulation had been lost at 1,660 m, which gave hopes to the TSSC that the productivity of the well could be tested. However, during completion of the well, about 80 m of debris from the uncased section of the well, accumulated at its bottom, preventing the testing from being carried out. It should be noted that even if good productivity had been found, the cost of generating electricity from the fluid from B-2 would still be significantly higher than the cost from other available supply options (see paragraph 43).
37. The results from the two slim wells drilled in Phase I confirmed that the temperature conditions were in line with Scenario 3 identified in the PAD, i.e. that temperatures were too low for a flash power plant but might be in the technically feasible range for a binary technology power plant if permeability (i.e. geothermal flow) was present at depth. As per the project design, this result left the decision whether to pursue development of a binary plant to the Government, a decision that had to be agreed with the World Bank. Based on the result of the Phase I exploratory drilling, the Ministry of Energy and Natural Resources (MENR) and R2E2 carried out three activities to assess whether it was justified to proceed to Phase II:
- (i) First, R2E2 explored the possibility of contracting the drilling company that had drilled the two slim wells to clean the accumulated debris from the bottom of B-2, but the contractor viewed the task as technically very risky and did not wish to mobilize for such a small job. Other contractors were contacted but also viewed the job as too risky and small to undertake. It should be noted that—even if the debris in well B-2 had been cleaned out—it would only have had limited material implications on the evaluated unit cost of energy because the bottom hole temperature of the well is fairly well constrained. The Government and World Bank thus agreed not to pursue this option further in March 2017.
 - (ii) Second, the R2E2 Fund updated the original economic and financial analysis (E&FA) for a potential binary plant at Karkar based on the observed temperatures and water level. As a first step, R2E2 commissioned a pre-feasibility study to carry out a preliminary cost calculation of a geothermal binary



plant at Karkar based on the drilling results and under different temperature and flow rate scenarios. These costs were used as inputs for the updated E&FA, which showed that, under the assumption that sufficient well productivity would be found at Karkar, a geothermal plant would not be economically viable compared with other supply options and that the minimum tariff required to make the project financially viable would be significantly above the average supply cost for Armenia except when using unrealistically optimistic assumptions about resource temperature and flow rate (see paragraph 43)⁴.

- (iii) Finally, MENR reached out to about 50 international geothermal developers to gauge their interest in developing a plant at Karkar based on the technical information gathered. Only one firm expressed interest in the Project. This firm, however, was not viewed as credible as there was no proof of the firm's technical and financial capabilities to carry out the Project, the tariff offered was unrealistically low, and the firm stated it would only be interested if awarded the contract on a single-source basis.
38. In January 2018, the Bank team received verbal confirmation from MENR on its decision to close the Project without proceeding to Phase II, and the formal closing letter request was received on April 29, 2019.
39. **Outcome (ii)** *Involving the private sector in the development of the geothermal power plant*, is not relevant for this assessment given that the results from Component A did not justify proceeding with implementation of Component B.

Justification of Overall Efficacy Rating

40. The overall Project efficacy is rated **Substantial** as the Project achieved the intended outcome of providing the necessary evidence to decide whether or not to proceed to Phase II and construct a geothermal power plant at the Karkar geothermal site.

C. EFFICIENCY

41. Most international geothermal development experience shows that the upstream phases of development inevitably rely strongly on public sector investment, with private developers entering the Project at more mature phases (i.e., when resource risk has been significantly reduced). Considering the Project as the first one for testing the geothermal potential at Karkar through exploration drilling, the use of public resources (in the form of a SREP grant) was justified. The budget overruns experienced in the project (see description below), some of which were due to unforeseen drilling circumstances, also prove the riskiness associated with early-stage drilling.

Assessment of Efficiency and Rating

Rating: **Modest**

⁴ The most optimistic assumptions included a resource temperature of 160°C, 25 to 30°C higher temperature than what can be expected at Karkar based on the results of exploration drilling. Even though it is technically possible to generate electricity from a geothermal fluid at 130 to 135°C (the estimated bottom hole temperature in B-2) this would not be economically feasible even under the most favorable flow rate conditions.



42. Economic and financial analyses (E&FA) were not conducted for the Project per se, but for the potential power geothermal plant the Karkar site, which would have been built after Project closing with participation from the private sector if a suitable geothermal resource had been confirmed at the site. The E&FA carried out at appraisal were updated by the Government after completion of Phase I in order to inform the decision of whether to proceed with Phase II of the Project (i.e. Component B).
43. **Economic Evaluation.** At appraisal, the economic analysis of the potential geothermal power plant was conducted for two different geothermal plant concepts assuming the possible highest expected temperature and the lowest technically feasible temperature, corresponding to Scenarios 2 and 3, respectively. Specifically, the economic analysis was conducted for a flash cycle plant with expected resource temperature of 250°C and a binary plant (Organic Rankine Cycle, ORC) with expected resource temperature of 130°C⁵. The appraisal stage economic analysis suggested that a potential flash cycle geothermal power plant at the Karkar site would be one of the least-cost supply options available for Armenia. The LEC of the potential flash cycle geothermal power plant was estimated at US\$ 0.09/kWh, which was below the estimated economic LEC of all new supply options available to Armenia. On the other hand, if the exploratory drilling suggested that the resource temperature was in the order of 130°C and thus only a binary plant would be technically feasible, its LEC could be around US\$ 0.15/kWh, or significantly higher than other supply options⁶.
44. A new economic analysis was prepared in September 2017 based on the results of the Phase I drilling. This analysis showed that a geothermal power plant built at the Karkar site would most likely not be an economically viable option compared to alternative supply options in Armenia (solar PV, natural gas, wind, and small hydropower). Several possible scenarios for a conceptual plant based on a range of possible temperatures and well flow rates based on the drilling results were assessed. Only the most favorable assumptions, i.e. (i) reservoir temperatures of 140°C or 150°C with very high well flow rates or (ii) temperature of 160°C at moderately high flow rates, resulted in LECs in the range of LEC for other options (US\$ 0.0909 to 0.1504/kWh). For any other less favorable combination of temperature and well flow volume, the LEC of the conceptual plant ranged from US\$ 0.1938 to 0.5105/kWh, significantly higher than the LEC of any other supply option available in Armenia and therefore not economically viable.
45. **Financial Evaluation.** The financial analysis carried out on the basis of the drilling results assessed the tariff level required to make a conceptual geothermal plant financially viable. The tariff required, in almost all temperature and flow scenarios, was substantially higher than the range of tariffs already in force for existing generation in Armenia (US\$ 0.065–0.067/kWh). For instance, a tariff of at least US\$ 0.300/kWh (five-times the rates in force) would be required for the financial viability of a plant operating at a resource temperature of 120°C and a well flow volume of 30 kg/s, assuming public financing terms. Only the most optimistic conceptual plant scenario would allow for a tariff below the tariffs already in force in Armenia (i.e. a conceptual plant with a 160°C resource temperature and well flow volume of 70 kg/s would be financially viable at a tariff of US\$ 0.061/kWh, assuming public financing were available). It must be noted that Armenia does not have a feed-in-tariff (FiT) for geothermal. At the time of appraisal, FiTs were only available for small hydropower plants. Currently, small PV, wind, biogas and biomass plants can also benefit from FiTs.

⁵ This analysis was based on international reference parameters for flash and binary power plants, given that no information was available on the specific temperature and flow parameters at Karkar (these could only be assessed through exploration drilling).

⁶ LEC estimates for other supply options at appraisal were: US\$ 0.148/kWh for solar PV, US\$ 0.101/kWh for new CCGT, US\$ 0.077/kWh for Loriberd HPP, and US\$ 0.068/kWh for Shnogh HPP.



46. **Budget overruns:** The original budget for Component A, as per the PAD, was US\$5,375,000. However, the final expenses, at project closing, were \$7,870,000, or about 46% higher than the estimate. For most of the main contracts under this Component (TSSC, well logging and testing, and construction of access road and other infrastructure), the difference is the result of an underestimation of costs at appraisal, as the original contract values were 70-87 percent above the original estimates. These estimates were based on benchmark costs for the geothermal sector. However, discussions with the selected bidders revealed that the relatively small size of the contracts (i.e. compared to other active or prospective geothermal projects in the world), the remoteness of the project site, and logistical challenges with respect to shipping equipment and consumables to Armenia contributed to the higher costs for this relatively small-scale investment.
47. On the other hand, the higher cost of drilling the two slim wells (the main cost item in the project) compared to the original contract value was mostly the result of the longer than expected time that it took to drill the first well, 70 days, compared to the original 35 days in the drilling plan, and thus the additional day-rates to be paid to the contractors. This additional time requirement was the result of unforeseen circumstances and events, including the need to cement the upper sections of the well due to a total loss of drilling fluid (resulting from unexpected permeability), the slower drilling progress due to unstable layers (i.e. tuff formations) as well as harder than anticipated rock formations, the drilling string getting stuck, and the failure of one of the engines. The Drilling Service Contractor (DSC) also had to purchase additional materials (e.g. drilling fluids, casings and accessories such as drill bits) which were not included in the original bill of quantities to resolve some of these unforeseen events.

Table 1: Cost of main project contracts under Component A

Contract	Estimated cost at appraisal (USD)	Original contract value (USD)	Actual cost (USD)	Difference (ACT-EST)
Technical supervision and support consultant (TSSC)	125,000	271,000	279,400	70%
Well logging and well testing consultant	290,000	650,820	492,652 (1)	70%
Construction of access road, rig pad, and water supply	775,000	1,323,251	1,447,887	87%
Drilling of two slim wells	4,200,000	4,124,000	5,404,000 (2)	30%

(1) The actual cost of well logging and testing was below the original contract value due to two main reasons: (i) well testing of well B1 was not carried out since no permeability was found, and (ii) well testing of B2 could not be carried out due to the debris that accumulated at the bottom.

(2) The actual cost of drilling two slim wells was higher than the original contract value due to the additional day-rates incurred by the longer than expected time that it took to drill well B1 and to the need to purchase additional materials not included in the original bill of quantities (see para. 46 above)



D. JUSTIFICATION OF OVERALL OUTCOME RATING

48. The overall outcome is rated **Moderately Satisfactory** due to the relevance of the PDO at Project preparation (high) and closing (substantial), its substantial efficacy in achieving the intended outcome with only minor deviations from the original plan, and the modest efficiency with which the inputs and resources translated into results due to cost overruns.

E. OTHER OUTCOMES AND IMPACTS (IF ANY)

Gender

49. The Project had limited impact on gender issues due to its inherent nature. However, gender-sensitive consultation mechanisms were followed by R2E2 during project preparation. In addition, temporary local job opportunities were generated during the drilling operation, both at the work site and for the provision of services to the workers. These jobs were advertised through the appropriate local channels to ensure that both male and female applicants had equal opportunities and that the hiring processes were non-discriminatory. Although all the jobs related to construction and drilling were performed by men, most of the jobs for the provision of services in the workers' camp (e.g. food provisioning, cleaning) were provided by women from the nearby communities.

Institutional Strengthening

50. The technical complexity of the Project, which introduced new technologies never used before in Armenia, created the conditions to develop new technical and managerial capacities, especially at the implementing agency, R2E2 Fund. The R2E2 Fund also strengthened its procurement capacity, given the complex contractual nature of the Project and the need to manage several contract modifications due to the changing conditions in the drilling operation.

Mobilizing Private Sector Financing

51. One of the main objectives of the project was to support the Government to mobilize participation from a private sector developer under a Public-Private Partnership (PPP) scheme if the existence of an exploitable geothermal resource was confirmed during the Phase I exploration drilling at Karkar. Although the results from Phase I were not positive, MENR and R2E2 still decided to make an attempt to gauge private sector interest to develop a geothermal plant at Karkar, by sharing the results of Phase I with about 50 developers (both through written communications and through presentations and meetings during international renewable energy conferences) and inviting them to submit proposals informally. The lack of response from most developers, and the explicit negative response from some of them, confirmed that Karkar was not a good prospect.
52. Although the exploration drilling did not demonstrate the feasibility of geothermal power production at Karkar under the current market conditions considering available technologies, it has demonstrated that temperatures in the range of 125 to 135°C can be reached at relatively shallow depths in the Karkar area. The exploration drilling has also provided information about the subsurface stratigraphy in the area and the nature



of the rock formation where elevated temperature is observed. While significant uncertainty remains regarding the productivity of the resource, the information collected through the exploration drilling project could inform future feasibility and exploration studies in the area aimed at exploring the use of the resource for direct use or electricity generation using technologies that are not currently commercially available.

Poverty Reduction and Shared Prosperity

53. The Project had potential to contribute to the Bank’s twin goals of reducing poverty and promoting shared prosperity. Specifically, low-cost electricity from a potential geothermal plant, especially under the high-temperature Scenario 1, would have helped keep electricity affordable and reliable by ensuring the least-cost optimal addition of new capacity. However, given that the project did not proceed to Phase 2, these benefits were not realized.

Other Unintended Outcomes and Impacts

54. One of the main indirect (but not unintended), long-lasting positive impacts of the project was the construction of the 12 km gravel access road from the main road to the project site. The road, replacing an old and very primitive track, may be considered as a critical infrastructure for further development of the agricultural industry (e.g. cattle breeding, honey production) as it improves access to pasture lands in the area for the surrounding communities.
55. The project also contributed, both through the formal consultation process during project preparation, as well as through its Grievance Redress Mechanism, to the establishment of an institutionalized inter-community communication platform among the three villages affected by the project.
56. Creation of temporary local employment and contribution to the domestic economy were indirect (but not unforeseen) positive impacts of the Project. Communities around the project site benefitted from business opportunities such as selling and preparing food for workers and providing temporary accommodation to the project management personnel and visitors.
57. Finally, the communication effort carried out by MENR and R2E2 to reach out to potentially interested developers also had the positive effect of building international awareness about investment opportunities in the Armenian renewable energy sector, beyond geothermal, at a time when MENR was also promoting development of solar and wind resources.

III. KEY FACTORS THAT AFFECTED IMPLEMENTATION AND OUTCOME

A. KEY FACTORS DURING PREPARATION

58. **The original objectives of the Project were well settled within the participatory framework applied during preparation of the SREP IP, which ensured broad support for the project.** An extensive internal and public



consultative process was led by MENR to identify priorities in the development of renewable energy technologies for electricity and heating. The consultations included a wide range of government agencies, as well as representatives from the private sector, civil society and academia. Discussions were also joined by the group of Multi-lateral Development Banks (MDBs) as well as bilateral agencies. The consultations, which were informed by the analysis carried out by R2E2 Fund and its consultants, helped to ensure the relevance and general buy-in for the proposed project.

59. **Extensive engagement by the World Bank was essential to ensure the quality of Project design.** Following approval of the SREP IP, the World Bank team mobilized additional grant resources (about USD 250,000) from the Energy Sector Management Assistance Program (ESMAP) to complement the USD 300,000 Project Preparation Grant provided by SREP. These additional funds were used to provide Bank-executed technical assistance for project design, including: (i) assessment of drilling and water supply options, preparation of suggested technical inputs for the drilling program, costing of the drilling program for different well types, advice on contractual structure (i.e. integrated drilling contract), preparation of estimated project timeline, exploration of the market for drilling companies; (ii) additional surface exploration, including CO₂ soil flux measurements and geo-radar survey to adjust the final coordinates of the exploration wells to increase the likelihood of hitting the faults at depth; and (iii) expert advice on the two-phase exploration drilling program design to inform the proposed design as well as management approval at the Quality Enhancement Review stage. In addition, the Bank team thoroughly reviewed the bidding documents for the DSC, the TSSC, and the well logging and testing consultant. Given the lack of prior experience with geothermal development in Armenia, this comprehensive support was essential to ensure a sound project design, as well as to start building technical and procurement capacity within the R2E2 Fund.
60. **The division of the Project Objective into two phases, with appropriate outcome indicators, was envisioned as a risk mitigation measure to make an efficient use of scarce SREP grant resources.** This approach was considered especially sensible by the Bank team given that the likelihood of finding a viable geothermal resource was already considered low at the time of project design based on the interpretation of the available surface exploration results. The Bank team engaged two renowned industry experts from two well-known geothermal development companies, who confirmed that, based on the geothermal information available, the most sensible approach would be to first try to confirm the presence of the resource through drilling one or two slim wells and, only after the resource had been confirmed, proceed to drilling a full-size exploration well, which would provide the necessary additional information to possibly attract private developers to participate in a PPP scheme with the Government to develop a power plant at Karkar.
61. **The choice of Implementing Agency was appropriate.** R2E2 Fund was already highly experienced with implementation of Bank-financed energy efficiency and renewable energy projects and technical assistance activities and was staffed with a competent team, which made the Bank team confident that they would be able to successfully manage the Project. To address its lack of experience with implementation of geothermal drilling projects, the project would finance various expert consultants, most notably the TSSC, to support project implementation.

B. KEY FACTORS DURING IMPLEMENTATION

62. **Seamless communication among the key actors and proactivity by R2E2 Fund and its contractors (TSSC and DSC) were essential for successful Project implementation.** The communication between R2E2 Fund and the Bank team, as well as with the TSSC and the DSC, was very fluid throughout project implementation, which helped ensure that the works were carried out following international best practices, both from a technical, as well as an environmental and health and safety perspective. Initially, a few changes to the original



implementation plans were introduced by R2E2 Fund during the infrastructure construction work and in the early drilling stages which were not timely communicated to the World Bank. These included the extraction of road construction material from a hill in the road corridor and the construction of a small pond to collect water for the drilling operation, none of which were contemplated in the original ESIA (see section IV.B below on compliance with environmental safeguards). In addition, the final drilling program, which was submitted to the Bank in preparation for the July 2016 mission, included a well design modification of the original contractual specifications. R2E2 had agreed to this modified well design proposed by the DSC in April 2016, but the modifications had not been communicated to the World Bank team. Although the World Bank found the change of well design acceptable, the team also noted that the casing program had to be modified accordingly to meet international safety standards. The modifications were made promptly by the TSSC, and additional casing pipes were procured, resulting in a few days delay of the drilling activities. After the July 2016 mission, and the constructive dialogue established to resolve these issues, a trust relationship had been established with the TSSC and the DSC, which was fundamental during the rest of the drilling operation.

63. **The short window of time available for the drilling operation impacted some key decisions and forced the team to take some informed risks.** Due to the access restrictions imposed by expected onset of winter at the site in October (based on historical weather data), it had originally been foreseen that drilling operations would need to be finalized by late September 2016 to then proceed to demobilization of the drilling rig and other equipment. However, given the delays in starting and completing drilling for B-1, a decision whether to immediately proceed with drilling B-2 had to be taken in the last week of September 2016. In order not to lose time, the civil contractor was instructed to prepare the well pad for B-2 while B-1 was still being logged and discussions were ongoing among R2E2, TSSC and the Bank to decide whether to drill B-2. A positive decision was made considering that: (i) the steep thermal gradient found near the bottom of B-1 could be a sign of the existence of a geothermal reservoir at higher depths; (ii) weather conditions in the previous years had only become critical towards the end of November, (iii) strong confidence by the TSSC and the DSC that B-2 could be drilled in only 37 days; and (iv) it would be almost impossible to re-mobilize the rig for the following spring due to the likely unavailability of the rig itself and the high cost associated with such re-mobilization. Drilling of B-2 had to stop on day 52 of drilling (November 28, 2016) at 1,660 m, before reaching the target depth of 1,800 m, given that the low ambient temperatures had frozen the water supply. The site had to be evacuated on December 4, 2016 due to dangerous weather conditions.
64. **The official Government decision not to proceed with Component B and close the Project was delayed by one and a half years due to the changes of responsible Ministers as well as of R2E2 Director.** MENR and R2E2 Fund were initially reluctant to close the Project as, according to SREP rules, this required returning the unused grant funds (about \$2 million) to SREP, without a guarantee that they could then be re-allocated to other projects in the Armenia SREP IP (as opposed to being re-allocated to priority projects in other SREP countries). A decision to close the project was finally made in January 2018 by MENR. However, changes at the Minister and Deputy Minister level, as well as the R2E2 Director level caused a delay in the final communication being sent to the World Bank. The ensuing team from the Ministry and R2E2 Fund had to be properly briefed about the Project and the evidence justifying its cancellation, which took time given the technical complexity of geothermal and the fact that this was a novel technology for Armenia. Once the technical justification to close the Project was fully clarified, and it was re-confirmed that there was no process that would allow Armenia to directly reallocate the remaining funds to another project in the SREP IP, a totally new process of internal decision-making within MENR, as well as within the Ministry of Finance, had to be completed. This delayed the formal request for project closing until April 2019, only a few weeks before the official original closing date of the project. As a result, unused SREP resources could not be swiftly returned to SREP for deployment in other priority projects (in Armenia or other SREP countries) as soon as the results from Phase 1 confirmed



that there was not a geothermal resource suitable for power generation at Karkar⁷. During this time, the World Bank never considered to proceed unilaterally with restructuring and partial cancellation of the Project. It was considered logical that the Government wanted to have every possible assurance that a geothermal project at Karkar was not viable and that it was not possible to keep the unused grant resources, and that this could also be unequivocally justified to all the relevant national stakeholders.

IV. BANK PERFORMANCE, COMPLIANCE ISSUES, AND RISK TO DEVELOPMENT OUTCOME

A. QUALITY OF MONITORING AND EVALUATION (M&E)

M&E Design

65. Two levels of M&E were planned and implemented for the Project. R2E2 would submit regular progress reports as well as engage in regular communication with the Bank team. The M&E framework was designed to be simple but fully aligned with the Project objectives. Implementation progress was to be systematically tracked based on data and information gathered through specific missions of the World Bank team and regular reporting and communication from the key stakeholders (i.e. R2E2 Fund and the TSSC).

M&E Implementation

66. M&E activities were carried out as planned. Responsibilities were clearly established at the design stage to ensure methodologically sound reporting and analysis. The World Bank team adequately recorded its monitoring activities through regular mission Aide Memoires and Management Letters as well as through semi-annual ISRs.
67. Despite the relative simplicity of the Project's results framework, adequate monitoring by R2E2 and the Bank was critical to ensure the safety and technical soundness of the drilling operation. During the drilling and well logging and testing activities, daily reports prepared by the TSSC, who was in charge of daily monitoring of project activities on behalf of R2E2 Fund, were shared with the Bank team. In addition, regular calls were organized with the TSSC and R2E2 Fund to review drilling progress and discuss any necessary corrective measures or changes in the drilling plan. To ensure the quality of its monitoring and implementation support to R2E2 Fund, the Bank team engaged the services of a drilling engineer and a well logging and testing consultant, who also reviewed relevant technical reports and visited the site at critical stages of the drilling operation (e.g. first week after drilling of B-1 commenced, testing of B-1).
68. Besides the regular progress reporting by R2E2 Fund and the ISRs prepared by the World Bank team, the "Well completion report", prepared by the TSSC and issued on April 3, 2017 and the "Update to the Economic and Financial Appraisal of the Potential Geothermal Power Plant at Karkar" prepared in September 2017, provided additional data and analysis that was considered essential to complete the evaluation of the Project.

⁷ Funds could only be returned to SREP once the TF funding this project was legally closed.



M&E Utilization

69. The World Bank team diligently and consistently implemented the M&E framework, using the ISRs not only for monitoring and updating the Project status under the defined framework, but also to raise to management's attention relevant issues that emerged during implementation. The Bank team also shared its views on implementation issues, mostly regarding drilling decisions and interpretation of drilling and logging and testing results, and often requested clarifications and updates from R2E2 Fund and the TSSC. The regular missions, including site visits, by the Bank team and its expert consultants were also a key component of the monitoring activities.

Justification of Overall Rating of Quality of M&E

70. The overall quality of M&E is rated **Substantial**. The World Bank set a number of indicators to monitor the progress of activities and achievement of objectives. The monitoring and analysis methodology identified during the preparation was applied for regular reporting. The implementation and the utilization of the M&E framework has been done well. The World Bank team diligently and regularly developed and submitted ISRs reflecting all Project-related issues in a structured and well-justified way. The Bank team also used the reporting as a means of close supervision. In addition, all the relevant communications between the World Bank and R2E2 Fund were adequately documented and filed in the World Bank's electronic filing system.

B. ENVIRONMENTAL, SOCIAL, AND FIDUCIARY COMPLIANCE

71. **Environmental and social safeguards.** The Project was assessed to have low Systematic Operations Risk-Rating Tool (SORT) rating on environment and social risk category and classified as Category B with Environmental Assessment (OP/BP 4.01) and Involuntary Resettlement (OP/BP 4.12) policies triggered. The Project had a strong commitment to full compliance with Bank safeguard policies and management of safeguard issues was rated Satisfactory for most of the implementation period. The Project also complied with the World Bank Group's Environmental, Health and Safety Guidelines.

72. The one instance when the safeguards rating was downgraded to Moderately Satisfactory was following the July 2016 mission, due to two issues revealed during the site visit. Two deviations from the planned activities were decided by R2E2 Fund during preparation for the drilling operations in the summer of 2016. The water supply strategy for the drilling operation had to be changed from the original plan of transporting drilling water by tanker trucks from a fresh water well located some 8 km from the project site as had been anticipated when the Environmental and Social Impact Assessment (ESIA) report was prepared. To create an alternative source of reliable water supply that could be relied upon in any drilling emergencies, R2E2 decided to construct a small pond for collecting surface water from a nearby stream about 2km away from the drilling site. The use of surface water for the drilling operation was not contemplated in the original ESIA but it was confirmed by R2E2 Fund's and the Bank's environmental specialists that this alternative would not cause any significant impacts. The second issue observed during the field visit in July 2016 was that extraction of earth for construction material for the road had been ongoing from a hill next to the road corridor, an option that was also not included in the ESIA. To address these issues, R2E2 prepared a revised ESIA report and



Environmental Management Plan (EMP). The amended ESIA and EMP were disclosed in-country and by the Bank. The revised documents included a justification of how and why the alternative solutions for supply of water for the drilling operation and of materials for road construction were revised as well as additional details of how the solutions were implemented and an analysis of associated impacts and mitigation measures. The safeguards rating was again upgraded to Satisfactory in the following reporting period.

73. It is also noted that there was no gender-based violence caused by labor influx at the project site.

74. **Fiduciary compliance.** The Project's financial management was **Satisfactory** overall. Although there were issues during the first 18 months of Project implementation due to delays by R2E2 Fund in the implementation of adequate internal controls as well as delays in submitting Interim Financial Reports in a timely manner, these issues were finally resolved. The Final Audit Report was published in July 2019. Based on transaction review results during supervision, the internal control system was assessed to be adequate.

75. Procurement compliance was also considered **Satisfactory** overall but downgraded to Moderately Satisfactory during part of the reporting period as a result of the need to modify both the original cost estimates and procurement method (from QCBS to CQS) for two of the main consulting contracts (i.e. TSSC and well logging and testing). It is however considered that these issues were mostly beyond the control of R2E2 Fund and were a result of the lack of experience in such complex projects and also the fact that qualified developers required a premium to mobilize for such a small drilling project.

C. BANK PERFORMANCE

Quality at Entry

76. The Project's objective was highly relevant to the World Bank-Armenia Country Partnership Strategy and the SREP Investment Plan. During preparation, the Bank team provided sufficient inputs and guidance to R2E2 Fund on technical aspects as well as on Bank procedures. The Bank team conducted due diligence on R2E2's implementation capacity and appraised the Project design with a sound methodology. The Bank team also notified the R2E2 of fiduciary requirements. The M&E framework was also adequately set up and the methodology for reporting identified during preparation.

Quality of Supervision

77. The Bank team carried out close supervision and implementation support, including seven official supervision missions with key staff and frequent working meetings with R2E2 Fund and the TSSC during the planning and implementation period. At each official mission, the Bank checked on the progress toward achieving the development objectives. The Bank team recorded the implementation status and issues in aide-memoirs and ISRs. The Bank was always responsive when issues emerged or R2E2 had requests. The Bank's support included dispatching a geothermal drilling engineer to the site at the beginning of the drilling activities and a reservoir engineer during the completion and testing of well B-1, review of daily drilling reports by experienced borehole geologists, providing training on procurement, reviewing revisions of the drilling programs, and so on. Even when official missions were not conducted, the Bank maintained close supervision of the Project in close collaboration with R2E2 team members.



78. The Bank team captured technical and operational issues in the ISRs in a candid manner with accurate analysis. They flagged important issues for management attention in a timely manner and recorded detailed measures to be taken along with realistic timelines in the ISRs and followed up in a systemic way.

Justification of Overall of Bank Performance

79. Overall, the World Bank performance is rated **Satisfactory**. During project preparation and at appraisal, the World Bank provided extensive inputs and guidance to the R2E2 team for compliance with Bank policies as well as with best international practices for geothermal drilling projects. During implementation, the Bank team provided close supervision and technical support, and all progress as well as issues encountered were recorded and monitored with candor under a high-quality performance reporting.

D. RISK TO DEVELOPMENT OUTCOME

80. Based on these results of the exploratory drilling campaign and the results of the updated E&FA analysis, it is not expected that additional drilling activities or technological advances (e.g. in generation technology) would unveil the existence of an economically exploitable resource. It is thus considered that the risk to the development outcome (i.e. confirmation that the geothermal resource at the project site is *not* suitable for power generation) is Low.

V. LESSONS AND RECOMMENDATIONS

81. **The phased approach of the project was consistent with emerging industry practices in geothermal areas with high resource uncertainty (e.g. in Dominica, Indonesia and the planned exploration drilling project in St Lucia; P161316) and was essential to its satisfactory outcome and to the efficient use of scarce grant resources.** The assessment of the quality of the resource in Phase I indicated a geothermal power plant at Karkar would not be economically viable, even if geothermal resources (i.e. geothermal flow) had been found. This has allowed for the preservation of the remaining SREP grant funds, which have been returned to SREP and can now be reallocated to other priority projects in the SREP pipeline (including in countries other than Armenia).
82. **A comprehensive and open outreach effort to private geothermal developers proved to be an effective way to unequivocally determine the commercial viability of further resource development after exploration drilling.** The three possible outcome scenarios foreseen in the PAD did not fully contemplate the possibility that the test well results would yield a result which fell in a grey area between *Scenario 2* (temperatures suitable for a flash cycle power plant) and *Scenario 3* (temperatures lower than required for a flash cycle power plant but higher than the minimum threshold needed for a binary power plant). The project was designed to include a pre-feasibility assessment based on the drilling results from Phase I. Such an assessment was prepared, based on a range of possible temperature and flow rate scenarios, and the results fed into the updated E&FA, demonstrating that a binary plant would only be economically or financially viable only in the most optimistic (and highly unlikely) temperature and flow scenario. Despite these relatively unequivocal indications some doubts remained within the Government regarding whether closing of the project and



“losing” the unused SREP grant funds was justified after Phase I. The solution the Project team and the client developed at this juncture was to use market sounding to see whether there was any private sector interest in partnering with the government in further exploration drilling. This approach, essentially using the private sector expertise to decide on the viability of the resource, perhaps having in mind opportunities for other higher-value uses of the site, could be considered in other exploration drilling projects designed with a phased approach.

83. **Availability of adequate funding for project preparation is key to mobilize industry expertise required to design a technically-sound project.** This is especially relevant in small countries with limited or no prior experience with geothermal development (e.g. Armenia, Djibouti, Dominica, St. Lucia) and thus no local expertise available. Geothermal is a highly technical and risky field that requires top industry professionals to prepare sound drilling programs (as well as cost estimates) in order to ensure that the drilling operations are designed and carried out according to the required technical and safety standards and that the drilling strategy is such that it maximizes the probability of success.
84. **Grant-funding and/or concessional financing of early-stage exploration is essential for the development of geothermal resources, especially in low enthalpy regions because of the substantial risk associated with finding a commercially-viable resource.** This experience in Armenia is backed by international experience in geothermal development, in which purely private development of geothermal resources is less common, and more typical of higher-enthalpy regions, and well-developed geothermal markets (with multiple experienced developers). International experience also shows that, in many countries, later-stage development of geothermal projects still require some concessional funds, and would likely have been necessary in Armenia as well to catalyze any serious private sector involvement.
85. **Adequately budgeting for contingencies is essential to avoid cost overruns in high-risk exploration drilling projects.** The cost overruns experienced in Phase I illustrate, to some extent, the magnitude of the risks and unknowns that characterize geothermal resource exploration and development. Whereas the cost overruns in this Project were relatively modest, the high-risk nature of the activity, and the unique component of geological risk (not present in other power projects) suggests that a higher cost contingency may have been warranted in budgeting and should be considered for any similar upstream geothermal projects going forward.
86. **Capacity building at the implementing agency is key to the project’s success.** The institutional strengthening approach encouraged by the Bank team helped build capacity at R2E2. The technical assistance provided by the independent experts on operational, financial, and economic aspects was also very useful in this regard. R2E2’s did not always communicate the deviations from the envisaged technical plan in a timely fashion, but its close cooperation with the World Bank team generally helped to build its internal capacity, which will be very relevant not only for evaluating possible geothermal projects in the future, but also for implementation of other complex projects in general.



ANNEX 1. RESULTS FRAMEWORK AND KEY OUTPUTS

A. RESULTS INDICATORS

A.1 PDO Indicators

Objective/Outcome: Confirm whether the geothermal resource at the project site is suitable for power generation

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Evidence provided to the Government for its decision on whether or not to construct a geothermal power plant at the Karkar geothermal site	Yes/No	N 14-Jan-2015	Y 31-May-2018	Y	Y 25-Jan-2019

Comments (achievements against targets):

Objective/Outcome: If resources are confirmed, to involve the private sector in the development of a geothermal plant

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
If geothermal resource is	Yes/No	N	N	N	N



confirmed, power plant development is competitively awarded to qualified private developer(s)		14-Jan-2015	31-May-2019		25-Jan-2019
Comments (achievements against targets):					

A.2 Intermediate Results Indicators

Component: Phase I Exploratory Drilling Program

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
One or two slim exploratory wells drilled to a depth of around 1,200 meters	Text	0 30-Mar-2015	2 31-Oct-2017	2	2 31-May-2019
Comments (achievements against targets):					

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Percent of registered project related grievances responded to within stipulated service standards	Percentage	0.00 30-Mar-2015	100.00 31-May-2016		100.00 31-May-2019



for response times

Comments (achievements against targets):

Component: Phase II Exploratory Drilling Program and Transaction Advisory

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
One production-size well drilled to a depth of around 1,800 meters if the results of the drilling of slim well(s) warrant such drilling	Number	0.00 30-Mar-2015	1.00 31-Oct-2018		0.00 31-May-2019

Comments (achievements against targets):

Since Phase I confirmed that the geothermal resource at Karkar was not suitable for power generation, the project did not proceed to Phase II, so this indicator is not relevant

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Feasibility study for a potential power plant completed	Text	No 30-Mar-2015	Yes 31-Dec-2018		No 31-May-2019



Comments (achievements against targets):

Since Phase I confirmed that the geothermal resource at Karkar was not suitable for power generation, the project did not proceed to Phase II, so this indicator is not relevant

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Tendering for private sector involvement in construction of a geothermal power plant completed if results from the feasibility study confirm technical and economic/financial viability of such a plant	Text	No 30-Mar-2015	Yes 31-May-2019		No 31-May-2019

Comments (achievements against targets):

Since Phase I confirmed that the geothermal resource at Karkar was not suitable for power generation, the project did not proceed to Phase II, so this indicator is not relevant



B. KEY OUTPUTS BY COMPONENT

Objective/Outcome 1: Confirm whether the geothermal resource at the project site is suitable for power generation	
Outcome Indicators	1. Evidence provided to the Government for its decision on whether or not to construct a geothermal power plant at the Karkar geothermal site
Intermediate Results Indicators	1. One or two slim exploratory wells drilled to a depth of around 1,200 meters
Key Outputs by Component (linked to the achievement of the Objective/Outcome 1)	1. Two slim exploratory wells were drilled. 2. Evidence was provided to the Government indicating that the geothermal resource at the power site was not suitable for power generation.
Objective/Outcome 2: If resources are confirmed, to involve the private sector in the development of a geothermal plant	
Outcome Indicators	1. If geothermal resource is confirmed, power plant development is competitively awarded to qualified private developer(s)
Intermediate Results Indicators	1. One production-size well drilled to a depth of around 1,800 meters if the results of the drilling of slim well(s) warrant such drilling 2. Feasibility study for a potential power plant completed 3. Tendering for private sector involvement in construction of a geothermal power plant completed if results from the feasibility study confirm technical and economic/financial viability of such a plant



Key Outputs by Component
(linked to the achievement of the Objective/Outcome 2)

1. Since Phase I confirmed that the geothermal resource at Karkar was not suitable for power generation, the project did not proceed to Phase II, so there are no outputs to report on.



ANNEX 2. BANK LENDING AND IMPLEMENTATION SUPPORT/SUPERVISION

A. TASK TEAM MEMBERS

Name	Role
Preparation	
Artur Kochnakyan, Almudena Mateos Merino	Task Team Leader(s)
Armine Aydinyan	Procurement Specialist(s)
Garik Sergeyan	Financial Management Specialist
Thrainn Fridriksson	Team Member
Vipasha Bansal	Team Member
Irina Tevosyan	Team Member
Jennifer Shkabatur	Social Specialist
Sarah G. Michael	Social Specialist
Rocio Mariela Malpica Valera	Counsel
Ilhem Salamon	Peer Reviewer
Gevorg Sargsyan	Program Manager
Jose C. Janeiro	Team Member
Marina Lysiakova	Team Member
Darejan Kapanadze	Social Specialist
Wendy E. Hughes	Peer Reviewer
Hiwote Tadesse	Team Member
Supervision/ICR	
Almudena Mateos Merino, Thrainn Fridriksson	Task Team Leader(s)
Armine Aydinyan	Procurement Specialist(s)



Lusine Grigoryan	Financial Management Specialist
Hiwote Tadesse	Team Member
Luis M. Schwarz	Team Member
Luz Meza-Bartrina	Counsel
Marina Lysiakova	Team Member
Arcadii Capcelea	Environmental Specialist
Sanjay Agarwal	Social Specialist
Artur Kochnakyan	Team Member
Irina Tevosyan	Team Member
Emil Zalinian	Team Member

B. STAFF TIME AND COST

Stage of Project Cycle	Staff Time and Cost	
	No. of staff weeks	US\$ (including travel and consultant costs)
Preparation		
FY15	17.204	89,618.88
Total	17.20	89,618.88
Supervision/ICR		
FY16	21.453	48,389.27
FY17	8.890	141,578.70
FY18	1.800	11,053.94
FY19	3.975	25,408.74
FY20	6.738	52,999.71
Total	42.86	279,430.36



ANNEX 3. PROJECT COST BY COMPONENT

Components	Amount at Approval (US\$M)	Actual at Project Closing (US\$M)	Percentage of Approval (US\$M)
Phase I exploratory drilling program	5.37	7.87	147 %
Phase II exploratory drilling program and transaction advisory	5.31	0	0
Total	10.68	7.87	74 %

NOTE: As its contribution to the Project, the Government co-financed 20 percent of all the contracts under the Project (including the Project Preparation Grant, which is not covered by this ICR). The details for each contract are available in the Project files.



ANNEX 4. BORROWER, CO-FINANCIER AND OTHER PARTNER/STAKEHOLDER COMMENTS



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N 01/22.3 Մ.Մ/19816-19

Համաշխարհային բանկի Հայաստանի
գրասենյակի ղեկավարի պաշտոնակատար
Ա. Հովհաննիսյանին

Ի պատասխան Ձեր 25.10.2019թ.-ի
թիվ WB-195/19 գրության

Հարգելի պարոն Հովհաննիսյան

Հայտնում ենք, որ Համաշխարհային բանկի՝ «Երկրաջերմային հետախուզական
հորատման ծրագրի» իրականացման ավարտի և արդյունքների հաշվետվության նախագծի
վերաբերյալ ՀՀ տարածքային կառավարման և ենթակառուցվածքների նախարարությունը
նկատառումներ չունի:

12.11.2019

X

VERIFIED OCSP 12.11.2019 16:49:16 GMT+4

Հարգանքով՝ Signed by: PAPIKYAN SUREN 3604860490



Ա.Պապիկյան



REPUBLIC OF ARMENIA
MINISTER OF TERRITORIAL ADMINISTRATION AND INFRASTRUCTURE

14.11.2019

To: A. Hovhannisyan
Acting Country Manager for Armenia
World Bank

Dear Mr. Hovhannisyan,

This is to inform you that The Ministry of Territorial Administration and Infrastructure of the Republic of Armenia has no comments to the Draft Implementation Completion and Results Report of Geothermal Exploratory Drilling Project.

Sincerely,

S. Papikyan