

## PREFEASIBILITY STUDIES OF THE AZUFRAL GEOTHERMAL FIELD

(TC-97-06-34-4)

### EXECUTIVE SUMMARY

<b>Requester:</b>	Republic of Colombia
<b>Executing agency:</b>	Instituto de Investigación e Información Geocientífica, Minero-Ambiental y Nuclear [Institute for Geoscientific, Mining and Environment, and Nuclear Research and Information] (Ingeominas)
<b>Financing:</b>	<p>IDB (Japanese Trust Fund for Consultancy): US\$1,500,000</p> <p>Local contribution: US\$ 300,000</p> <p>Total: US\$1,800,000</p>
<b>Terms:</b>	<p>Execution period: 18 months</p> <p>Disbursement period: 24 months</p>
<b>Objectives:</b>	The objective of this proposed nonreimbursable technical cooperation (TC) operation is to support the financing of prefeasibility studies for the Azufral geothermal field. The general objective of the prefeasibility studies is to determine the technical and economic advisability of preparing feasibility studies on the use of geothermal resources in the Azufral field, for the purpose of electric power generation in strict observance of environmental and social considerations.
<b>Description:</b>	The prefeasibility studies include geo-scientific studies; social and environmental analyses; a review of the political, legal, and regulatory context for geothermal resource development; and a probability-oriented economic and financial prefeasibility analysis. The feasibility studies per se, which would include exploratory drilling and address overall feasibility, are not included in this operation and can go forward only if recommended by the prefeasibility studies. If so recommended, they would be executed under private initiative.
<b>Environmental and social review:</b>	As part of the prefeasibility studies on the Azufral geothermal field, environmental and social studies will be conducted to identify the potential impact of developing the field on natural resources and human groups. The subsequent feasibility studies would include the design of appropriate mitigation measures.

<b>Benefits:</b>	The studies will provide: a model of the geothermal resource; an assessment of the sociological and environmental impact of developing it; policy recommendations with respect to private sector development of the geothermal resource, as well as on legal and regulatory matters. It will also provide an estimate of the financial resources required to develop this resource combined with an analysis of its projected value—in economic as well as financial terms.
<b>Risks:</b>	There is the risk of reaching a mistaken conclusion in favor of continuing with the actual feasibility studies. To mitigate this risk, the best possible illustrated terms of reference have been prepared by an international specialist with broad experience in the identification of geothermal resources. This will in turn reduce the risk of investing unnecessarily in subsequent feasibility and/or investment studies.
<b>The Bank's country and sector strategy:</b>	This operation is consistent with the objective of sustainable growth set forth in the most recent country paper, in that it would help to identify opportunities for private sector participation in the development of productive infrastructure and environmental protection.
<b>Special contractual clauses:</b>	As conditions precedent to the first disbursement, the contract with the consulting firm must have been signed and the Project Manager must have been designated.
<b>Social and poverty classification:</b>	This TC is not a specifically poverty-targeted operation.
<b>Exceptions to Bank policy:</b>	This operation does not entail exceptions to Bank policies and procedures. Furthermore, as a nonreimbursable JCF operation, it will be conducted in accordance with the consulting contract procedures stipulated by the donor.

## **I. BACKGROUND**

### **A. Introduction**

- 1.1 This document contains the plan of operations for prefeasibility studies of the Azufral geothermal field, to be conducted in Colombia with nonreimbursable financing from the Japanese Trust Fund for Consultancy (JCF). The field in question would be developed for the purpose of generating electric power for the Colombian energy market. The studies of the Azufral geothermal field would be conducted in two phases: the first includes prefeasibility studies, and the second, feasibility studies. The prefeasibility studies would in turn be divided into two stages, which would include geoscientific studies; social and environmental analyses; a review of the political, legal, and regulatory context for geothermal resource development; and a probability-oriented economic and financial prefeasibility analysis. The feasibility studies per se would include exploratory drilling and assess overall viability.
- 1.2 The nonreimbursable technical cooperation (TC) operation proposed here would finance the prefeasibility study activities only. This document refers exclusively to that first phase and presents the objective, description, study methodology, matters pertaining to organization and execution of the studies, their estimated cost and financing, and the benefits and risks they entail.
- 1.3 If the results of the prefeasibility phase are positive, with a recommendation to proceed with the second phase, the feasibility studies, it is anticipated that these latter studies—which would cost US\$3.5 million according to a preliminary estimate—would be conducted on the basis of private sector initiative and contributions. It is also expected that this resource would be developed by the private sector, should it prove feasible within the Colombian electric power market. This is consistent with the objectives of the Electric Power Sector Program currently being supported by Bank Loan 1159/OC-CO (PR-2362).

### **B. The Colombian electric power sector**

#### **1. Institutional framework**

- 1.4 The highest authority for the Colombian electric power sector is the Office of the President of the Republic, which exercises this responsibility with support from the Economic and Social Policy Council (CONPES). Most institutions in the sector fall under the Ministry of Mines and Energy (MME), but the Ministries of Finance and Public Credit (MHCP), Development (MD), and the Environment (MMA), as well as the National Planning Department (DNP), an advisory office to the Office of the President of the Republic, are also directly involved.

- 1.5 The sector's central authority is the MME, which operates through its specialized divisions, the National Energy Financing Division (FEN) and the Energy Mine Planning Unit (UPME). It also participates in the Energy and Gas Regulatory Commission (CREG). The FEN is essentially a financial support agency for the sector, whose purpose is to raise funds in capital markets and lend them to businesses in the energy sector. The UPME's function is indicative planning for the energy sector and monitoring expansion of the electric power system. CREG is responsible for regulating the energy and gas sectors. Its members are the Minister of Mines and Energy, the Minister of Finance and Public Credit, the Director of the DNP, and five independent commissioners. Environmental control functions are performed by the MMA, either directly or through the regional corporations under its authority.
- 1.6 The Superintendency of Household Public Services (SSPD), under the MD, is responsible for supervising the administration and quality of services provided by all public electric, gas, telephone, and water utilities.
- 1.7 The other players in the electric power sector are the agents and consumers. The agents are companies engaged in electric power generation, transmission, distribution, or marketing activities. The consumers may be regulated or unregulated.
- 1.8 Another related agency, though not traditionally considered part of the electric power sector, is Ingeominas, formally known as the "Instituto de Geociencias, Minería y Química". Its name was subsequently changed to "Instituto de Investigación e Información Geocientífica, Minero-Ambiental y Nuclear" [Institute for Geoscientific, Mining and Environment, and Nuclear Research and Information] by decree 1129 of 1999. Ingeominas is a national public establishment with legal capacity, administrative autonomy, and independent assets, placed under the authority of the Ministry of Mines and Energy. It is administered by a Board of Directors and a General Manager. The Board of Directors is composed of the Minister of Mines and Energy, or the Vice Minister of Mines, as chair; the Minister of the Environment, or his delegate; the President of ECOPETROL, or his delegate; the President of Minercol, or his delegate; and a representative of the President of the Republic.
- 1.9 There are currently no electric power plants operating within Ingeominas's electricity-related areas of authority: geothermal and nuclear energy. The institution has, however, conducted geoscientific research on the use of geothermal resources for electric power development in fields other than Azufral—specifically in Nevado del Ruiz. It is also contributing to geothermal research in other areas—mainly in the Department of Nariño—although in less depth than that planned for the Azufral field.

## **2. Legal and regulatory context**

- 1.10 The electric power sector is governed by provisions contained in the Household Public Services Act (Law 142/94), the Electric Power Act (Law 143/94), the Environment Act (Law 99/93), and regulations issued by CREG.
- 1.11 The regulatory framework under Law 143/94 is highly developed. Work is now being done to delineate areas of authority in the award of concession contracts. At the current time, there are virtually no regulations specifically covering geothermal resources, although it is assumed that a number of provisions concerning hydraulic or thermal electric power generation and the development of other mainly non-renewable resources, such as petroleum, are applicable. It is believed that the lack of specific regulations for geothermal resources may have hindered its development, given the uncertainty created by a regulatory void.
- 1.12 One of the most highly developed areas of electric sector regulation is the wholesale energy market. This market is of fundamental importance to the use of geothermal resources for electric power generation in that it defines the rules governing energy competition, dispatching, and contracts for energy generated within the national interconnected system.
- 1.13 The Wholesale Energy Market, which has been functioning since July 1995, encompasses the various systems for exchanging blocks of energy between generators and marketers within the national interconnected system, subject to operating regulations and other applicable provisions. The basis for this market consists of: (i) a power "pool", in which generators conduct commercial transactions on a spot market, with hourly booking and a central operator for the national interconnected system (National Dispatching Center), which is responsible for plant dispatching; and (ii) a long-term or contract market, which serves to reduce the risks implicit in the power pool.

## **3. The model for modernization of the electric power sector**

- 1.14 The globalization and open market process began in Colombia in the late 1980s, leading to structural reforms to promote more efficient and competitive economic activity and to refocus government attention primarily on the functions of planning, coordination, and regulation. With the enactment of a new Political Constitution in 1991, the way was opened for private sector participation in all economic activities, including public utilities and, more specifically, the supply of electric power.
- 1.15 Until the early 1990s, the structure of the electric power sector was under direct state control: the MME was the sector's nominal administrator; the DNP was responsible for approving investment plans; and the National Rates Board, under the DNP, approved electricity rates. As a result of the modernization process, and pursuant to laws 142 and 143 of 1994, a new framework was established for the

sector, characterized by: competition between generators; the separation of generation, transmission, distribution, and marketing activities; the establishment of a wholesale energy market as a means of dispatching and determining the price of electricity among generating plants; and free access to transmission and distribution systems to permit transactions between agents irrespective of their location.

#### **4. The Colombian electric power market**

- 1.16 **Generation.** In 1998, net electric power generation totaled 44,000 GWh, with maximum demand of 7,350 MW. The average growth rate for generation over the past twenty years was 6.4% per annum. Effective installed capacity as of the end of 1997 was 11,200 MW, of which 8,100 MW consisted of hydraulic power and 3,100 MW of thermal power. Between the second half of 1996 and the first half of 1997 there were sweeping changes in generator ownership, with more than 50% coming under private control in less than a year.
- 1.17 **Projected generation.** UPME is required by law to produce an indicative plan based on information available on a determined date, as well as a guide for investors reflecting the needs of the electric power sector in order to meet demand with a determined level of reliability. Electric power supply is highly dynamic, with installed capacity expected to rise from approximately 11,000 MW as of the end of 1997 to approximately 14,300 MW by 2001. During this interval, an additional 1,884 MW are expected to come from gas turbines, 549 MW from combined-cycle units, 150 MW from coal-steam, and 733 MW from hydraulic facilities, for a total of 3,316 MW, or 30% of the existing plant.

#### **C. Geothermal energy in Colombia**

- 1.18 Prospecting studies conducted by the Latin American Energy Organization (OLADE) and the Instituto Colombiano de Electricidad (ICEL) in 1982 concluded that there are several significant geothermal areas in Colombia with potential for different forms of development: some for the purposes of electric power generation and others for direct use of steam in industrial processes or as tourist sites. The untapped potential in terms of installed electric power generation capacity is estimated at some 1,000 MW.
- 1.19 According to studies conducted, inter alia, by Ingeominas, there are two potential areas for electric power generation. The first, in the southern portion of the Department of Nariño, near the border with the Republic of Ecuador, includes the country's largest geothermal field, with the Azufral de Tuquerres volcano and the fields associated with the Cumbal, Chiles - Cerro Negro, and Galeras volcanoes. The second area is the Parque Nacional de los Nevados in central Colombia, which includes Las Nereidas (Nevado del Ruiz), Laguna del Otún (Nevado Santa Isabel) and Machín volcano fields. The studies conducted by OLADE assign highest

priority for geothermal prospecting to the Azufral area in Tuquerres, based on geological, vulcanological, geochemical, and hydrogeological evidence.

- 1.20 The Paipa-Iza geothermal area, located in the Department of Boyaca, to the northeast of Bogota, is considered more suitable for the direct use of steam than for electric power generation.

#### **D. Environmental considerations**

- 1.21 By tapping into the natural heat found in tectonically active areas, geothermal power represents one of the cleanest means of generating electricity, releasing only small amounts of pollutants into the atmosphere. Geothermal power provides a means to avoid or replace fossil fuel generation, which pollutes the air. Geothermal generating plants require little space compared with hydroelectric or thermal power plants—taking into account, in the latter case, the areas of land needed for fuel extraction. Geothermal plants emit only 5%-8% of the gases discharged by conventional thermoelectric plants and contribute far less to global warming.
- 1.22 The potential environmental impact of a geothermal project relates primarily to drilling operations, the construction of civil works, and the release of geothermal fluids when new wells are tested and during operation of the plant. Liquid wastes from the larger drill holes are stored in basins or reservoirs, while those from the long-term tests and plant operations, which may contain pollutants, are eliminated through reinjection into the deep permeable layers of the geothermal field. This not only minimizes or prevents any adverse environmental impact but also increases the productivity of the field.

## **II. OBJECTIVES**

- 2.1 The objective of this proposed nonreimbursable technical cooperation (TC) operation is to support the financing of prefeasibility studies for the Azufral geothermal field, entailing a series of geoscientific, environmental, economic, financial, and social studies. The general objective of the prefeasibility studies is to determine the technical and economic advisability of preparing feasibility studies on the use of geothermal resources in the Azufral field, for the purpose of electric power generation in strict observance of environmental and social considerations.

## **III. DESCRIPTION**

- 3.1 The prefeasibility studies to be financed consist of a geoscientific program entailing a series of geothermal exploration studies and studies to assess the sociological and environmental impact of geothermal development on the region. A review of the policies and legal and regulatory provisions applicable to the development of

geothermal resources by the private sector and an economic and financial analysis will also be conducted during the prefeasibility phase.

- 3.2 The studies will provide an inferred geothermal resource model, an assessment of the sociological and environmental impact of developing this resource, recommendations concerning the policies and legal and regulatory provisions applicable to geothermal resources, an estimate of the financial resources required for private-sector development of the resource, and an analysis of the projected value of development in economic as well as financial terms.
- 3.3 To sum up, the main activities include: analysis of the existing database; preparation of a project map; regional geological, hydrogeological, geochemical, and geophysical studies; a review of policies and applicable legal and regulatory provisions; preparation of regional environmental and sociological surveys; and the compilation of geoscientific information for use in selecting the areas for study. Subsequently, the activities will focus on the areas selected and will consist of: geological, geochemical, and geophysical studies, including surveys; and detailed environmental and sociological surveys. Finally, economic and financial prefeasibility will be determined.
- 3.4 The logical framework is provided in Annex I, enumerating each of these activities, their indicators, and means of verification. The methodology, scope, organization, execution, cost, and financing for the work are discussed below.

#### **A. Methodology**

##### **1. Phases of the studies**

- 3.5 The studies are divided into two phases. The first, to be financed under this TC operation, consists of geoscientific studies, social and environmental analyses, a review of policies and legal and regulatory provisions applicable to geothermal resources, and a probability-oriented economic and financial prefeasibility analysis. This first phase is in turn divided into two stages, as explained in the following paragraph. The second phase, consisting of exploratory drilling and comprehensive feasibility studies, is not included under this TC operation.

##### **2. Stages of the prefeasibility studies**

- 3.6 The geographic area concerned covers approximately 900 square kilometers. Given its large size, the entire area must be investigated first in order to select priority areas for detailed study. Because of the practical requirement to begin with coverage of the entire area, referred to here as "regional coverage", and to subsequently focus on smaller geographic areas, the prefeasibility studies have been divided into the following two stages:



- (i) Stage 1 consists of regional exploration and the collection of baseline data in order to reduce the 900 square kilometer area to one or more relatively small areas for detailed study.
- (ii) Stage 2 consists of the detailed studies to be conducted in the smaller areas for the purpose of compiling information and presenting a prefeasibility study with a recommendation to proceed or not proceed with the feasibility studies per se.

### **3. Timetable for the stages**

- 3.7 It is planned to perform all of the activities for the prefeasibility studies over a continuous period of 14 months. The planned duration for the exploration program under Stage 1 is six months. The detailed studies under Stage 2 would be conducted over a period of eight months immediately following the completion of Stage 1.

### **4. The goals of the prefeasibility studies**

- 3.8 The prefeasibility studies are intended to provide: (i) an inferred model of the geothermal resource, its temperature and probable location; (ii) identification of the type of geothermal resource concerned and its potential capacity; (iii) environmental and sociological studies according to the scope of these activities<sup>1</sup>; (iv) a review of applicable legal and regulatory provisions and recommendations concerning policies related to geothermal resource exploration and development; (v) an economic and financial prefeasibility study; and (vi) a concrete decision to proceed or not proceed with the feasibility studies.

## **B. Organization and execution**

### **1. Executing agency**

- 3.9 The executing agency will be the Instituto de Investigación e Información Geocientífica, Minero-Ambiental y Nuclear [Institute for Geoscientific, Mining and Environment, and Nuclear Research and Information] (Ingeominas).

### **2. Organization**

- 3.10 **Participants.** Ingeominas will hire a consulting firm to execute the prefeasibility studies. A Steering Committee, Project Manager, and Technical Committee will see to it that the studies are carried out properly. An evaluation of the two stages of the prefeasibility studies will be conducted with the participation of Scientific

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<sup>1</sup> Consultations will be conducted with the groups concerned, and, as appropriate, will include the Indigenous Miners Protection Council (COVAMI).

Review Panels. The Colombian Agency for International Cooperation (ACCI) and state budgetary control and execution institutions will also participate in the project.

- 3.11 **Steering Committee.** The purpose of this committee will be to guide strategic project decisions and liaise with other state institutions in order to: help obtain and apply national counterpart resources; ensure that information is disseminated among the institutions represented to help them anticipate the decisions regarding the feasibility studies; and to plan the measures to be taken. The Steering Committee will be composed of: (i) the Minister of Mines and Energy, or the Vice Minister of Mines, as chair; (ii) the Chief of the Infrastructure Division of DNP; (iii) the Director of the ACCI; and (iv) the General Manager of Ingeominas.
- 3.12 **Project Manager.** A high-level, technically trained official of Ingeominas will be appointed to perform the functions of Project Manager on a full-time basis. The Project Manager will perform the executive functions assigned to Ingeominas in its capacity as executing agency, either directly or, in the case of functions that cannot be delegated, through the General Manager of the Institute. The salary and benefits to be paid to the Project Manager will be covered by Ingeominas and will not form part of the local counterpart.
- 3.13 **Consulting firm.** The consulting firm will be a Japanese company or a consortium of firms led by a Japanese company, selected following an international invitation to submit statements of qualification open to all firms meeting the aforementioned conditions. This firm will be hired by the executing agency in accordance with the procedures set forth in the agreement with ACCI, subject to a prior indication of no objection from the IDB.
- 3.14 **Technical Committee.** This committee is responsible for supervising the technical aspects of the study, reviewing reports and other technical materials produced by the consulting firm, and determining whether or not to approve technical compliance with contractual clauses stipulating the conditions for payments or disbursements to the consulting firm. The committee will be composed of the chiefs of all the geoscientific departments of Ingeominas and, at the initiative of the study director, can expand its membership to include ad hoc specialists in geoscientific, environmental, social, legal, regulatory, economic, financial, or other disciplines relevant to national geothermal development policies. Through the Project Manager it may also request the hiring of contractors for the preparation of such technical concepts as may be required. The Technical Committee will approve its own rules of procedure.
- 3.15 **Scientific Review Panels.** The purpose of these panels is to conduct a scientific review of the findings, documents, conclusions, and recommendations presented by the consulting firm during the prefeasibility studies. They will meet twice: once following the completion of Stage 1 to review its execution and submit ideas for the planning of Stage 2; and again upon presentation of the prefeasibility studies, in

their preliminary versions, at the end of Stage 2. The panels will be composed of international specialists with combined experience covering the broad range of scientific specialization involved in the prefeasibility studies. Some members of the group will be experienced in exploration, others in development and production. Panel recommendations that need to be brought to the attention of the consulting firm will be conveyed by the Technical Committee through the Project Manager.

- 3.16 **Ad hoc advisers.** The Project Manager may hire ad hoc advisers on technical issues as requested by the Technical Committee, drawing for this purpose on the budget for the Scientific Review Panels.
- 3.17 **Budgetary control and execution agencies.** These are the same agencies that monitor and review budget execution by Ingeominas in its other activities. They will perform their institutional functions as part of the local counterpart.
- 3.18 **IDB.** The IDB's involvement in the process of hiring the consulting firm is by way of its no objection, and as administrator of resources from the Japanese Trust Fund for Consultancy throughout execution of the prefeasibility studies.

### **3. Procedures for the procurement of goods and services**

- 3.19 A Japanese consulting firm, or a consortium led by a Japanese consulting firm, will be hired to execute the prefeasibility studies. This hiring will be conducted pursuant to an international invitation to submit statements of qualification open to firms meeting the conditions mentioned and in accordance with IDB policies and guidelines for the procurement of goods and services, as well as the procedures for hiring consultants specified by the donor.
- 3.20 To simplify the processes of publicity and the pre-qualification of Japanese consulting firms, the executing agency may issue the appropriate notices or announcements in Japanese newspapers and/or technical reviews
- 3.21 Since the hirings to be conducted by the Project Manager at the request of the Technical Committee will amount to less than US\$40,000, they will be conducted by means of direct contract payable from the budget for the Scientific Review Panels. The Project Manager must inform the Bank of such hirings, even if only ex post, and must keep the related vouchers for possible review by the Bank.
- 3.22 Goods and services payable with resources from the local counterpart will be procured in accordance with Colombian procurement rules.

### **4. Execution and disbursement period**

- 3.23 The planned execution period for the prefeasibility studies is 18 months, which includes an initial four months to process the consultancy contract. In view of the time that may be required to wrap up the contract with the consulting firm, because

of the analysis to be performed by the Technical Committee or the final Scientific Review Panel, a disbursement period of 24 months is recommended.

### **5. Conditions precedent to the first disbursement**

- 3.24 Prior to the first disbursement, the contract with the consulting firm must have been signed and the Project Manager appointed on a full-time basis.

### **6. Recognition of prior expenditures**

- 3.25 Expenditures prior to signature of the contract between the Bank and Ingeominas will be recognized as part of the local counterpart if effected after the TC was formally requested by the MME; if intended for scientific activities under the Azufral project to supplement the information available in the Ingeominas database; or for the purpose of preparing contributions or support in the form of local goods and services. Such expenditures must not exceed US\$30,000.

### **7. Revolving fund**

- 3.26 To facilitate payment procedures, the project team recommends the establishment of a revolving fund of up to US\$150,000, equal to 10% of the total contribution from the JCF.

### **8. Accounting and auditing**

- 3.27 Ingeominas will establish independent accounting records within its administrative organization for canceled payments drawn from the local counterpart. It will also maintain a budget execution account for the local counterpart and another for Bank-authorized payments from the nonreimbursable TC funds.
- 3.28 Payments charged to the local counterpart will be subject to Ingeominas's regular accounting and auditing rules.

### **9. Project monitoring**

- 3.29 During project execution, technical missions will be conducted on a semiannual basis. With support from these missions, Ingeominas and the Bank will evaluate progress in executing the prefeasibility studies and monitor compliance with established targets. Based on the results of these evaluations, Ingeominas and the Bank will agree on the modifications that may be required to fulfill the objectives of the project.

### **C. Cost and financing**

- 3.30 The total cost of the prefeasibility studies is estimated at US\$1.8 million. The estimated cost of the activities and their sources of financing are shown in

Table III-1. The resources to be provided by the JCF would amount to US\$1.5 million. The local counterpart resources to be provided by Ingeominas would come to the equivalent of US\$300,000, and would be used to cover local currency expenses for consultants and payments for local support and consulting services.

- 3.31 This operation does not entail exceptions to Bank policies and procedures. Furthermore, as a nonreimbursable JCF operation, it will be conducted in accordance with the consulting contract procedures stipulated by the donor.

**Table III-1**  
**Estimated Costs And Financing**  
**(in thousands of US\$)**

Item	Description	IDB JCF <sup>1</sup>	INGEO- MINAS	Subtotal
<b>Stage 1</b>				
1	Mobilization	7.5	0.0	7.5
2	Review of available information	12.5	0.0	12.5
3	Project map	50.0	0.0	50.0
4	Regional geology and hydrology	109.0	25.0	134.0
5	Regional geochemistry and hydrology	82.0	13.0	95.0
6	Regional geophysical characteristics	281.0	30.0	311.0
7	Review of policies and legal and regulatory framework	35.0	8.0	43.0
8	Regional environmental impact	28.5	7.0	35.5
9	Regional sociological impact	28.5	5.0	33.5
10	Compilation of geoscientific data	70.0	4.0	74.0
11	Scientific Review Panel	87.0	34.5	121.5
<b>Stage 2</b>				
12	Definition of refined scope for Stage 2	19.5	1.5	21.0
13	Detailed geology	106.0	34.0	140.0
14	Detailed geochemistry	75.0	15.0	90.0
15	Geophysical characteristics	175.0	30.0	205.0
16	Detailed environmental impact	28.5	7.0	35.5
17	Detailed sociological impact	28.5	5.0	33.5
18	Economic and financial prefeasibility	69.0	11.0	80.0
19	Report on the feasibility studies	75.0	5.0	80.0
20	Scientific Review Panel	87.0	27.5	114.5
	Contingencies	45.0	37.5	83.0
	<b>TOTAL</b>	<b>1,500.0</b>	<b>300.0</b>	<b>1,800.0</b>
	<b>%</b>	<b>83</b>	<b>17</b>	<b>100</b>
<sup>1</sup> Japanese Trust Fund for Consultancy				

#### **IV. BENEFITS AND RISKS**

- 4.1 This TC operation will provide financing for prefeasibility studies of the Azufral geothermal field, which, according to the studies available, has been assigned the highest priority for diagnostic geothermal prospecting based on geological, vulcanological, geochemical, and hydrogeological evidence. Once the prefeasibility studies have been completed, there will be clear recommendations to proceed or not proceed with the feasibility studies, which would include exploratory drilling.
- 4.2 Within the context of a modern electric power sector, such as the institutional model adopted by Colombia, it is the role of private agents to invest in expanded generation capacity, and the role of the state to refrain from business activities and to focus on indicative planning, the formulation and implementation of clear and stable development policies, supervision, control, and regulation.
- 4.3 Despite this functional dichotomy between the public and private sectors, the private sector has generally shown little inclination to invest in studies. Its reluctance could stem from a normal aversion to risk—although this seems insufficient reason, since private investors do take on high-risk projects, which frequently prove to be the most profitable. Slow investment recovery is the more likely deterrent, and this is precisely what characterizes projects requiring prolonged studies. This is the case, for example, of studies for large hydroelectric projects. Once the studies have been completed, however, private sector willingness to execute projects, and even to defray the costs of prior studies, becomes more apparent. In short, if the state does not invest in such studies, projects may never be carried out and potentially valuable geothermal resources may be wasted.

##### **A. Benefits**

- 4.4 The studies will provide: an inferred model of the geothermal resource; an assessment of the sociological and environmental impact of developing it; and policy recommendations with respect to geothermal resources and related legal and regulatory matters. It will also provide an estimate of the financial resources required to develop this resource combined with an analysis of risk and projected value—in economic as well as financial terms.
- 4.5 The benefits expected from development of the Azufral geothermal field are as follows:
  - (i) An increase in installed generating capacity in the central interconnected system, through the installation of generating units characterized by minimal variable operating costs and reliability of production.

- (ii) An increase in the reliability and security of electric power supply to the department of Nariño, which now depends essentially on the national interconnected system. In the event that the interconnection line should fail, the Azufral geothermal plant would provide a regional point of power supply. In addition, the quality of service in this area would be improved, particularly in terms of reduced variation in voltage levels, with the introduction of an energy supply point at the extreme end of the interconnection system, which is long and radial.
- (iii) An increase in energy exchanges between Colombia and Ecuador, which are currently limited by the reduced capacity of the subtransmission line interconnecting the two systems. International exchanges are beneficial in terms of the opportunity cost of foreign exchange.
- (iv) The initiation of a geothermal exploration and development program in the Azufral area of Tuquerres, which has been assigned the highest priority for geothermal prospecting based on geological, vulcanological, geochemical, and hydrogeological evidence, and which lies in the area of greatest potential, including the fields associated with the Cumbal, Chiles - Cerro Negro, and Galeras volcanoes.
- (v) The development of a new industrial activity favorable to modernization of the department of Nariño, which lags behind the rest of the country and is dependent on an agricultural sector that for various reasons is extremely depressed.

## **B. Risks**

- 4.6 What cannot be considered a project risk is the possibility that expenditures will be incurred for prefeasibility studies which then conclude, correctly, that work should not proceed on the feasibility studies because the existence of a viable geothermal resource has not been confirmed. At first glance, it might be said that this is a risk inherent in proceeding with the prefeasibility studies, because they may not be successful. The reality, however, is just the opposite: an accurate determination as to the existence or nonexistence of geothermal resources constitutes the study's *raison d'être*.
- 4.7 The risk that is being run is that of mistakenly pre-identifying the feasibility of developing the geothermal resource. The cost of erroneously recommending that work on the studies proceed is the opportunity cost of the resources that would be invested in the feasibility studies until the error is inevitably detected. The cost of erroneously recommending that work on the studies not proceed is much greater, because it would preclude the development of a natural resource and thus eliminate all related benefits.

- 4.8 To mitigate this risk, two types of measures have been taken, both specifically designed to prevent an erroneous scientific prognosis. The first was to prepare the best possible illustrated terms of reference, with the assistance of an international specialist widely experienced in matters related to the identification of geothermal resources, hired with resources from the Japanese Trust Fund for Consultancy. The second measure was to take all reasonable steps to ensure that the study is carried out accurately, including: (i) selection of the consulting firm, essentially on the basis of technical excellence, pursuant to an international invitation to submit statements of qualification; (ii) monitoring by a Technical Committee composed of the appropriate sector entities; (iii) the appointment of a full-time Project Manager; (iv) a review of the work by two Scientific Review Panels upon completion of each of the two stages of the prefeasibility studies; and (v) the possibility for the Project Manager to hire specialists when so requested by the Technical Committee.



## PREFEASIBILITY STUDIES FOR THE AZUFRAL GEOTHERMAL FIELD

### LOGICAL FRAMEWORK

OBJECTIVES	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTION
<p>conduct a prefeasibility study of the Azufra geothermal field and decide whether it is advisable to proceed with the study.</p>	<p>Recommendation issued by the Steering Committee concerning measures to be taken</p>	<p>Reports containing the results of the geoscientific, environmental, social, economic, and financial studies and of the analysis of policies and applicable legal and regulatory provisions.</p>	<p>Policies, laws and regulations that support the efficient use of geothermal resources are in place.</p>
<p>Identify the knowledge available on the Azufra geothermal field and on the environmental, social, and regulations that will affect the development by the private sector.</p>	<ol style="list-style-type: none"> <li>1. Greater confidence concerning the potential of the Azufra geothermal prospect.</li> <li>2. Availability of environmental baseline data.</li> <li>3. Availability of sociological information.</li> <li>4. Availability of the economic and financial evaluations to determine the advisability of proceeding with Phase 2.</li> <li>5. Proposals to improve development policies and legal and regulatory provisions applicable to geothermal exploration and development.</li> </ol>	<ol style="list-style-type: none"> <li>1. Construction of an inferred geothermal resource model.</li> <li>2. Information compiled on the sources and targets of environmental impact and analytical reports.</li> <li>3. Compiled sociological information, analytical reports, and records and evaluations of the information and education campaigns.</li> <li>4. Economic and financial prefeasibility report.</li> <li>5. Analytical reports on policies and legal and regulatory provisions applicable to the development of geothermal resources. Recommendations.</li> </ol>	<p>The Steering Committee will make a strategic decision on project development consistent with, and supporting, the studies performed.</p>

OBJECTIVES	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTION
OBJECTIVES			
Geology and vulcanology.	1. Indication of the types of rocks, structures, contact zones, and alterations for use in developing the model showing location, extent, and hydrology of the hydrothermal system.	1. Maps, results of laboratory analysis and field work, and geological reports in accordance with the TOR for each of the two stages of Phase I.	The geoscientific studies inferred model of the resource that supports the advisability of proceeding with the exploration under Phase II.
Hydrology and hydrology.	2. Model showing hydrological flow, water supply and demand, and geothermal temperatures for the entire project area during Stage 1, and for the selected priority areas during Stage 2.	2. Maps, results of laboratory analysis and field work, and geochemical reports in accordance with the TOR for each of the two stages of Phase I.	
Geophysical characteristics.	3. (i) Model of the subterranean structure controlling the flow of geothermal fluids beneath the Azufral complex; (ii) during Stage 1, determination of the resistive limits of the prospected area to determine probable distribution of subterranean geothermal activity through the use of magnetotelluric stations and, during Stage 2, interpretation of the magnetotelluric data and determination of the resistive limits of the priority areas.	3. Maps, results of the gravimetric and magnetotelluric stations, and geophysical reports in accordance with the TOR for each of the two stages of Phase I.	

OBJECTIVES	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTION
of policies and applicable regulatory provisions.	4. Identification of deficiencies in geothermal resource development policies and the current legal and regulatory framework that hinder or prevent the effective development of geothermal power in the country, and a proposal for corrective measures.	4. Reports providing: (i) a compilation of international and national information on policies and legal and regulatory frameworks; (ii) a comparative analysis of their consistency and effectiveness; and (iii) the identification of defects and the proposal of concrete measures and procedures to eliminate and replace them with others promoting private sector development of geothermal resources.	<p>The study of legal and frameworks does not identify in developing the resource, recommended changes are in</p> <p>The study on current policies of geothermal resource finds them to be suitable for notwithstanding any future developments it may propose.</p>
mental impact.	5. Identification and description of the natural resources that could be affected by the project. Collection of information on natural resources within the project area and their condition prior to intervention. Study and description of the effects of the project on these resources, including: (i) positive effects that increase the value or significance of the natural resources, and negative effects detrimental to them; (ii) direct and indirect effects; and (iii) short-and long-term effects.	5. During Stage 1, reports providing a compilation of information on resources likely to be affected, such as water, air, soil, subsoil, animals, vegetation, and human beings. During Stage 2, monitoring reports on the areas selected as most promising and most exposed to environmental impairment, and reports identifying possible sources of project impact. Report providing a study and description of the project's effects on the environment.	Potentially adverse effects, and solutions, are identified.
cal impact.	6. Identification of the project's sociological impact on indigenous groups and other inhabitants of the project area; community information and education on the implications of any geothermal development.	6. During Stage 1, reports providing a compilation of sociological information on human groups settled in the project area and the results of consultations conducted with government and local authorities, or ethnic groups and community leaders. During Stage 2, reports containing a compilation of sociological information on human groups settled in the areas to be most affected by the project, a report on the study to	Potentially adverse sociological and solutions, are identified.

OBJECTIVES	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTION
		<p>identify the project's sociological impact on indigenous groups and other local inhabitants of the project area, and reports on community information and education measures concerning the implications of any geothermal development.</p>	
<p>c and financial prefeasibility.</p>	<p>7. The estimated value of the economic and financial benefits expected from development of the geothermal field on the basis of scenarios corresponding to specific variable factors and their probabilities of occurrence, in such a way as to illustrate the decision that would have to be taken by a private entrepreneur in order to develop the field, using explicit risk and benefit values.</p>	<p>7. Report providing: (i) the most likely estimates, and their respective degrees of probability, as to drilling costs, the cost of investments in generating plants, and the cost of investments in electric power stations, lines, and connection equipment in order to deliver plant production into the regional transmission system, supported with preliminary designs; (ii) the most likely estimates, and their respective degrees of probability, as to other investment costs, for or related to the project, to be incurred in order to operate and maintain the generating plant, such as the costs of operation, maintenance, waste disposal, environmental monitoring, etc.; (iii) estimates as to possible selling prices for the electricity based on exchange price forecasts; (iv) a probabilistic economic analysis of the project; and (v) a probabilistic financial analysis of the project from the viewpoint of a private investor.</p>	<p>The probabilistic economic prefeasibility analysis recommendations to proceed with the feasibility s</p>

OBJECTIVES	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTION
S			
of consultant	1. International invitation to submit statements of qualification, open to Japanese firms or consortiums led by Japanese firms.	1. Contract signed with no objection from the Bank.	Qualified firms respond to to submit statements of qual
of available information.	2. Performance of the activity (field visits, at headquarters, and with Ingeominas participation).	2. Report containing background information, an analysis of basic information and determination of the program to be executed during Stage 1.	The budget appropriations the local counterpart are ma
map	3. Construction of a basic map of the project area.	3. Approval of the project map.	
n of Stage 1 of Phase I.	4. Progress on all of the studies for Stage 1 of Phase I according to the TOR.	4. Aide-memoire of the Scientific Review Panel held at the end of Stage 1 of Phase I.	
n of Stage 2 of Phase I.	5. Progress on all of the studies for Stage 2 of Phase I according to the TOR.	5. Aide-memoire of the Scientific Review Panel held at the end of Stage 2 of Phase I.	
of the Final Report.	6. Presentation of the final version of the Final Report, reflecting the comments submitted. Budgetary execution of the consultancy contract.	6. Letter of acceptance of the final version of the Final Report and authorization to terminate the consultancy contract.	

PROPOSED RESOLUTION

COLOMBIA. NONREIMBURSABLE TECHNICAL COOPERATION TO THE  
REPUBLIC OF COLOMBIA  
Prefeasibility Studies for the Azufral Geothermal Field

The Board of Executive Directors

RESOLVES:

1. That the President of the Bank, or such representative as he shall designate, is authorized, in the name and on behalf of the Bank, as Administrator of the Japanese Trust Fund for Consultancy Services established pursuant to the letter agreement dated February 15, 1995 between the Government of Japan and the Bank, to enter into such agreements as may be necessary and to adopt such measures as may be pertinent for the execution of the Plan of Operations referred to in Document AT-\_\_\_\_\_, with respect to a technical cooperation, the purpose of which is to support the financing of the prefeasibility studies of the Azufral Geothermal Field.

2. That up to the sum of US\$1,500,000 is authorized for the purposes of this resolution, chargeable to the resources of the Japanese Trust Fund for Consultancy Services.

3. That the above mentioned sum shall be provided on a nonreimbursable basis.