THE REPUBLIC OF PERU
MINISTRY OF ENERGY AND MINES

THE REPUBLIC OF PERU

THE MASTER PLAN FOR DEVELOPMENT OF GEOTHERMAL ENERGY IN PERU

FINAL REPORT

February 2012

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

WEST JAPAN ENGINEERING CONSULTANTS, Inc.

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Callao has the status of a Department.
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Map of Peru

ABBREVIATIONS

Abbreviation	Description
ACRVM	Regional Conservation Area Vilacota Maure (Área de Conservacion Regional Vilacota Maure)
ANA	National Water Authority (Autoridad Nacional de Agua)
ADINELSA	Enterprise for the Administration of Electric Infrastructure (Empresa de Administración de Infraestructura Eléctrica S.A.)
ANP	Protected Natural Areas (Áreas Naturales Protegidas)
a.s.l.	above sea level
COES	Committee for the Economic Operation of the System (Comité de Operación Económica del Sistema)
CENERGIA	Energy and Environment Protection Center (Centro de Conservacion de Energía y del Ambiente)
CTE	Electricity Tariffs Commission (Comisión de Tarifas Eléctricas)
DEFENSORIA	Customers Protection (OSINERGMIN branch)
DGAA	General Directorate of Environmental Affairs (Direccion General de Asuntos.Ambientales)
DGAAE	General Directorate of Energetic Environmental Affairs (Dirección General de Asuntos Ambientales Energéticos)
DGE	Directorate General of Electricity (Dirección General de Electricidad)
DREM	Regional Directorates of Energy and Mines (Direcciones Regionales de Energía y Minas)
EIA	Environmental Impact Assessment
FONAFE	National Fund for the Financing of State Entrepreneurial Activities (Fondo Nacional de Financiamiento de la Actividad Empresarial)
GART	Division of Tariff regulation annexed to OSINERGMIN (Gerencia Adjunta de Regulación Tarifaria)
GOP	Government of Peru
INACC	Concessions and Cadastral Institute (Instito Nacional de Concesiones y Catastro Minero)
INDECOPI	National Institute for the Defense of Competition and Intellectual Property (Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual)
INGEMMET	Institute of Geology, Mining and Metallurgy (Instituto Geológico Minero y Metalúrgico)
INRENA	National Institute of Natural Resources (Instituto Nacional de Recursos Naturales)
IPEN	Peruvian Nuclear Institute (Instituto Peruano de Energía Nuclear)
JBIC	Japan Bank for International Cooperation (Banco del Japón para Cooperación Internacional)
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency (Agencia de Cooperación Internacional del Japón)

MEF	Ministry of Economy and Finance (Ministerio de Economía y Finanzas)
MEM (MINEM)	Ministry of Energy and Mines (Ministerio de Energía y Minas)
MINAG	Minister of Agriculture (Ministerio de Agricultura)
MINAM	Ministry of Environment (Ministerio del Ambiente)
MT	Magneto telluric
OGGS	Social Impact Management Office (Oficina General de Gestion Social)
OSINERGMIN	Organization of Supervising for Investments in Energy and Mines (Organismo Supervisor de la Inversión en Energía y Minería)
PPC	Citizen Participation Plan (Plan Participacion Ciudadana)
RER	Renewable Energy Resources (Recursos Energéticos Renovables)
SEIN	Electric National Interconnected System (Sistema Eléctrico Interconectado Nacional)
SERNANP	National Service of Natural Protected Areas (Servicio Natural de Áreas Naturales Protegidas)
SINANPE	National System of Protected Natural Areas State (Sistema Nacional de Áreas Naturales Protegidas por el Estado)
SNIP	National System of Public Investment (Sistema Nacional de Inversión Pública)
SRTM	Shuttle Radar Topography Mission
TOR	Terms of Reference
UTM	Universal Transverse Mercator, geographical coordinate system

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INTRODUCTION

1. BACKGROUND

The geothermal potential for power generation in the Republic of Peru (hereinafter abbreviated as "Peru") has been estimated to be 3,000 MW or higher. However, this is only estimation and there is no any geothermal exploitation in the country. This is because the country has not established technical know-how and experience for the geothermal resource exploration, development and for the exploitation of geothermal resources as well for geothermal power facilities construction and for their operation and maintenance.

The current total installed power generation capacity as of the end of 2010 is 7,309 MW (excluding 1,303 MW of private-owned power generation capacity), of which 3,345 MW (about 46%) is hydro power and 3,964 MW (about 54%) is thermal power (MEM, 2010). The predicted average annual power demand will grow at a rate of 8.1% between 2009 and 2018 according to an intermediate demand grow scenario. To respond to such a rapid growth of demand the expected actions will be the installation of large-scale hydropower stations and natural-gas-fired power stations.

However, for Peru it is desirable to utilize domestic renewable energy to supply its power demand in electrical power development in the future. First, from the point of view of national energy security, this will improve the energy self-sufficiency ratio and will contribute to the diversification of the energy portfolio. Secondly, the utilization of renewable energy will contribute to the less emission of greenhouse gases and will help of the mitigation of global warming. The energy self-sufficiency ratio in Peru has been getting decreasing year by year. The ratio declined below 70% in 2004. Recently, the natural gas production is progressively promoted, but the demand in domestic use and exportation are both increasing. It is known that the hydro electricity generation potential is very high in Peru; however, the possibility of future water shortages cannot be eliminated because of the effects of climate change.

Under these circumstances, in 2008 the law for promotion of electricity generation with renewable energy was enacted. This law targets 5% of total electricity generation utilizing renewable energy resources (solar, wind, biomass, geothermal, small-hydro). According to this law, the government shall elaborate and review the national plan to develop and utilize renewable energy every two years. In the case of geothermal resources, currently there is not any development, the only concrete geothermal activities in Peru are the two Pre-Feasibility studies conducted for the Borateras and Calientes fields. A committee for the promotion of geothermal development has been created within the Peruvian government. Peru energy authorities requested technical assistance to the Japanese government to formulate a Master Plan for the development of geothermal resources of the country.

2. OBJECTIVES AND CONTENTS OF THE STUDY

The objective of this study project is to make the nationwide geothermal power development plan (Mater Plan) for Peru in order to promote and accelerate the geothermal energy development and exploitation program in Peru.

The Master Plan will be formulated considering all factors including the geothermal resource potential in promising fields, the current and forecasted future situations of the electric power sector, and the framework established by the present policy/legal dispositions. The Master Plan will involve recommendations aimed to promoting geothermal developments in Peru through the establishment of adequate national policies. In addition, a database of information related to the Peru geothermal power development will be constructed to serve the purpose of a base upon which the Master Plan is formulated and a platform upon which the Peruvian corresponding authority can proceed to updates after this study is completed. Technology transfer to the counterpart staff of the Directorate General of Electricity (DGE), INGEMMET and other organizations in the Ministry of Energy and Mines (MEM) will be carried out all throughout the execution of the activities for this study.

3. BRIEF HISTORY OF THE STUDY

The study can be divided into three stages as follows;

- Preparation Stage (FY 2009-2010)
- Master Plan Research Stage (FY 2010)
- Master Plan Formulation Stage (FY2011)

In the Preparation Stage, existing data was collected and reviewed in Japan. The Inception Report was prepared also in this stage.

At the beginning of the Master Plan Research Stage, the Inception Report was presented and discussed with the Peruvian counterpart in the 1st Workshop in Peru held in the 1st work period in Peru.

Afterward, in the 1st work period in Japan, the compiling and review of the collected data and information, and then the 13 promising geothermal fields were selected. In the 2nd work period in Peru, the study team carried out the geological and geochemical surveys in the 13 fields and also the collection of additional data and information on the policies for power sector and other relating aspects. The results of surveys and collection of data and information were assembled as the Progress Report in the 2nd work period in Japan.

In the 3rd work period in Peru, the study team performed the explanation and discussion of contents of the Progress Report to/with the counterparts in Peru. In addition, the Magnetotelluric (MT) survey was conducted in the selected two most-promising fields for the resource evaluation. The study team also had the discussions and carried out the collection of additional information in terms of the power sector. The Interim Report was prepared in the period of the 3rd work in Japan aiming to express the current progress of the study at the end of Master Plan Research Stage.

In the 4th work period in Peru, the study team performed the explanation and discussion of contents of the Interim Report to/with the counterparts in Peru through the second workshop. Also, under the inauguration of a new President of Peru in July 2011, additional information concerning the national energy policy was collected and discussed with the Peruvian counterparts.

In the 4th work period in Japan, the draft of the Master Plan was devised based on the results of various study carried out, and the results of the study were integrated in the Draft Final Report.

In the 5th work period in Peru, the draft Master Plan was presented to the Peruvian counterparts. The Master Plan was completed in the 5th work period in Japan through the discussion and modifications based on the comments given by the Peruvian authorities.

4. CONTENTS OF THE FINAL REPORT

The Final Report will be composed of the following chapters:

- Main Report Chapter I : Current Status of Geothermal Power Development and Issues to be Solved
- Main Report Chapter II: The Master Plan
    - Recommendations and Action Plan
    - Geothermal Development Database
    - Geothermal Development Plan
- Annex: Results of Investigations
    - Study Results for the Promising Fields (Resources/Environmental)
    - Geothermal Development Plans for the Promising Fields
    - Materials of Various Analysis

I STATUS AND TASKS FOR GEOTHERMAL DEVELOPMET

I-1 Energy Sector

I-1.1 Energy Sector and its Policy

Peru's energy supply had significant participation of crude oil and derivatives (53%) and biomass (37%, mainly wood) in the 70's. Recently, however, there has been a strong involvement of natural gas (around 33%) while there has been a significant reduction in crude oil and derivatives (35%) and biomass (15%). On the other hand, the hydro, which reached its peak in 2004 with 17%, has fallen to the only 14% because of the penetration of natural gas in electricity generation. The participation of natural gas and derivatives (from the year 2004 the impact of Camisea can be clearly seen), which has helped decrease of the dependence of the crude oil and in recent years the smaller share of biomass (especially the wood) is also notable. On the other hand, the country's abundant water resources (about 58,000 MW) have not been sufficiently exploited. Figure I-1.1.1shows the evolution of the share of each energy in the domestic energy supply.

With respect to the power generation, in 1970, among the total installed capacity of 1,677MW, the diesel-fired generation occupied 34% (570MW). However, in 2008, it declined to 8% (570MW) among the total installed capacity of 7,158M. As for the hydro power generation, it occupied 40%(670MW) of the total installed capacity in 1970 and increased to its maximum level of 67% (3,957MW) among the total installed capacity of 5,906 MW in 2001. However, with the introduction of natural gas-fired power generation, in 2008 the share of the hydro power generation declined to the level of 1970's. Figure I-1.1.2 and Figure I-1.1.3 show the evolution of the installed capacity of thermal and hydro electricity plants and the evolution of the share of each generation source in the total installed capacity respectively.

In summary, the steady decline in local crude oil production is observed, which causes that the country became the importer of crude oil, not exporter anymore in the second half of 80s, and a marked increase in the penetration of natural gas in electricity generation matrix is also observed, which causes a reduction of the participation of other major sources such as diesel oil, residual oil and hydropower.

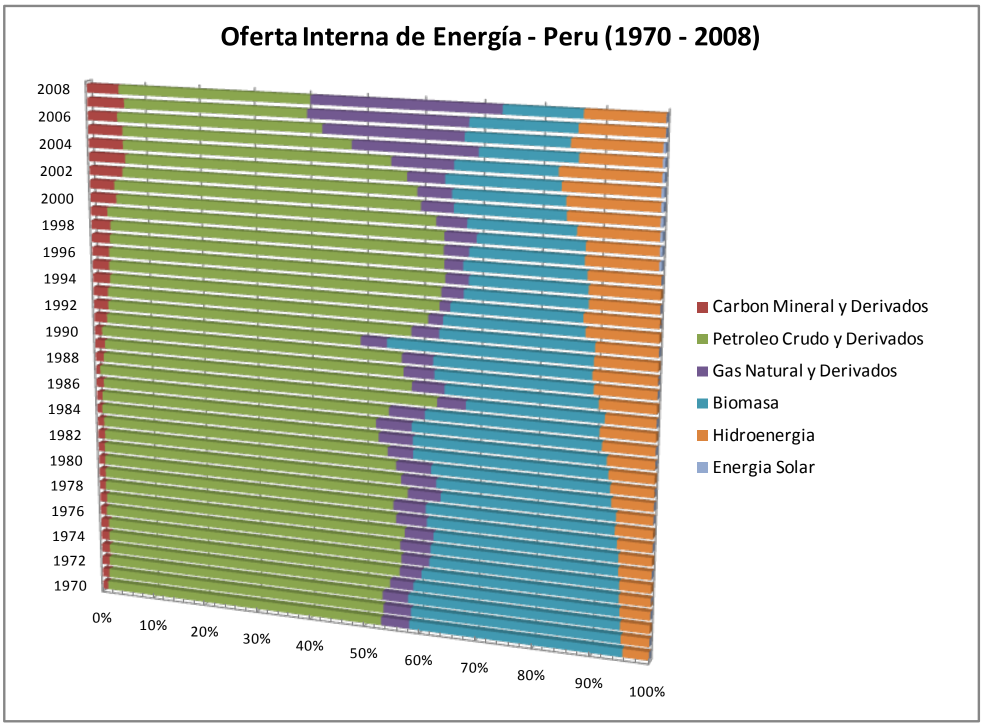


Fig. I-1.1.1 Evolution of the share of each energy source in the domestic energy supply

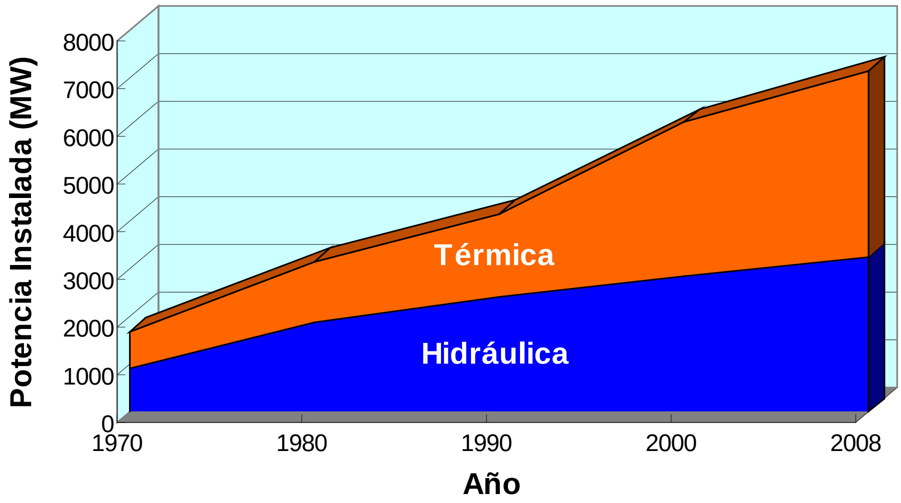


Fig. I-1.1.2 Evolution of the installed capacity by energy source

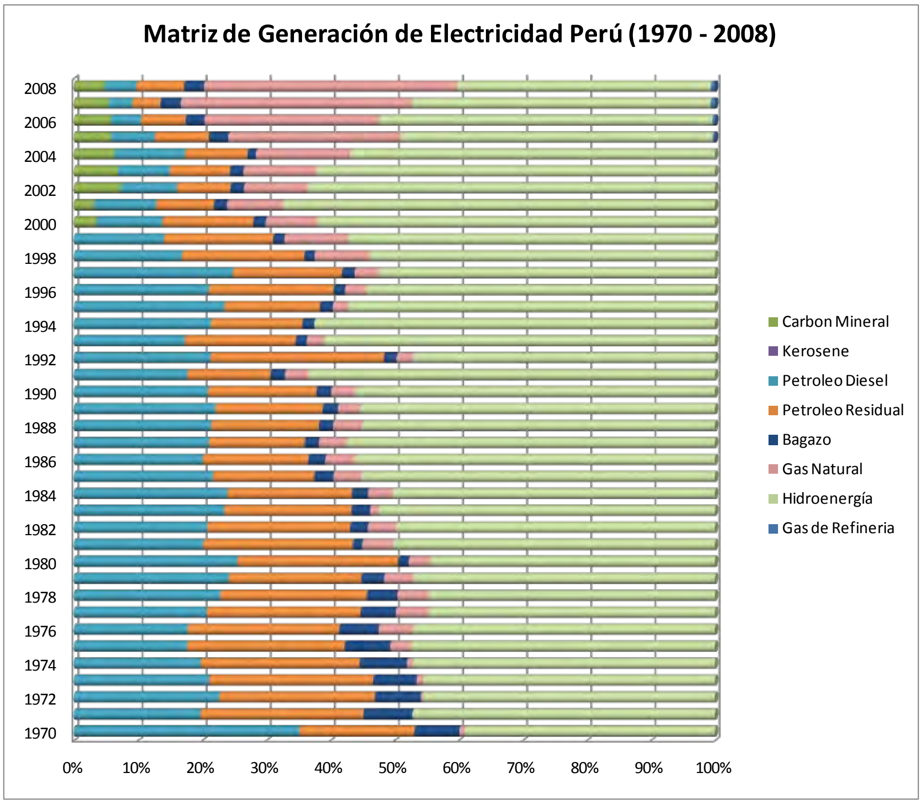


Fig. I-1.1.3 Evolution of the share of each generation source in the total installed capacity

The country's energy policy aims at securing energy self-sufficiency in a competitive environment through the promotion of private investment. Sector is expected to have a locomotive role for sustainable growth of the economy. Particularly the diversification of energy mix (through the reduction of oil dependence while increasing the use of natural gas, liquefied gas and renewables), promoting development of renewable energy resources (biomass, wind, solar, geothermal, tidal and hydropower capacity less than 20 MW), rural electrification, sustainable development of the sector with a minimum environmental impact, low carbon emissions and greater integration with the region's energy markets are a long-term vision of the Ministry of Energy and Mines for the energy sector. In Peru's National Energy

Policy 2010-2040, approved by Supreme Decree (No.060-2010-EM) in November 2010, the objectives of national energy policy are:

1. Having a diversified energy mix, with emphasis on renewables and energy efficiency
2. Having a competitive energy supply
3. Universal access to energy supply
4. Having greater efficiency in the production chain and energy use
5. Achieving self-sufficiency in energy production
6. Development of energy sector with a minimal environmental impact and low carbon emissions in a sustainable development framework
7. Development of the natural gas industry, and its use in household activities, transportation, trade and industry as well as efficient power generation.
8. Strengthen energy sector institutions
9. Integration with the region's energy markets, capable of achieving long-term vision.

I-1.2 Competent Organizations

The competent authority of the country's energy sector is the Ministry of Energy and Mines (MEM), with responsibilities for overseeing the activities of oil, gas, electricity and mining and environmental issues in the sector as well as development and implementation of sector policies. The MEM regulates, manages and oversees the judicious use of mineral and energy resources of the country on their exploitation activities, which are implemented accordingly to the guidelines of the national development plan and the national environmental regulations. The MEM has two divisions: the Vice Ministry of Energy and the Vice Ministry of Mines. The Vice Ministry of Energy is responsible for energy policy and is composed of the Directorate General of Electricity, Directorate General of Hydrocarbons, Directorate General of Rural Electrification, Directorate General for Efficient Utilization of Energy, Directorate General of Energy Environmental Affairs. The Vice Ministry of Mines is responsible for policies related to identification, evaluation and planning of mineral resources exploration. There are three decentralized public institutions in the energy sector: the Geological Mining and Metallurgical Institute (INGEMMET), responsible for exploration, evaluation and planning of mineral resources of the country, the National Institute of Concessions and Mining Cadastre (INACC), responsible for assisting potential investors in the documentation of applications of mineral concessions and carrying out cadastral activities, and the Peruvian Institute of Nuclear Energy (IPEN). Supervisory Agency for Investment in Energy and Mining (OSINERGMIN) is the agency responsible for overseeing and monitoring compliance with the laws and technical issues of business development activities in the subsectors of electricity, oil and mining as well as regulate electricity and gas tariffs, which has been covered by the former Committee on Energy Tariffs. OSINERGMIN does not assume the role of regulating prices of petroleum products and liquefied gas, which are determined by the MEM. OSINERGMIN serves to inform the MEM.

I-2 Electricity Sector

I-2.1 Power Sector Reform

In 1972 the electricity sector was nationalized by the enactment of the Electricity Law. Until then, the electricity supply had been administered by private companies in major cities and public enterprises in the municipalities. At the same time, they created the Electricity Board in the MEM, which was responsible for policy-making planning and investment licenses, regulation and tariff determination. A public company, Electroperú was created at that stage. After the territory was divided to eight regions with responsibility for supply of eight regional companies respectively, among which Electrolima was the largest. The sector was made under Electroperú, who owned the shares in these companies. However, sector planning and management of public companies did not necessarily generate the expected positive results in terms of rate of electrification and credibility of supply. The reason for this was that the electricity tariff was not in the proper level to maintain a sound financial management and to implement the required investments. In this context, awareness for the necessity of introducing private investment to the sector started to grow.

The country began to liberalize its economy in the 90's through the promotion of private investment, export promotion and macroeconomic stabilization. The power sector reform was a government priority as part of the privatization of public enterprises.

The government enacted the Electricity Concessions Law in November 1992 with the objective of restructuring the sector, following the model of Chile, who was the first Latin American country to introduce a free electricity market. The three pillars of the restructuring of the electricity sector were: 1) establishment of the new legal framework, 2) end to the vertical structure of state monopoly, 3) privatization of public enterprises. They were also incorporated the following components:

- Introduction of competition in generation activities
- Separation of the activities of generation / transmission / distribution
- Allow private participation in the planning, construction and operation of transmission facilities
- Creation of the free market for electricity (Originally for users > 1,000 kW. In 2006, modified for uses > 2,500 kW),
- Ensure open access to transmission networks
- Provision of incentives for competing in the generation activities through an economic load dispatching scheme.

I-2.2 Legal Framework and Related Institutions

I-2.2.1 Legal Framework

The electricity subsector activities are regulated for the Electricity Concessions Law (Law No.25844) and its Regulations, which entered in force since 1992. These rules are supplemented by the Law to ensure the Efficient Development of Electricity Generation (Law No. 28832) which entered in force since 2006 for the purpose of gradual improvement and adaptation of the legal framework along the evolution of the electricity market. In accordance with this law, now all the generators can commercialize their energy production in four modalities;

- Contracts with distributors through the bidding of electricity supply. The price is fixed for 20 years at longest. In the bidding, the bid price of hydro project, when it is higher than the prices of the thermal projects, the discount factor can be applied to the price of the hydro project. The application of the discount factor is only for the evaluation purpose, and once the project is awarded, the project can sell the electricity in the bidding price.
- Contracts with distributers in the regulated market. The price corresponds to the node tariff fixed by OSINERGMIN.
- Contracts with free users at the negotiated price
- Trade of energy and capacity in the spot market administered by COES.

I-2.2.2 Related Institutions

Figure I-2.2.1 shows the actors involved in the electricity subsector and their interaction according to current regulations.

<u>Ministry of Energy and Mines (MEM)</u>

The MEM is responsible for energy policy development and planning sector. The Directorate General of Electricity (DGE) is the technical body responsible for proposing policy and evaluates the policy of Electricity Subsector. The DGE is composed of three directions Electricity Policy Directorate, Department of Electrical Studies and Promotion, Department of Electrical Concessions.

Supervisory Organism for Investment in Energy and Mining Sectors (OSINERGMIN)

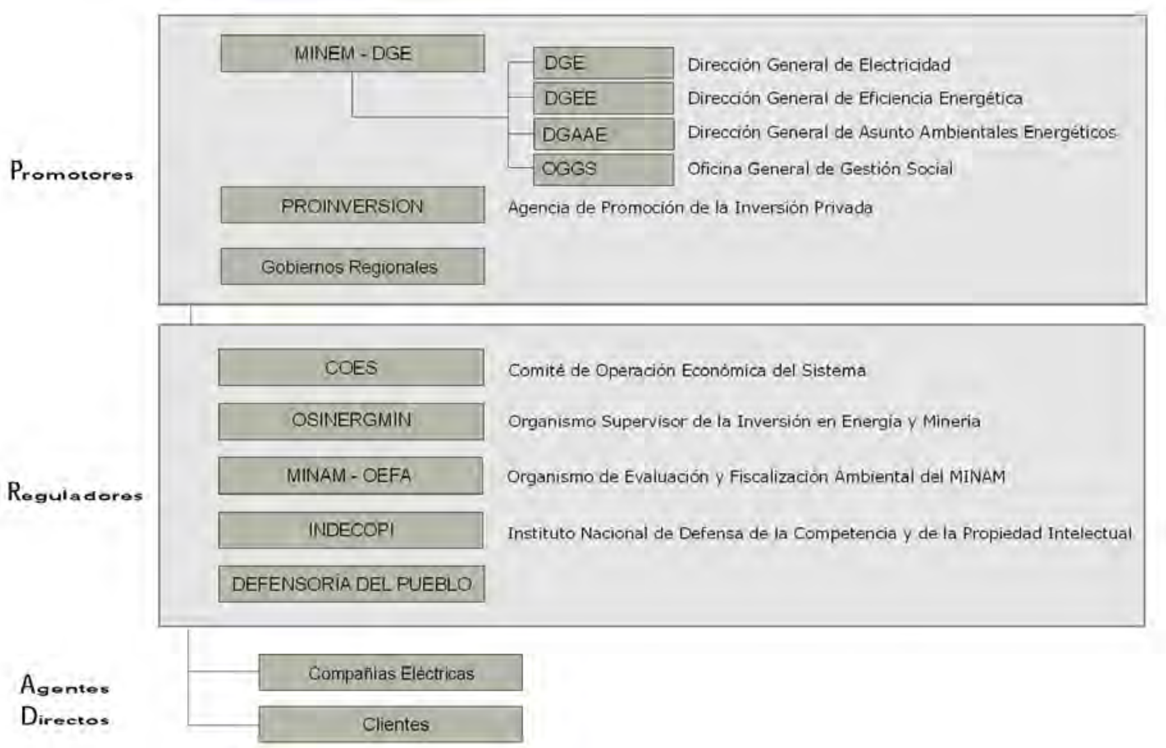
The OSINERGMIN was created in 1997 to oversee and monitor compliance with the laws and technical issues of business development activities in the sub-sectors of electricity, oil and mining. Also the functions of regulating electricity tariffs after OSINERGMIN absorbed the Electric Tariffs Commission (CTE).

Committee of Economic Operation of the National Interconnected System (COES-SINAC)

COES-SINAC is the body composed of the owners of power plants, transmission systems, distribution and large users to organize the economic dispatch of interconnected national electricity system, to ensure security of supply and optimization of energy resources.

National Institute for the Defense of Competition and Intellectual Property Protection (INDECOPI)

INDECOPI is the body created in 1992 to promote the economy a culture of honest competition, protecting all forms of intellectual property and protect the rights of consumers.



(Source: MEM Electric Sector 2010)

Fig. I-2.2.1 Participants in the electrical subsector

Promoter

- MEM-DGE: Grants concessions, sets policies and norms
- PROINVERSION: Promote competitiveness and development investments
- Regional Governments: Encourage regional and local plans in the subsector
- MEM-OGGs: Promote the harmonious relationship between business and local people for local sustainable development

Regulating agent

- OSINERGMIN: Price regulation, supervision and technical and legal aspects of environmental protection related to the activities of the subsector
- OMBUDSMAN: Defend the rights of the individual and the public. Monitor the provision of public services. Monitor performance of duties of the state.
- INDECOPI: Defend a competition and intellectual property protection
- COES-SINAC: Organize the economic dispatch of interconnected national electricity system

Direct Agents

- Power Companies: Companies for generation, transmission and distribution
- ADINELSA: Autonomously manage the state's electric infrastructure
- FONAFE: Fund with a status as public enterprises
- Customers: Regulated and Free Customers in the national electricity demand
- SNMPE / SEIN: Associated Companies (National Society of Mining, Petroleum and Energy / National Society of Industries)

I-2.2.3 Power Companies

The generation, transmission and distribution are separated by the Electricity Concessions Law which was enacted in 1992. In Generation, EDEGEL is the largest company in the country, resulting from the privatization of Electrolima, with installed capacity of 1,580,000 kW and with the participation of Entergy (USA) and ENDESA (Chile). Electroperú, after the vertical disintegration of the generation, transmission and distribution has been so far as the state-owned generation. EGASA and Termoselva are two generation companies separated from Electroperú. EGASA continues as the public company and Termoselva became the private company with the participation of ENDESA (Spain).

The activities of transmission are mainly by seven private companies. REPS, a subsidiary of ISA (Colombia), is the largest transmission company and owns 25% of transmission system assets throughout the country. ISAPERU which operates the regional interconnection is also a subsidiary of ISA.

The distribution business is comprised of 25 private and public companies. As the result of vertical disintegration and privatization of Electrolima, EDELNOR is operating in the northern part of Lima and the company Luz del Sur in the south of Lima. These two companies represent 63% of total energy sales across the country.

I-2.3 Power Supply and Demand Situation

I-2.3.1 Generation

The installed generation capacity is 7,309MW (excluding 1,303 MW of private-owned power generation capacity) in December 2010. The power plants are owned by 45 companies. The principal generators are shown in Table I-2.3.1

Table I-2.3.1 Generation companies

Company	Installed Capacity (MW)	Effective Capacity (MW)
EDEGEL	1,583	1,475
ELECTROPERÚ	1,096	964
ENERSUR	1,086	1,046
EGENOR	695	687
KALLPA GENERACIÓN	602	566
EGASA	331	324
SN POWER	267	264
CELEPSA	220	220
CHINANGO	185	194
TERMOSELVA	203	176
Others	1,041	959
Total	7,309	6,875

Source: MEM 2010

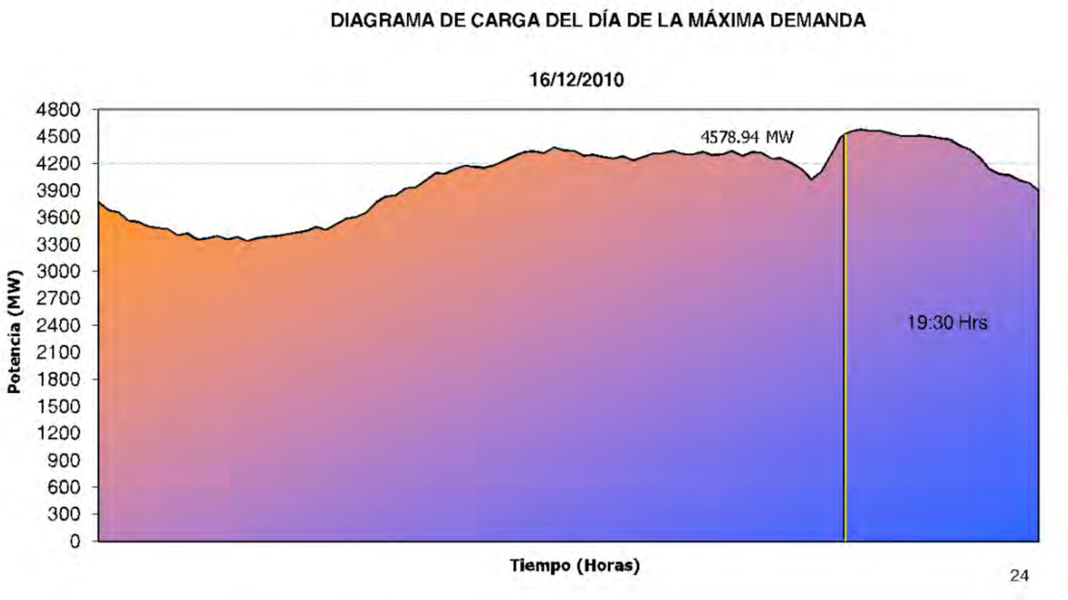
As shown in the Table I-2.3.2, the generations are mainly consisting of, 3,345 MW (45.8%) by hydro and, 3,964 MW (54.2%) by thermal. Natural gas generation (2,479 MW) occupies about 63% of thermal power. In 2010, wind power generation has been joined in the market, while the capacity is only 0.7 MW (0.01%).

Table I-2.3.2 Installed capacity / effective / type of generation

Energy source	Installed Capacity (MW)	%	Effective Capacity (MW)	%
Hydro	3,345	45.8%	3,237	47.1%
Thermal	3,964	54.2%	3,637	52.9%
Gas Natural	*2,479*	*33.9%*	*2,306*	*33.5%*
Dual (Gas Natural - Diesel)	*544*	*7.4%*	*509*	*7.4%*
Diesel	*500*	*6.8%*	*407*	*5.9%*
Carbon	*426*	*5.8%*	*404*	*5.9%*
Others	*15*	*0.2%*	*11*	*0.2%*
Wind	0.7	0.01%	0.7	0.01%
Total	7,309	100.0%	6,875	100.0%

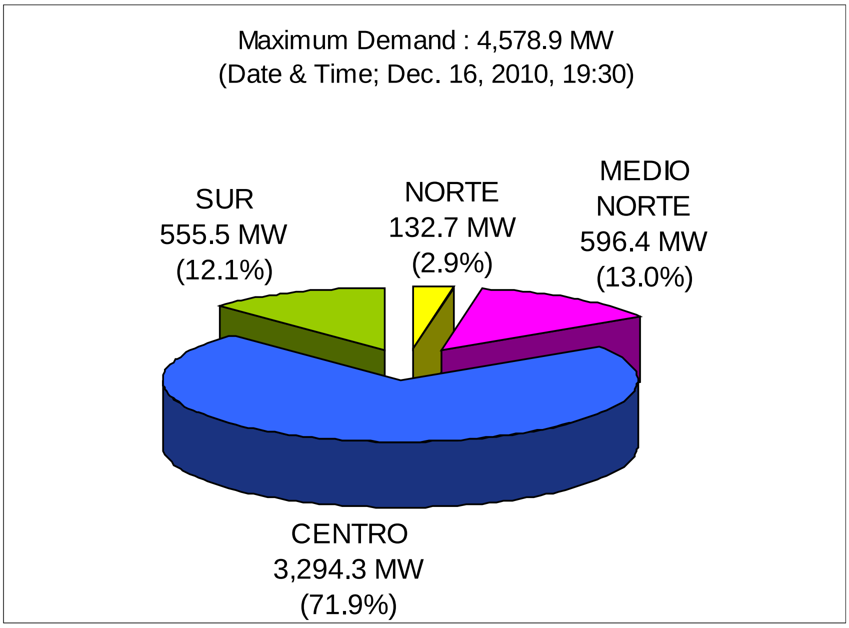
Source: MEM 2010 data

Figure I-2.3.1 indicates the capacity demand on December 16, 2010, the date recorded the peak demand during the same year. Figure I-2.3.2 shows the maximum demand by geographical area.



Source: MEM 2010 data

Fig. I-2.3.1 Load diagram peak day (December 16, 2010)



Source: MEM 2010 data

Fig. I-2.3.2 Demand by geographic area (December 16, 2010)

Figure I-2.3.3 shows the demand registered by resources. As shown the figure, the hydro (>(20 MW) and the natural gas are the primary sources of generation. However, as the renewable energy resource (RER), biomass. also participated in around 0.3% (12MW) as base load.

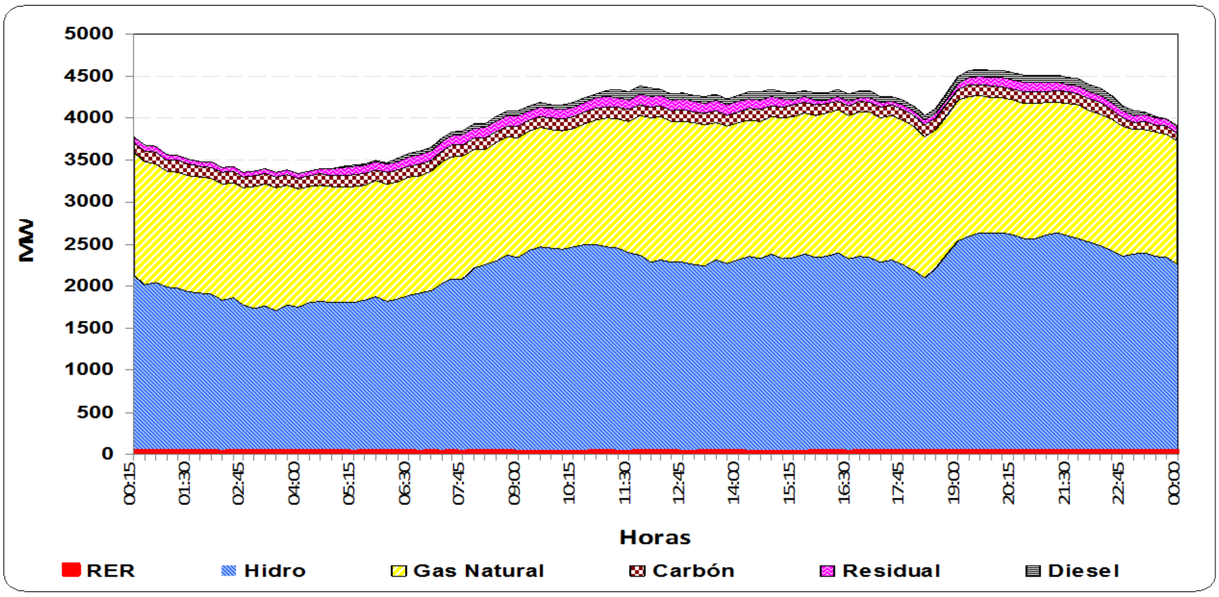
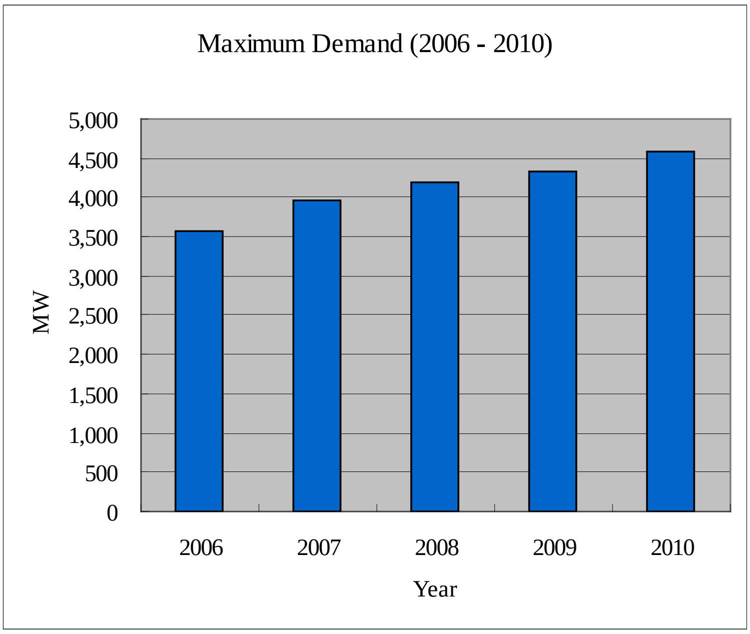


Fig. I-2.3.3 Demand registered by sources (December 16, 2010)

Table I-2.3.3 and Figure I-2.3.4 show the evolution of recorded annual peak demand from 2006 to 2010. The year 2010 the peak demand increased 5.9% compared to the previous year.

Table I-2.3.4 Maximum demand (2006 – 2010)

Year	2006	2007	2008	2009	2010
Peak Demand (MW)	3,580.3	3,965.6	4,198.7	4,322.4	4,578.9
Growth (%)	-	10.8	5.9	2.9	5.9

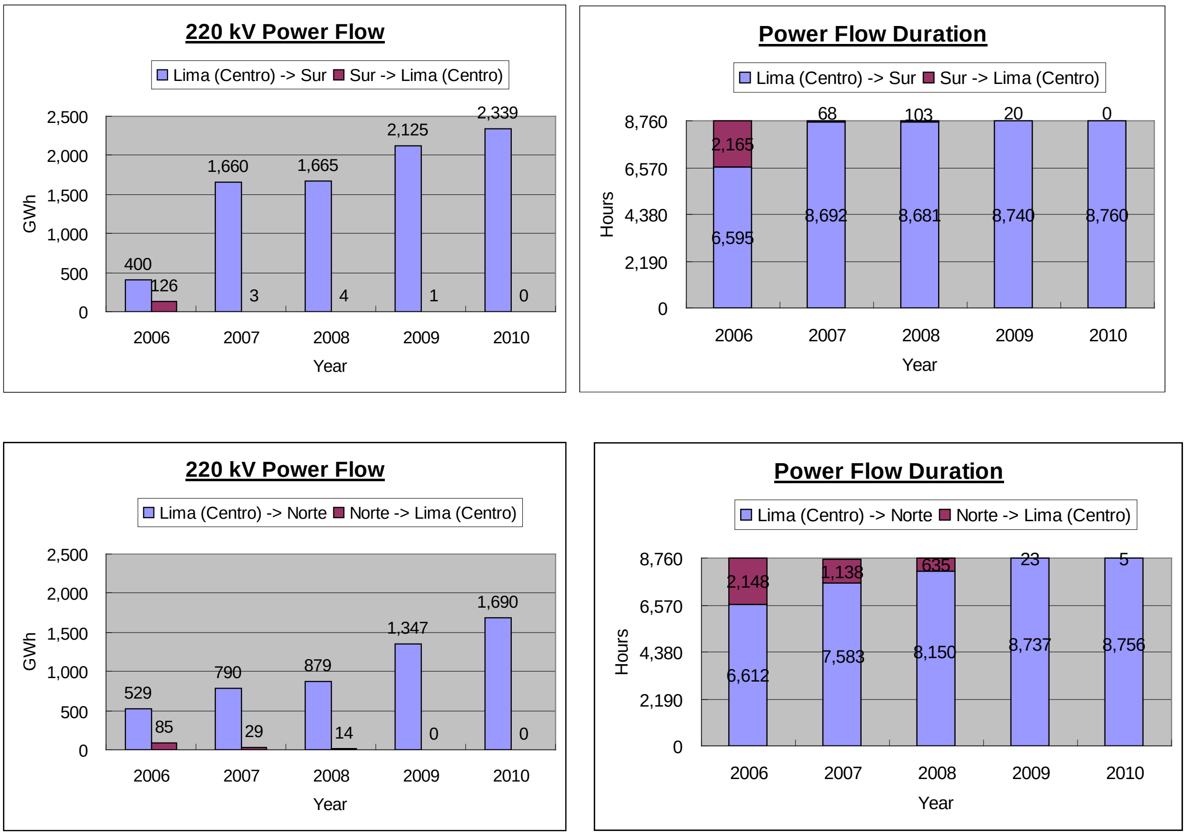


Source: MEM 2010 data

Fig. I-2.3.4 Maximum demand (2006 – 2010)

I-2.3.2 Power flow between Areas

Figure I-2.3.5 shows energy in GWh and its duration in hours of 220 kV power flow between Lima city (central of the country) and Sur / Norte for recent 5 years (2006 to 2010). In 2006, 126 GWh energy delivered from Sur to Lima city for 2,165 hours (while 400 GWh from Lima city to Sur), and 85 GWh energy delivered from Norte to Lima city for 2,148 hours (while 525 GWh from Lima city to Norte). Both the power flow and its duration from Sur and Norte to Lima city began to decrease from 2007, and finally in 2010, it was almost zero, i.e. all power flow are from Lima city to both area. In this connection, the power flow made transmission losses increased, 188 GWh transmission loss in 2010 (20% increased than previous year 2009) in Sur and 109 GWh loss in 2010 (58% increased than 2009). (Source; COES-SINAC Estadistica de Operaciones 2009 & 2010)



Source; COES-SINAC Estadistica de Operaciones 2006 - 2010

Fig. I-2.3.5 Power Flow between Lima city and Sur / Norte (Total Energy and Duration)

I-2.3.3 Transmission Lines and Substations

In late 2010, the transmission system in Peru was mainly composed of networks of 220kV, 138kV and 66/30kV. The network is interconnected in 220 kV with a length of 2,200 km from north to south. Figure I-2.3.6 shows the interconnection of transmission lines at December, 2010. Table I-2.3.4 shows the lengths of transmission lines.

Table I-2.3.4 Length of transmission lines

Voltage	Lines	Main network* (km)	Secondary Network** (km)	Subtotal (km)	Total (km)
220 kV	1 circuit	1,450.9	3,305.7	4,756.7	8,265.9
	2 circuits	1,468.9	2,040.4	3,509.3	
138 kV	1 circuit	400.6	3,104.9	3,505.5	3,738.5
	2 circuits	0.0	233.0	233.0	
66/33 kV	-	0.0	1,884.4	1,884.4	1,884.4

Source: COES data

Note) (*): Trunk line Transmission lines
(**): Other Transmission lines except Trunk lines

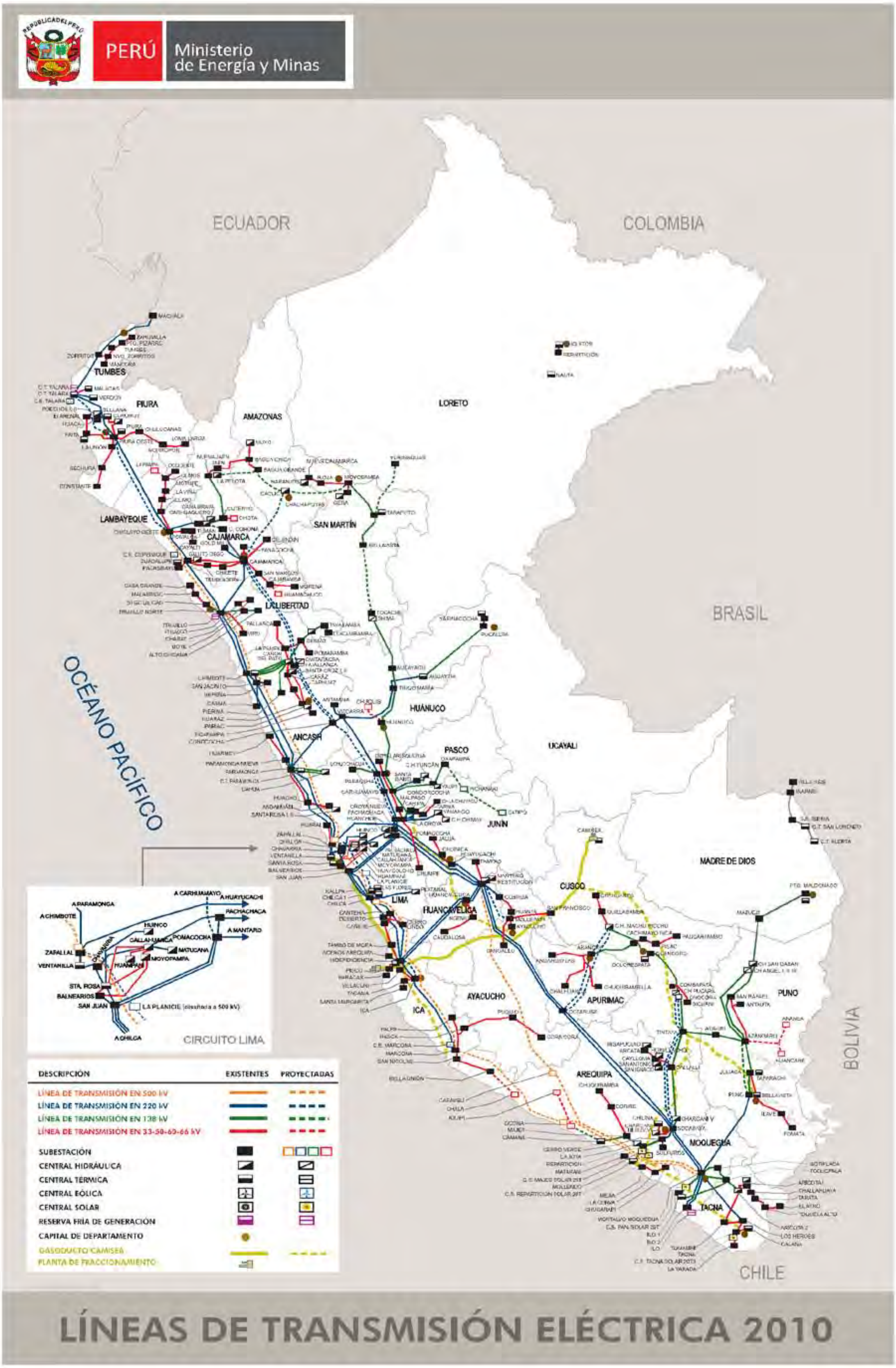


Fig. I-2.3.6 Transmission line network (MEM, 2010)

Table I-2.3.5 and Table I-2.3.6 show the capacity of substations, transformers, capacitors available in 2010. The capacity of transformers include transformers in generation plants.

Table I-2.3.5 Installed transformer capacity

Lines	Primary Transmission System (MVA)	Secondary Transmission System (MVA)	Total (MVA)
Step up S.E. (MVA)	0.0	4,452.7	4,452.7
Transformation S.E. (MVA)	710.0	13,358.8	14,068.8

Source: COES (2010)

Table I-2.3.6 Installed compensation equipment capacity

	Ind./Cap.	Primary System (Mvar)	Secondary System (Mvar)	Distribution System (Mvar)
Comp. Synchronous.	Inductive	0.0	10.0	0.0
	Capacitive	0.0	20.0	0.0
Reactor		150.0	235.0	0.0
Capacitor		170.0	112.2	176.2
S.V.C.	Inductive	65.0	45.0	50.0
	Capacitive	75.0	90.0	100.0

Source: COES (2010)

I-2.4 Power Supply Structure

I-2.4.1 Generation

The wholesale market is free and has the participation of generation companies. In the wholesale market ,power generators sell power to distribution companies or directly to large users (consumers of more than 2,500 kW). The dispatch center, COES-SINAC, which is an organization composed of all generation and transmission and distribution companies (for each transmission system) has the function of commercial daily dispatch. The dispatch is planned every hour in merit order in the principle of optimal economic dispatch at the minimum cost.

I-2.4.2 Transmission and Distribution

To assure the liberalized wholesale and retail markets, the law guarantees free access to transmission networks. Users of the transmission and distribution lines, transmission and distribution charges, approved by OSINERGMIN must be paid.

I-2.4.3 Small Users Market

To sell electricity, there are two markets. The free market for large users (consumers above 2,500 kW) and the regulated market for small users (consumers below 200 kW). Large users can freely contract with the generation companies or distributors. There are currently 343 free contracts, occupying 46% of total energy sales in the country and representing the transaction of 11.4 GWh. In the regulated market, distribution companies are required to supply electricity to small users in their proper area.

I-2.5 Tariff Structure

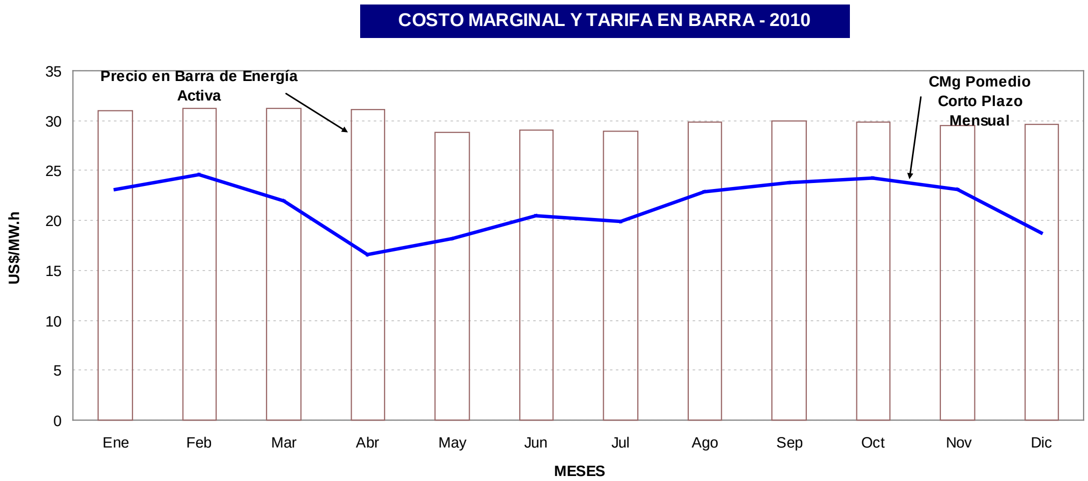
Electricity tariffs in the regulated market are determined by the OSINERGMIN. In that case, the tariff for users is calculated by adding the fee at node (the generation fee and transmission fee to the node) and the distribution fee. Generation fee has two components: the capacity fee (USD/MW) and energy fee (USD/MWh). The energy fee is defined for on- and off-peak hour, respectively.

I-2.5.1 Generation

Large consumers can buy electricity from generators or distributors under the direct contracts in the freely agreed prices. Consumers in the regulated market pay the tariff defined by OSINERGMIN.

COES revises the regulated tariff for generation in May each year. The regulated tariff of generation is calculated for each node in the system based on demand forecast of 24 months ahead and the actual demand for 12 months till March of the same year, taking into account the fuel price, maintenance of plants, projected storage in dams, the official discount rate etc. There are 82 nodes in the SEIN and 16 nodes in the SSAA (isolated systems). The capacity fee (USD/MW) is calculated based on the annual investment cost of marginal generation plant. The energy fee (USD/MWh) is the weighted average value of short-term marginal cost of energy per node.

Figure I-2.5.1 shows the evaluation of the short term marginal cost in the SEIN and the energy cost at the busbar during 2010.



(Source: MEM 2010 data)

Fig. I-2.5.1 Evolution of short-term marginal cost and the energy cost in the busbar (2010)

I-2.5.2 Transmission

The transmission fee has two components; line usage fee and connection fee. The total cost of transmission on a trunk system is the sum of investment cost and operating and maintenance cost. The line usage fee is calculated by COES for each system based on power (MW) and energy (MWh) supplied to each node. The connection fee covers the difference between transmission cost and line usage fee.

I-2.5.3 Node Price

The COES calculates the rate at bar, adding the generation fee at each node and the fee for use of transmission line. The bar price calculated by COES and requires an approval from OSINERGMIN.

I-2.5.4 Distribution

The distribution costs include the cost of investment for distribution lines, the operation and maintenance costs related directly to the users as the electricity meter measurement, collection, etc. The cost of distribution is calculated based on an efficient distribution model for each area. The rate of return is reviewed every four years, taking into account investment costs, costs of operation and maintenance and replacement of equipment for 25 years of project life.

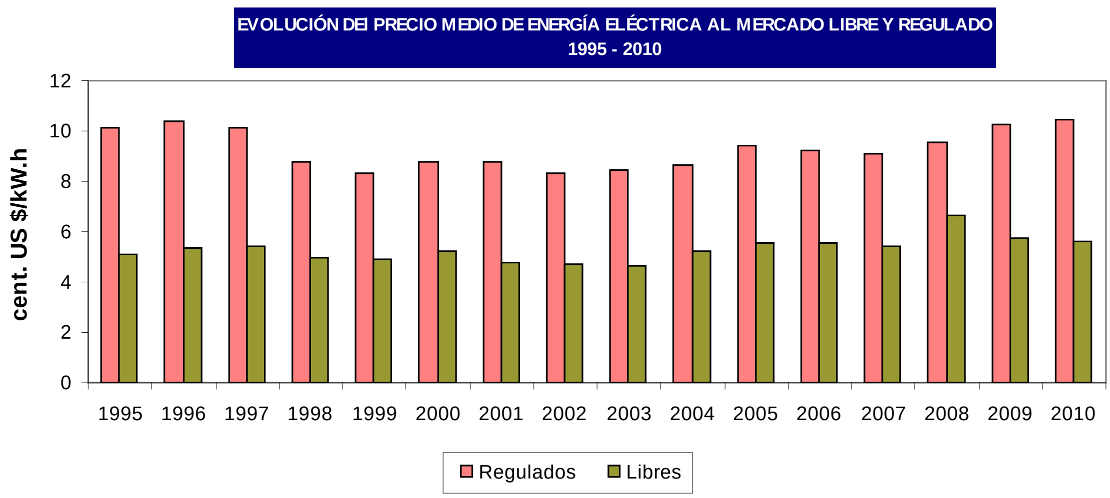
Table I-2.5.1 shows the average electricity price sold by distributers and generators from 1995 to 2010. Figure I-2.5.2 shows the average electricity price in the regulated market and free market respectively from 1995 to 2010.

Table I-2.5.1 Evolution of energy price (1995 – 2010)

US cents/kWh

Year	Market			Distributors			Generators
	Total	Regulated	Free	Total	Regulated	Free	
1995	**8.4**	10.1	5.1	9.0	10.1	5.5	4.2
1996	**8.6**	10.4	5.3	9.4	10.4	6.0	4.5
1997	**8.2**	10.1	5.4	9.2	10.1	5.7	5.2
1998	**7.1**	8.8	4.9	8.0	8.8	5.0	4.9
1999	**6.8**	8.3	4.9	7.6	8.3	5.1	4.9
2000	**7.2**	8.8	5.2	8.0	8.8	5.3	5.2
2001	**6.9**	8.8	4.7	8.2	8.8	5.4	4.5
2002	**6.6**	8.3	4.7	7.8	8.3	5.2	4.5
2003	**6.6**	8.4	4.6	8.0	8.4	5.3	4.5
2004	**7.0**	8.7	5.2	8.2	8.7	5.4	5.2
2005	**7.6**	9.4	5.6	8.9	9.4	5.6	5.5
2006	**7.6**	9.2	5.6	8.7	9.2	5.4	5.6
2007	**7.4**	9.1	5.4	8.7	9.1	5.4	5.4
2008	**8.2**	9.6	6.6	9.2	9.6	6.2	6.7
2009	**8.3**	10.2	5.7	9.9	10.2	6.6	5.6
2010	**8.3**	10.5	5.6	10.1	10.5	6.9	5.4

Source: MEM 2010 data

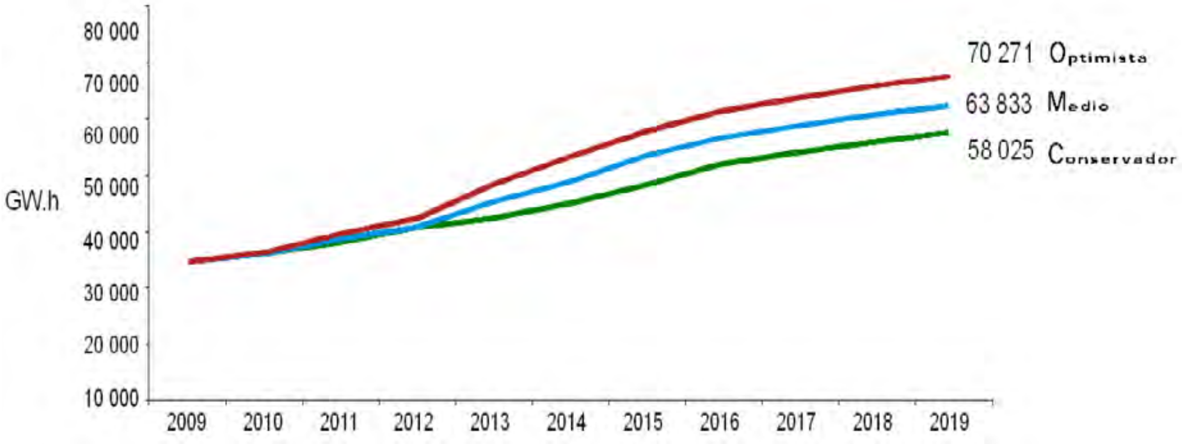


Source: MEM 2010 data

Fig. I-2.5.2 Evolution of electricity price (1995 - 2010)

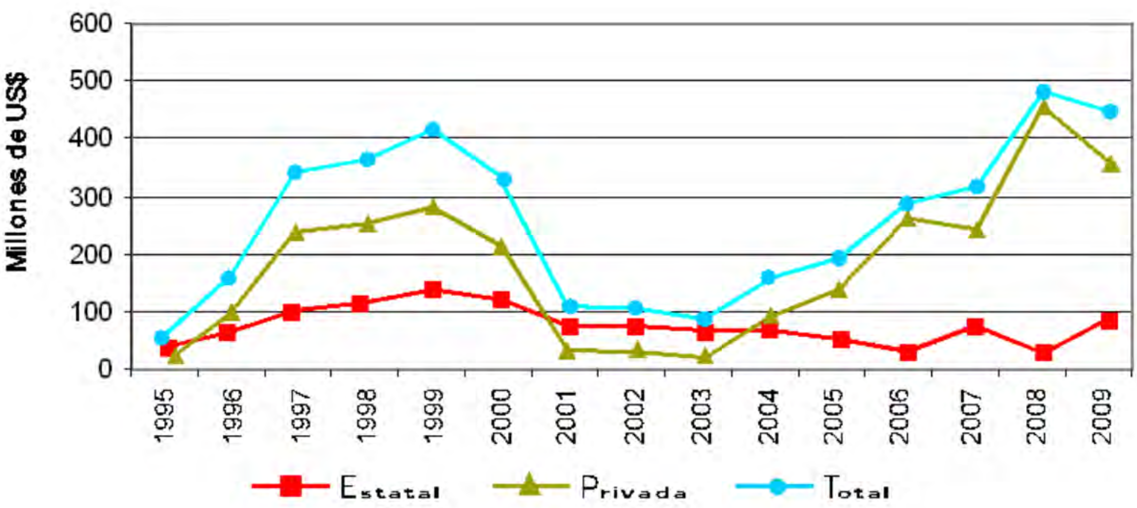
I-2.6 Policies of Power Sector

In the past five years, the demand for electricity has had an average annual growth of 8% due to the strong development of mining and manufacturing. Figure I-2.6.1 shows the projected demand through 2019 in three different scenarios (Optimist: 9.0%, Medium: 8.1% Conservative: 7.0%). Although macroeconomic conditions in the country maintain this level of growth and in the last five years investment in electricity has grown at an average annual rate of 23%, the country needs to accelerate the implementation of new projects to ensure the supply of electricity (Fig. I-2.6.2).



(Source: MEM 2010)

Fig. I-2.6.1 projected energy demand 2009-2019



(Source: MEM 2010)

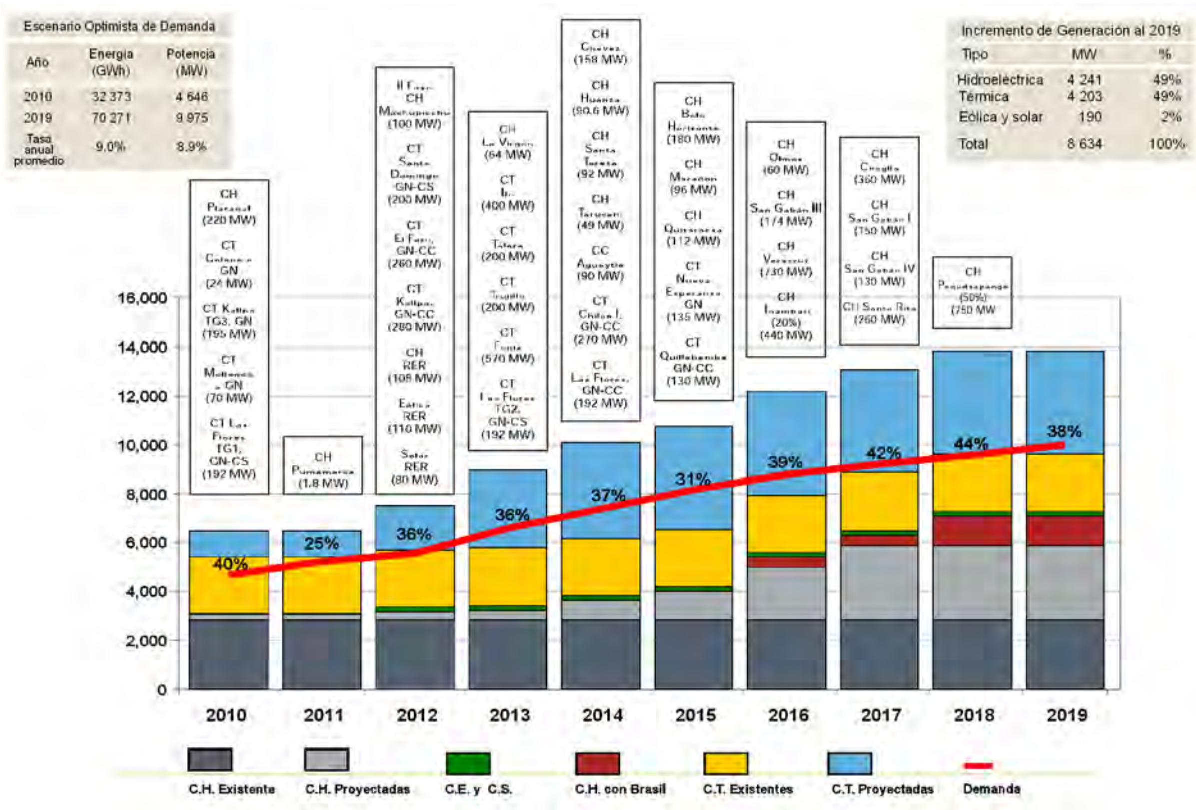
Fig. I-2.6.2 Investments in electric generation

Based on these facts, the MEM is implementing policies in the following lines:

- Diversify the energy matrix
- Mechanisms of incentive for private investment
- Perfect the regulatory and legal framework of the subsector to ensure timely and adequate supply

- Promote the development and use of renewable energy sources for electricity generation, particularly hydro
- Use efficient natural gas for power generation
- Security and coverage of electric transmission
- Regulation of tariff in the regulated market
- Continue the expansion of electricity coverage in rural, remote and border areas of the country
- Promote a culture of energy efficiency and electrical safety users
- Energy Security
- Promote investments in generation and transmission of electricity for the regional energy integration (to become an exporter of electricity in the region, considering its huge potential of hydropower)
- Promotion of energy development while preserving the environment

According to the MEM's "Electricity Sector 2010", the estimated increment of generation capacity for 2019 will be 8,634 Mw. This will be given at the rate of 49% from hydropower, 49% in power plants to natural gas and 2% in renewable energy (excluding hydro) (Fig. I-2.6.3).



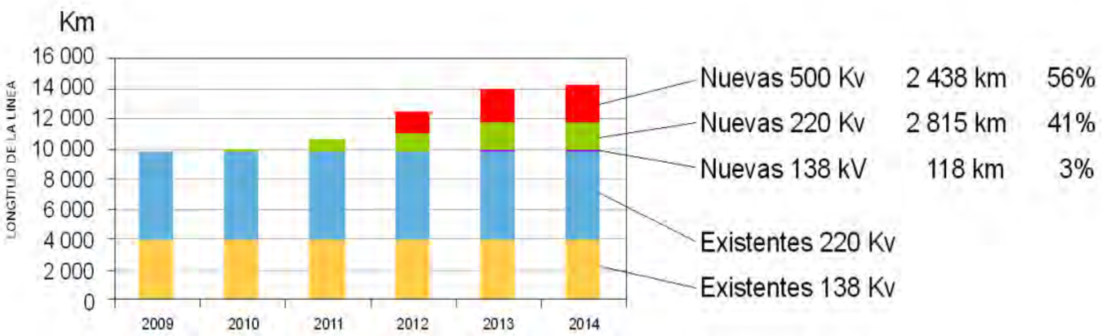
(Source: MEM 2010)

Fig. I-2.6.3 Projected supply and demand, for SEIN, 2010 - 2019

As for the transmission, to enhance the efficiency, reliability and security in the operation of the system, it is expected that the SEIN operate on a new and higher voltage of 500 kV. For the period 2010 to 2014, it will be operating new transmission lines, totaling 4,371 km further, where 56% are 500 kV network, 41% of 220 kV and 3% of 138 kV (Table I-2.6.1 and Fig. I-2.6.4).

Table I-2.6.1 New T/L programmed for year 2014

Estado	Lineas en proyecto	Tension (Kv)	Longitud (km)	Año de puesta en operación
Licitado	LT Chilca Planicie Zapallal	220	94	2010
Licitado	LT Chilca Zapallal	500	94	2011
Licitado	LT Carhuamayo Paragsha Conococha Huallanca Cajamarca, LT Cerro Corona Carhuaquero	220	671	2011
Licitado	LT Independencia Ica (Doble Circuito)	220	55	2011
Licitado	Mantaro Caraveli Montalvo	500	742	2012
Licitado	LT Machupicchu Cotaruse	220	204	2012
Licitado	LT Zapallal Chimbote Trujillo	500	530	2012
Licitado	LT Chilca Marcona Ocoña Montalvo	500	872	2013
Licitado	LT Tintaya Socabaya	220	207	2013
Licitado	LT Piura Talara (2do circuito)	220	103	2012
Licitado	LT Pomacocha Carhuamayo	220	110	2012
En licitación	LT Machupicchu Abancay Cotaruse	220	204	2013
En licitación	LT Trujillo Chiclayo	500	200	2013
En licitación	LT Cajamarca Norte - Caclic	220	167	2013
En licitación	LT Caclic Moyobamba	138	118	2013
Previsto	LT Onocora Tintaya	220	75	Por definir



(Source: MEM, Sector Eléctrico 2010)

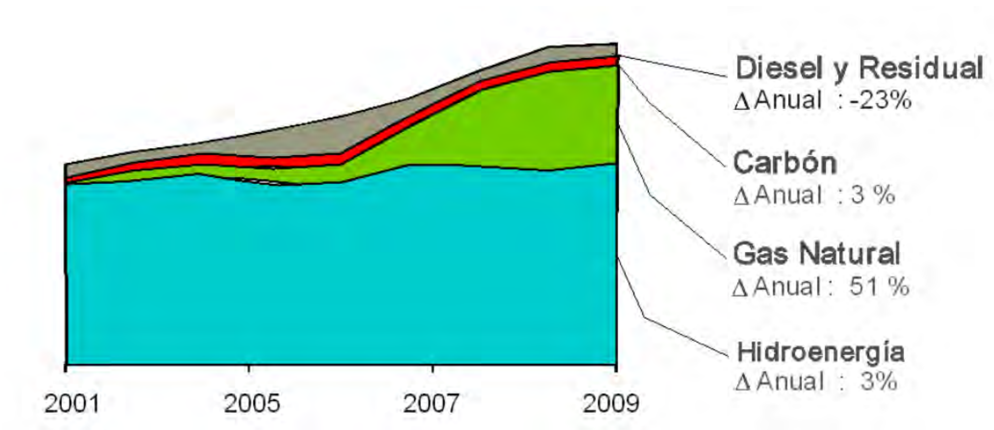
Fig. I-2.6.4 Length of T/L in SEIN

Interconnection with neighboring countries, such as with Brazil, is associated with the implementation of major hydropower projects in the country. Interconnection with Ecuador has already implemented a transmission link of 220 kV, between Tumbes and Machala, with limited capacity of 160 MW and asynchronous operation. For existing regulatory differences in both countries, the link has not operated continuously. Given the difficulty of access and poor development of electrical systems in the border zone with Colombia, the link with Ecuador would also allow an energy exchange with Colombia. As for interconnection with Bolivia and Chile, there exists a technical limitation of the frequency difference, which makes difficult such interconnection.

I-3 Promotion of Renewable Energy Development

I-3.1 Background

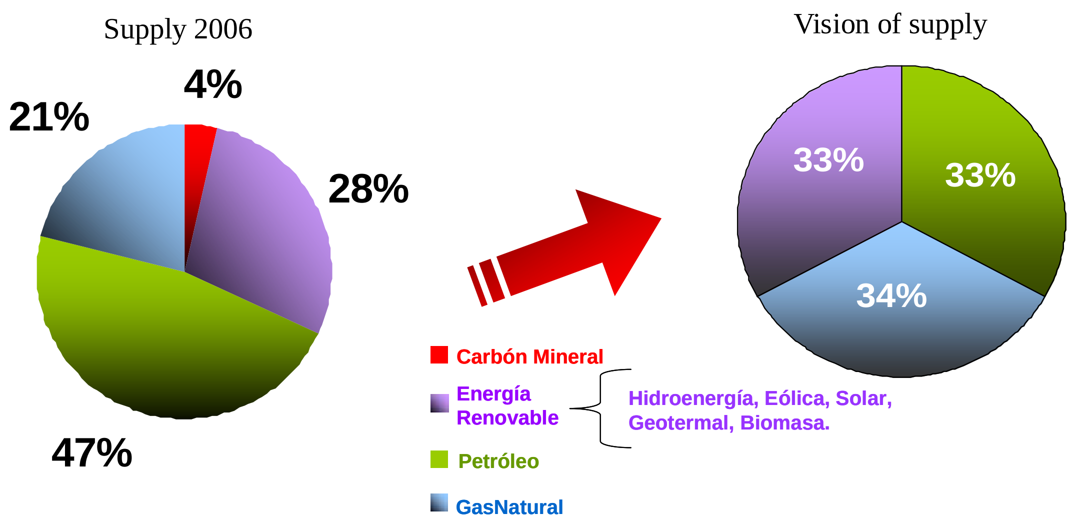
In policies for power sector, promotion of use of renewable energy resources is one of the pillars and the government is implementing concrete measures. For the country it is a requirement not only from the standpoint of view of the environment, but in order to meet the growing demand for electricity in the medium term it will be essential to use renewable energy resources. However, as shown in Fig I-3.1.1, the country is highly dependent on the production of electricity from hydro resources and on the other hand, the generation of electricity by burning natural gas has also increased recently. In this sense, the importance of the introduction of renewable resources of the country's energy mix will be increasing from the point of view of the country’s energy security.



(Source：MEM, 2010)

Fig. I-3.1.1 Generation by resource 2001 - 2009

The Peruvian government has the vision for the change of the energy matrix in the future, in which about one-third of the energy supply (including power generation) should be met with renewable energy sources (Figure I-3.1.2). In June 2010, the government presented officially the national actions for mitigation of climate change in accordance with the international agreement in COP 15 under the framework convention on climate change (Copenhagen Agreement). Among the activities which the government compromised to realize voluntarily, the modification of the actual energy matrix in the way that at least 33% of the energy matrix should be represented with “non-conventional energy, hydroenergy, biomass” in 2020 is included.



(Source：MEM“ Norms and facilities to develop Renewable Energy” 10/2008)

Fig. I-3.1.2 Vision for a change in the energy matrix

I-3.2 Laws for Promotion of Electricity Generation with Renewable Resources

The government established an obligation of 5% of energy consumption in the next five years should be covered with renewable energy resources (RER: biomass, wind, solar, geothermal, tidal and hydropower up to 20 MW). The government is implementing rules and incentives to promote the use of renewable energy resources and within the promulgation of the Law to Promote Electricity Generation with Renewable Energy (Law No.1002) in May 2008 and its Regulation (Supreme Decree No. 050-2008-EM) enacted in October of the same year are the most important.

Under the Law and its Regulation, the government carried out the first and second auctions of electricity supply with renewable energy resources in SEIN for the period of 20-30 years in the awarded price. The auction was conducted in the following manner:

- The country guarantees that the 5% of annual energy consumption should be covered by energy generated from renewable energy resources during the next 5 years. This percentage of participation of renewable energy resources may be increased by the MEM.
- To meet the requirement, the country guarantees the payment of the awarded price in the auction for a period between twenty and thirty years (renewable energy resources generator receives the guaranteed income from the sale of energy produced at the awarded price. In case of that the awarded price exceeds the marginal cost of the spot market, that difference will be covered as premium).
- The composition of energy by type of technology is defined accordingly to the National Renewable Energy Plan, projects with requested for concession. The bidding documents are prepared by MEM.
- The bidding process is conducted by OSINERGMIN at the request of MEM.
- For the determination of the Base Price, MEM considers a return of not less than 12% as defined in Article 79 of the Electricity Concessions Law. Base Price will be calculated by OSINERGMIN by type of generation technology with renewable energy resources (See Fig. I-3.2.1).

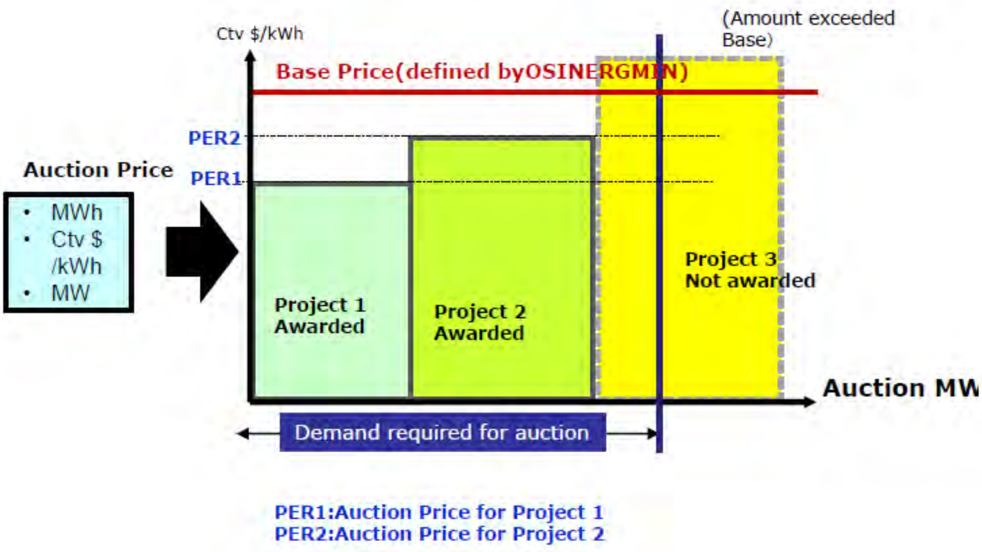


Fig. I-3.2.1 Auction scheme for generation with renewable energy resources

- The Award Price shall be guaranteed to each successful bidder for the sale of its energy production, expressed in USD/MWh.
- The evaluation of bidders is independently done by technology type of renewable energy resources.
- The award is determined in merit order within the Base Price up to complete the share of each technology defined in the bid document to cover the total energy required.
- The term of validity is established in the Rules, within not less than twenty years nor more than thirty years.
- The call to auction will be taken place with intervals of 2 years.
- The sale of power generated with renewable energy resources in the short term market at marginal cost plus a premium is guaranteed, in cases where the marginal cost is less than the corresponding award price (See Fig. I-3.2.2) The premium will be reflected in the price of electricity for end users.

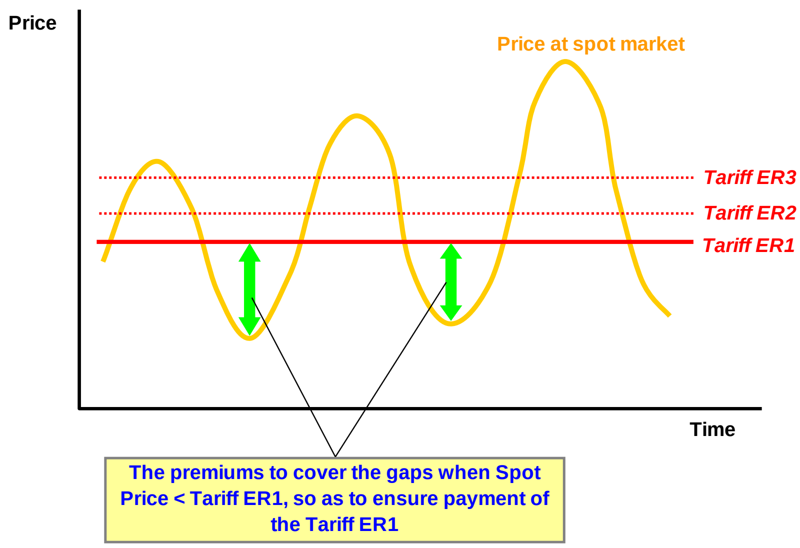


Fig. I-3.2.2 Selling price of power generated by renewable energy resources

- Be owner of a temporary concession is not a requirement for bidders.
- Preferential dispatch and free access to connection networks.

In October 2009, the government conducted the first auction of renewable energy resources electricity supply in order to have an installed capacity of 500 MW (converted from required energy 1,134 GWh/year at the capacity factor of 30%) with renewable energy resources other than hydro. The award was determined in February 2010 among 20 qualified bidders with 31 projects: 17 hydro, 6 wind , 2 solar and 6 biomass. Finally, 26 projects have been awarded. The maximum prices set by OSINERGMING previously were: hydro 74 USD/MWh, wind 110 USD/MWh, biomass 120 USD/MWh and solar 269 USD/MWh. These prices were calculated by OSINERGMIN according to its own methodology, and were kept in reserve until the public act of opening of bids.

The term of the award price is 20 years and the projects awarded will enter into commercial operation no later than December 31, 2012. Auction to complement the missing portion of 500 MW was announced in March 2010 and 25 projects (5 biomass, 17 solar and 3 hydroelectric) participated. However, most projects had a price above the base price and only two hydroelectric projects were awarded. The second auction was announced in April, 2011 and awarded for one biomass project, one wind project and one solar project in July, 2011. The base price was revealed after the auction only for the biomass project, which was 65 USD/MWh. Table I-3.2.1 shows the awarded biomass, wind and solar projects up to now.

Table I-3.2.1 Awarded renewable energy resources projects

Project Name	Capacity (MW)	Price (centUSD/kWh)	Capacity Factor (%)	Tender Year	Generation Start Year
Biomass	***29.4***				
Generación Ingenio Azucarero Paramonga	23.0	5.20	57.10	2009	2010
CTB Huaycoloro	4.4	11.00	73.40	2009	2011
La Gringa V	2.0	9.999	80.00	2011	2014
Wind	***232.0***				
Marcona	32.0	6.55	52.93	2009	2012
Central Eolica Talara	30.0	8.70	46.00	2009	2012
Central Eolica Cupishnique	80.0	8.50	43.00	2009	2012
Central Consorcio Tres Hermanas	90.0	6.90	52.73	2011	2014
Solar	***96.0***				
Panamericana Solar 20TS	20.0	21.50	28.90	2009	2012
Majes Solar	20.0	22.25	21.50	2009	2012
Tacna Solar	20.0	22.50	26.90	2009	2012
Reparticion Solar 20T	20.0	22.30	21.40	2009	2012
Solarpack Corporación Tecnologica S.L.	16.0	11.99	30.50	2011	2014
Total	**357.4**				

The renewable energy resources generator connected to the SEIN may sell part or all of their energy in the spot market. Additionally they get a premium if the amount awarded is higher than a marginal cost in the spot market. The renewable energy resources generator connected to an isolated system will sell its distributor at the awarded price. The renewable energy resources generator not awarded may sell part or all of their energy freely in the contract with third parties or in the spot market.

I-3.3 Other Laws and Regulations to Promote Utilization of Renewable Energy Resources

The government is implementing other laws and regulations to promote use of renewable energy resources such as;

Law to Promote Investment in Hydroelectric and the Efficient Use of Natural Gas (DL No.1041, June 2008)

- Promote investment in hydroelectric plants, extending the maximum period of 15 years to 20 years for electricity supply contracts resulting from tenders for electricity.
- In the bidding process for electricity a discount factor will be applied to the hydroelectric projects in case of that those projects exceed the investment cost of thermal projects. The discount factor will be applied only for the evaluation of economic proposals. Supply contracts will be signed with actual prices offered.
- Promote investment in combined cycle power plants operating on open cycle to improve the efficient use of natural gas and transport infrastructure.

Law to promote investment in the electricity generation activity with other Water and Renewable Resources (Legislative Decree No. 1058, June, 2008)

- The power generation business on the basis of hydro or other renewable resources shall enjoy the status of Accelerated Depreciation for purposes of income tax. Accelerated depreciation not exceeding the overall rate of 20% annually.
- Depreciation rules for machinery, equipment and civil works required for installation and operation of the plant, which are purchased and / or constructed after the effective date hereof.

Cogeneration Regulations (Supreme Decree No. 037-2006, EM, July 2006)

- Establishes the requirements and conditions for qualifying cogeneration plants involved in the electricity market.
- Establishes the following benefits:
  - Price of natural gas equal to that of a generator.
  - Free access of connection to networks. Tolls for connection are not applied for its own power consumption.
  - Preferential dispatch preference by COES.
  - Secured sale of their surplus power and energy in the wholesale market at marginal cost.
  - Sale of surplus under contract to the Generators, Distributors or Free Customers.

Additionally, laws that grant tax benefits to investment on renewable energy have been adopted, a) Decree Law No.1058, which has the benefit of accelerated depreciation of assets, up 20% each year for purposes of payment of income tax for investments hydroelectric and other renewables (June, 2008) and b) No.28896 Act provides that the generation of electricity with renewable hydro resources and/or other, is eligible for Early Recovery System of General Sales Tax (GST) (June 2006).

I-4 Legal Framework for Development of Geothermal Resource

I-4.1 Organic Law of Geothermal Resources

To promote development of geothermal resources, the Organic Law on Geothermal Resources (Law No.26848) was promulgated in July 1997 and its Regulations in 2006. Later in April 2010, the new Regulation of Law No.26848 was approved with the objective of introducing private investment in developing this energy source and reduce the risk to them. Also, Ministerial Resolution No.191-2007-PCM established a Multisectoral Technical Commission.

I-4.2 Organizations Related to Geothermal Development

Relevant entities related to geothermal development in the country are;

Vice Ministry of Energy, Ministry of Energy and Mines
Ministry of Energy and Mines shall resolve as a second and final administrative entity those challenges against decisions of the Directorate General of Electricity.

General Directorate of Electricity (DGE)
The functions of DGE, in accordance with the provisions of the Geothermal Resources Law and its Regulation, are to process and settle in the first instance, as appropriate, all administrative procedures.

General Directorate of Energy Environmental Affairs (DGAAE)
The functions of the DGAAE, conforming to the Geothermal Resources Law and its Regulation, are to process and settle in the first instance, as appropriate, all administrative procedures relating to environmental studies of geothermal activities.

Supervisor of Investment in Energy and Mining (OSINERGMIN)
OSINERGMIN is in charge of supervision and monitoring of geothermal activity. Establish the scale of fines and penalties for geothermal rights holders who violate the law and regulations, under the legal provisions established for this purpose. Forward the case of disqualification of geothermal rights which may cause revocation, to DGE.

I-4.3 Definition of Geothermal Activities

According to the Organic Law on Geothermal Resources and Regulations, geothermal activities are divided into the following Phases (Table I-4.3.1);

Table I-4.3.1 Development phase of geothermal resources and geothermal rights

Development phase	Activities	Geothermal rights	Terms
(i) Identification	Activity to determine whether the area has geothermal resources or not by means of observation of terrain, geology and geo chemical studies.	None.	-
(ii) Exploration phase 1:realization of studies prior to the drilling of exploratory wells with a depth less than 1000 m. phase 2: realization of drilling of minimum of 3 exploratory wells	Activity to determine the dimensions, position, characteristics and extent of geothermal resources, including drilling of thermal gradient.	Requires Authorization	3 years phase 1: 2 years phase 2: 1 year, possible to be extended one time for 2 years
(iii) development (exploitation) to power generation	Activity to exploit the geothermal energy with the commercial aims by means of steam, heat and fluid of high and low temperature and others	Requires Concession. In the event of power generation, the concession contract shall be extend automatically for the same period of the concession for electricity generation.	30 years Possible to be extended for 10 years each time.

Development of geothermal resources should be done under the Organic Law of Geothermal Resources.

However, for the electricity generation, it requires to obtain the concession for electricity generation under the Electricity Concession Law, and the concession for geothermal exploitation can be automatically extended for the years of the concession for electricity generation.
Meanwhile, other renewable resources, the development and electricity generation are reigned by the Electricity Concession Law, according to which, the required rights are classified into the following three;

- Concession (Definitive Concession) : Required for electricity generation with hydro power (>20MW) and renewable energy resources (RER, including hydro less than 20 MW)
- Temporary Concession: Required for generation projects with any capacity, including the renewable energy resources, to conduct the F/S within the period of 2 years.
- Authorization: Required for thermoelectric plants over 0.5 MW

Table I-4.3.2 shows the rights required for resource development and generation with geothermal and other renewable energy resources.

Table I-4.3.2 Required right for resource development and electricity generation

		Thermelectric (more than 500kW)	Hidroellectric (more than 20MW)	RER except geothermal energy (biomass, wind, sun, tidal power, hidro less than 20 MW)	Geothermal Energy
Aplicable Law		Electricity Concessions Law			Geothermal Resources Law
Rights	Pre F/S	None	None	None	Authorization (for exploration)
	F/S	Temporary Concession	Temporary Concession	Temporary Concession	Concession (for exploitation)
	Generation	Authorization	Definitive Concession	Definitive Concession	For electricity generation, the definitive concession is required under the Electricity Concession Law (concession for geothermal exploitation can be extended automatically for years of definive concession.

For applications of authorization and concession for geothermal development, the submission of the Environmental Impact Assessment (EIA) is not a requirement. However, before beginning the exploration and exploitation activities, the EIA should be submitted to the DGAAE for their approval.

Documents required for application of definitive concession for electricity generation with renewable energy resources including geothermal energy are defined in the Electricity Concession Law and its Regulation, in which the requirements are stipulated, depending on the generation capacity (< 10 MW, 10 MW – 20 MW, < 20 MW).

I-4.4 Request of Authorization

I-4.4.1 Procedure for Request of Authorization

Authorization is required to run exclusive exploration of a particular area of geothermal resources. For the request for authorization the following will be required:

1. Request to the Directorate General of electricity, signed by the legal representative, (mentioning identification and legal domicile).
2. Proof of payment for processing in accordance with the TUPA.

3. Simple copy of the public deed of Constitution of the company if the applicant is a legal person. Must also prove registration in the corresponding public registry.
4. (a) identification of the grid and the closed land polygon requested, the coordinates in UTM (PSAD56), specifying the name of the Chart and the zone where the area is located. (b) drawing on the respective area (in scale 1: 100,000) according to the grid system adopted with RM No. 320-91-Ma-DGE, signed by the legal representative and the engineer responsible for its development.
5. (a) descriptive report, signed by the legal representative. (b) plans for exploration project, signed by the engineer responsible for elaboration.
6. Timetable and budget by major headings with precise indication of the number of wells and milestones of the critical path and for each of the phases, signed by the legal representative.
7. Sworn statement through which have an environmental study approved by DGAAE, before the start of the exploration work commitment is set. The type of study environment will be depending on the nature of the activity, signed by the legal representative.
8. Certificate of ability or capacity of engineer responsible for the drawings.

When two or more applications of geothermal rights on a same area, the DGE shall evaluate them according to the order of presentation. Where the request for geothermal right over an area of geothermal resources with different legal nature such as derivatives law rights registered prior rights hydrocarbons, mining or electricity, the previous owner will have a single preferential option to replace the request for geothermal right on its concession area. The holder of an authorization will have preference for the granting of geothermal resources up to 2 years beyond the duration of its authorization.

Figure I-4.4.1 shows the procedure followed until the grant of an authorization.

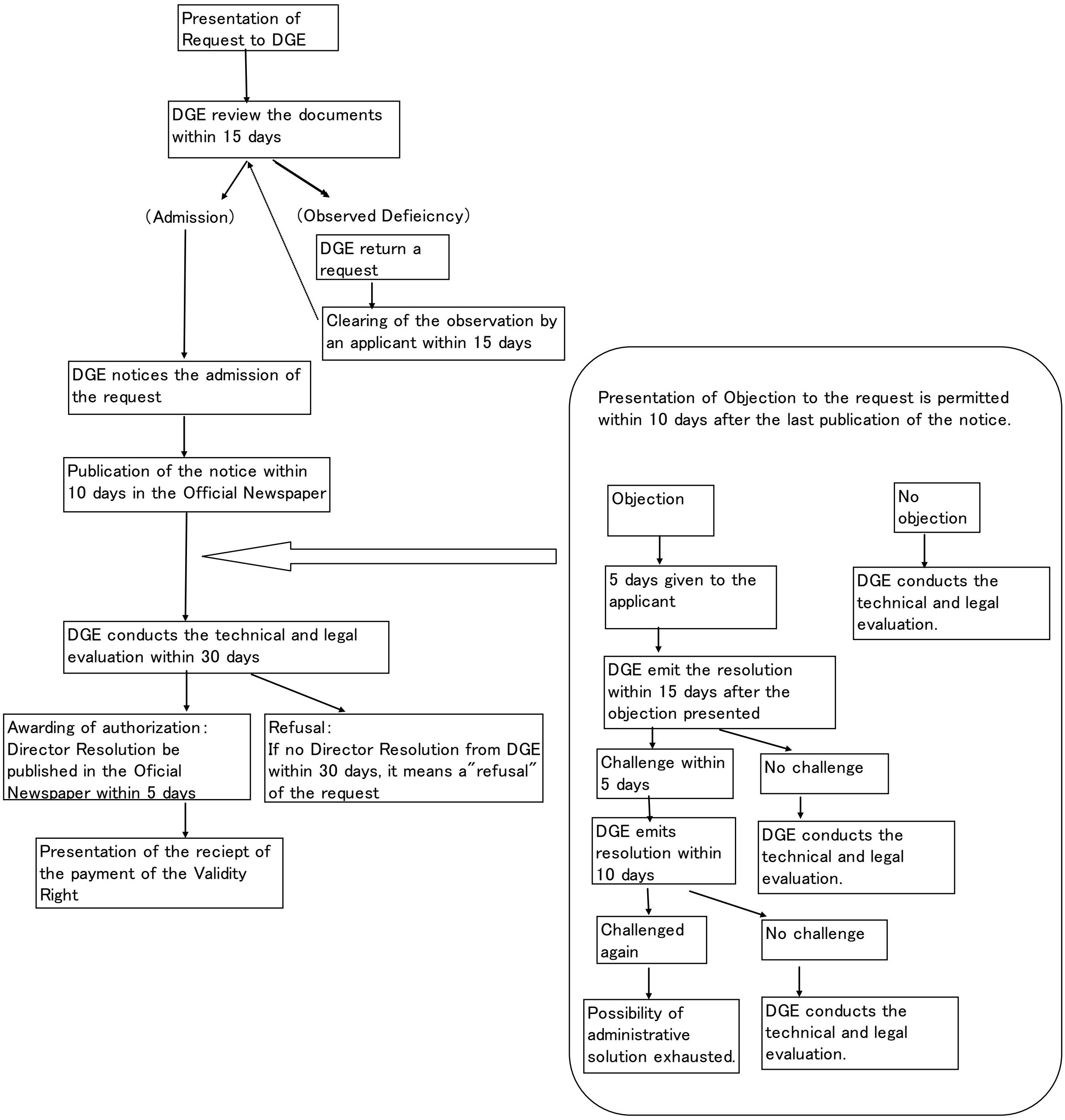


Fig. I-4.4.1 Procedure followed until the grant of an authorization

I-4.4.2 Request of Concession for Geothermal Resources

It is required to obtain a concession for geothermal resources to run geothermal resources exploitation activities. To apply a concession, the following will be required:

1. Request addressed to the Directorate General of electricity, signed by the legal representative, mentioning identification and legal domicile.
2. Proof of payment for processing in accordance with the TUPA.
3. Simple copy of the public deed of Constitution of the company if the applicant is a legal person. Must also prove registration in the corresponding public registry.

4. Simple copy of the resolution of granting of the authorization, in case of exercising the right of preference.
5. (a) identification of the grid and the closed land polygon requested, the coordinates in UTM (PSAD56), specifying the name of the Chart and the zone where the area is located. (b) drawing on the respective area (in scale 1: 100,000), according to the grid system adopted with RM No. 320-91-Ma-DGE, signed by the legal representative, and the engineer responsible for its development.
6. Technical report on the possibilities of production and proposal of the applicant for them.
7. Estimated date for start of production.
8. (a) Descriptive report, signed by the legal representative. (b) drawing project of exploitation, signed by the engineer responsible for elaboration.
9. Projected production capacity and scale of operations.
10. Work program and timetable for implementation of the same, signed by the legal representative. Project budget and investment program, signed by the legal representative.
11. Sworn declaration from which sets the commitment for elaborating and obtaining the EIA approved by DGAAE, before the start of work on the construction of the project. The environmental impact assessment will be granted depending on the nature of the activity, signed by the legal representative
12. Guarantee for an amount equal to one percent (1%) of the budget, until the subscription of the corresponding concession contract.
13. Certificate of ability and capacity of engineer responsible for the drawings.

In the event that the concession holders for geothermal resource exploitation generates electricity, the definitive concession for power generation is required. In that case, the concession period for geothermal resource exploitation can be extended automatically for the period of definitive concession for power generation. Figure I-4.4.2 shows the procedure for application of the concession for geothermal resource exploitation.

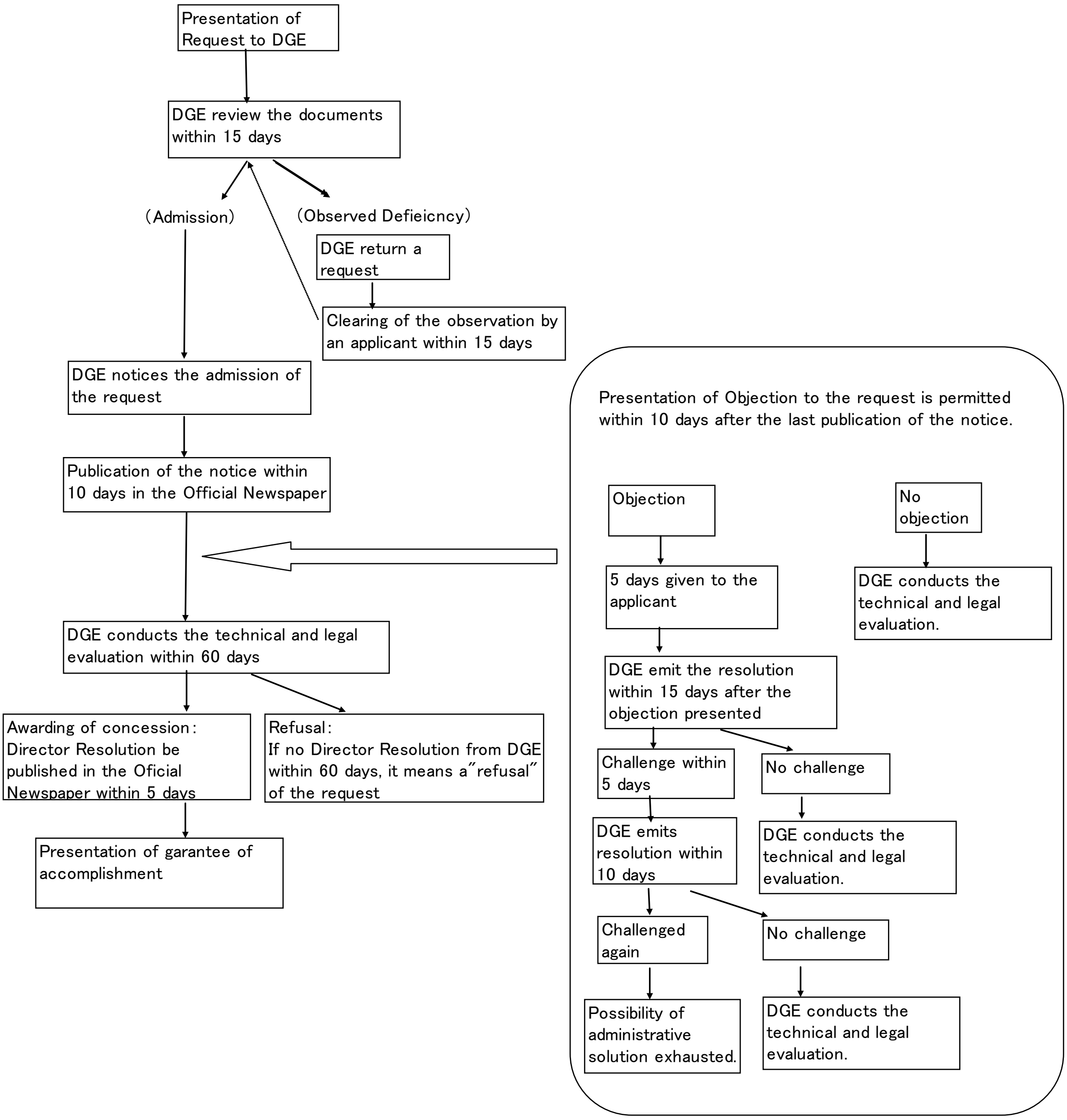


Fig. I-4.4.2 Procedure followed until the grant of concession

I-4.5 Legal Framework on Natural and Social Environmental Concerns

I-4.5.1 Current Situations of Legal Framework on Natural and Social Environmental Concerns

(1) Environmental Impact Assessment System

a) Agencies to Implement EIA for Power Development Projects

No governmental department or agency in Peru has the comprehensive authority over the environmental impact assessment (EIA). When the research was conducted, different ministries take charge of EIA according to the nature of projects. The Ministry of Environment (MINAM; Ministerio del Ambiente) was established in May 2008 to take charge of formulating environmental management rules to ensure sustainable and strategic development of natural resources, managing protected natural areas and conducting research of the indigenous people

in the Amazon river basin.
With examination of the EIA survey contents not included in its responsibility, the MINAM is not involved with the EIA procedures for power development projects. The National Protected Nature Areas Service (SERNANP: Servicio Natural de Áreas Naturales Protegidas) is an organ under MINAM with the authority to grant permission for development within protected natural areas and gives technical opinions on EIA submitted.
EIA for power development projects is reviewed and approved by the Directorate General of Energy-related Environmental Affairs (DGAAE; Dirección General de Asuntos Ambientales Energéticos) of the Ministry of Energy and Mines (MEM; Ministerio de Energía y Minas), while environmental rules and regulations are managed by the Directorate General of Electricity (DGE: Dirección General de Electricidad).
The functions of the DGAAE and DGE are defined as follows in D.S. No. 29-94-EM, Environmental Protection Regulations for Electrical Activities (Aprueban el Reglamento de Protección Ambiental en las Actividades Eléctrica):

- The DGAAE is responsible for establishing major environmental policies and guidelines under the authority of the MEM, and the DGE coordinates the rules and regulations established.
- Based on advice given by the DGAAE, the DGE administrates enforcement of the rules and regulations and penalties for violation, etc.
- The DGAAE is responsible for reviewing and approving the contents of EIA, and changing EIA procedures and setting maximum output capacity.

b) EIA for Power Development Projects

Implementation of EIA in Peru is stipulated in Law No. 27446 promulgated on April 23, 2001. EIA implementation for power development projects is provided for in Decree Law No. 25844, Law of Electricity Concessions and Regulations, promulgated in 1993, and the details of EIA implementation are set forth in D.S. No. 29-94-EM, Environmental Protection Regulations for Electrical Activities that came into effect in 1994.
The Law No. 25844 stipulates that the requirement for EIA for a power development project depends on the energy output capacity of power plant. An EIA is required for a project of 20 MW or greater capacity. For a project of 500 kW or greater output capacity, the MEM’s concession and approval (for the thermal power plant) are required.
In the meantime, Peru has Law of Geothermal Resources (Ley Orgánica de Recursos Geotérmicos), Law No. 26848 promulgated on July 29, 1997. Under Articles 30 and 49 of that law, EIA survey documents are required to be attached to the application for geothermal development concession, and EIA is essential for geothermal resources development.
The relationship between EIA and concessions required for power development projects are presented in Table I-4.5.1.

Table I-4.5.1 Relationship between EIA and concessions required for power development projects

Project		Requirement		
		Concessions	Authorization	EIA
Renewable Power projects[1)]	500 kW to 20 MW	O	-	-
	> 20 MW	O	-	O
Thermal Power[2)]	500 kW to 20 MW		O	-
	> 20 MW		O	O

Note) O : It is required - : No required Source: JICA study team, 2010
1) Hydropower, solar, wind, geothermal and biomass
2) By-products of petroleum, gas and mineral coal.

c) The EIA Procedures for Power Development Projects

For a power development project of 20 MW or greater output capacity, an EIA is to be prepared and processed in accordance with the provisions under Law No. 25844 and D.S. No. 29-94-EM. The procedures are as described below, and the EIA process is shown in Fig. I-4.5.1.

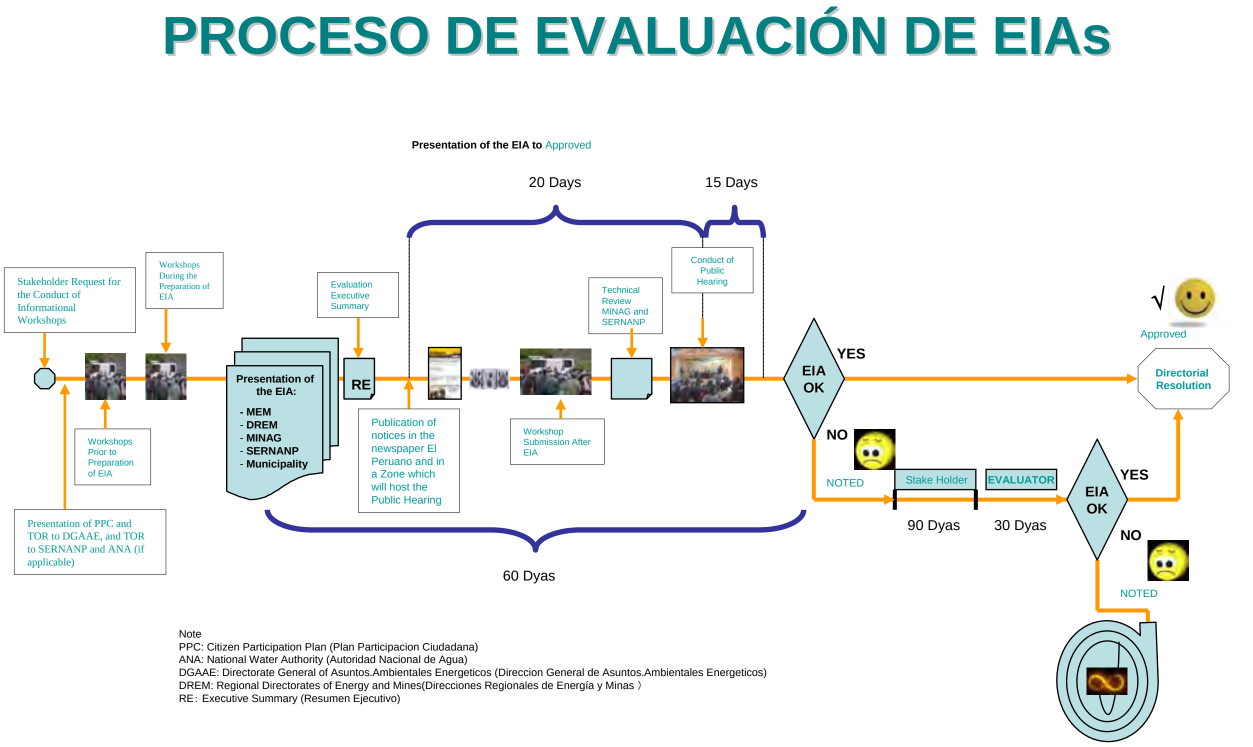


Fig. I-4.5.1 Process of evaluation of EIAs (DGAAE)

- Submission of stakeholders' opinions on the proposed project and holding workshops for collection of information
- Submission of a plan regarding resident participation (PPC) and TOR (TOR is to be sent to the SERNANP, Water Resources Bureau (ANA) of MINAG and other agencies concerned, as needed.)
- Holding workshops prior to commencement of EIA survey (preparatory stage) and during survey (mid stage of EIA survey)
- Submission of EIA statement to the DGAAE-MEM and other agencies concerned (DREM, MINAG, SERNANP and local municipal governments)
- Evaluation and approval of EIA statement overview
- Publication of EIA (In addition to publication on El Peruano newspaper and broadcast on local radio, EIA statement is to be available for viewing at the MEM, DREM and local municipal government offices.)
- Workshops to explain the details of the EIA statement
- Technical review by the SERNANP and MINAG
- Holding public hearings
- Approval of EIA (decision by bureau chief)

According to the DGAAE, PPC and TOR are to be prepared with the opinions and information collected from stakeholders reflected. The workshops are held at the planned development area, and the primary participants are the local community residents. The EIA must reflect the

opinions of the stakeholders including the local residents, and the DGAAE reviews and evaluates the EIA in terms of the environmental and social aspects while the MINAG and SERNANP evaluate it primarily from technical viewpoints.
EIA is a requisite for approval for a project. It takes approximately one year from EIA survey to completion of EIA statement preparation. After the EIA statement is submitted, processing of the EIA takes 60 days before approval, including 20 days set as the period for holding public hearings after publication of the EIA statement.

d) Contents of EIA for a Power Development Project

Items to be included in an EIA are provided for in Chapter 4 of Part 2 of D.S. No. 29-94-EM. The major items are as follows:

- Baseline study (the current conditions of resources, geography and society of the planned development area, and the effect of the project activities and facilities to be constructed on the local culture, economy and communities)
- Overview of the proposed project
- Forecasts and assessment of the direct and indirect impact on the environment in each stage of the project
- An environmental management program that includes the measures to avoid and/or minimize negative impact of the project on the environment and measures to enhance positive impact
- An environmental monitoring program incorporating the measures to mitigate the potential impact of the project
- A contingency plan and environmental restoration plan after closure of the power plant

D.S. No. 29-94-EM provides that the consulting firms that implement EIA must be those registered with the MEM. As of June 2010, 143 companies are registered with the MEM.

e) Guidelines of EIA

For power development projects there are two kinds of EIA survey guidelines formulated by MEM/DGAA:

1. Guidelines of Environmental Impact Studies for Electric Activities (Guía de Estudios de Impacto Ambiental para las Actividades Eléctricas, DGAA-2001)
2. Guidelines of Community-related Studies (Guía de Relaciones Comunitarias, DGAA-2001)

The major survey items required by the Guidelines of Environmental Impact Studies for Electric Activities are:

- Introduction (Framework of policies and laws, and administrative agencies)
- Environmental conditions (including natural geography, hydrology, meteorology, water quality, soil, flora and fauna, society, economy and culture) of the area where the project will be implemented
- Overview of the project development activities
- Environmental impact forecasts and assessment
- An environmental management program
- An environmental monitoring program
- A contingency plan and environmental restoration plan after closure of the power plant
- Cost and benefit analysis

The Guidelines of Community-related Studies are instructions on implementing survey with the focus on the social and economic effect of power development projects. It is defined in the Guidelines that the main purpose of the social and environmental surveys is to analyze the impact on the local residents, community relations, economy and culture. The Guidelines also make mention of activities to increase positive effect and eliminate or mitigate negative impact.

(2) Resident Participation and Information Disclosure

As to resident participation and information disclosure, Article 46 (Public participation) and Article 51 (Standards of general public participation procedures) of Law No. 28611, General Environmental Law (Ley General del Ambiente, 2009), provide that all the citizens have the right to express their opinions regarding the national government's policies on the environment, act affecting the environment and decision-making process, and stipulate the procedures of public participation and the roles of the national government.

The transparency of the MINAM, access to environmental public information, public participation and public consultation in environmental matters are provided for in D.S. No. 002-2009-MINAM (Reglamento sobre Transparencia, Acceso a la Información Pública Ambiental y Participación y Consulta Ciudadana en Asuntos Ambientales). The regulation sets forth the details regarding the access to environmental public information, transparency of environmental administration and the mechanism of citizen participation.

Citizen participation in EIA for power development projects is carried out in accordance with R.M. No. 223-2010-MEM/DM, Guidelines for Citizen Participation in Electricity Operations (Lineamientos de Participación Ciudadana en las Actividades Eléctricas) formulated by the MEM. The guidelines set forth the mechanism of citizen participation and public consultation, citizen participation plan, and implementation and record submission of workshops and public hearings, to guarantee citizens' access to EIA and their right to submit opinions.

For citizen participation, the project proponent must prepare the public participation together with TOR for EIA before starting EIA survey, and submit to the DGAAE. From the start of EIA preparation to the time when EIA approval is granted is the period of citizen participation. Based on the citizen participation plan prepared, submission of stakeholders' opinions prior to EIA survey, workshops during the stage of survey, and workshops concerning the contents of the EIA and EIA public hearings are implemented during this period.

(3) Land Acquisition and Resettlement of Residents

For land, Peru has a general law of expropriations, Law No. 27117 (LEY GENERAL DE EXPROPIACIONES), promulgated in May 1999 and applicable to acquisition of land for public-work projects. However, forcible expropriation is only authorized to the national government under the special law enacted by the congress. Law No. 27117 stipulates that fair compensation, payment of cash and compensation for potential damage must be made for expropriation of private properties and that contracts relevant to expropriation must be implemented in accordance with the procedures provided for by law.

Electricity Enterprises Law provides that resettlement of residents and land purchase must be compensated. According to DGE, the scope to be compensated includes land, crops and buildings. Since the MEM does not have concrete regulations to follow when implementing resettlement of residents and land purchase, the scope of compensation for land acquisition and residents' resettlement is decided through negotiation by the project proponents. At some areas, the proponents face difficulty in negotiation with residents.

Since geothermal fields in Peru are mostly located in mountainous areas at high-altitude where there are not many houses, it is unconceivable that large scale resettlement of residents will be involved with a geothermal power development project to be implemented in such a mountainous area. For projects expected to involve resettlement of residents, it would be necessary to prepare and implement a resettlement plan and plans for restoring residents' livelihood and monitoring after resettlement by referring to the provisions regarding the involuntary resettlement of residents included in the World Bank’s Safeguard Policies (OP 4.12 Operational Policy on Involuntary Resettlement and Electronic Resettlement Guidebook).

I-4.5.2 Protected Areas

(1) Categories of Protected Areas

Under Peruvian Law No. 26834, Protected Natural Areas Law (Ley de Áreas Naturales Protegidas), and D.S. No. 038-2001-AG, Regulation of the Law on Protected Natural Areas (Reglamento de la Ley de Áreas Naturales Protegidas), the protected natural areas (ANP: Áreas Naturales Protegidas) are classified into the following ten categories according to the protection level, and buffer zones are designated outside the protected natural areas. As of 2010, 67 protected areas are designated.

The distribution of the protected natural areas in Peru is shown in Fig. I-4.5.2.

- National park (Paque Nacional)
- National sanctuary (Santuario Nacional)
- Historical sanctuary (Santuario Historico)
- National reserve (RN: Reservas Nacionales)
- Wildlife refuge (RVS: Refugio de Vida Silvestre)
- Protected forest (BP: Bosque de Protección)
- Hunting refuge (CC: Coto de Caza)
- Communal reserve (CR: Reserva Comunales)
- Landscape reserve (RP: Reservas Paisajisticas)
- Reserved zone (ZR: Zona Reservadas)

Fig. I-4.5.2 Protected natural areas in Peru (SERNANP)

(2) Protected Area Administration Agency

The agency administering the protected natural areas is the National Service of Natural Protected Areas (SERNANP) of the MINAM. The SERNANP is the organ in charge of operation of the National System of Protected Natural Areas (SINANPE: Sistema Nacional de Áreas Naturales Protegidas por el Estado), and responsible for establishing technical management criteria and procedures for management of the protected natural areas. The SERNANP also has the authority to give permission for and technical opinions on resource development within protected natural areas, and takes an active role in zoning of protected areas and implementation of the master plan.

(3) Use Restrictions of Protected Areas

In accordance with the management and operation objectives of the protected natural areas, indirect or direct use is allowed on the condition of compliance with the rules under Law No. 27117.

a) Indirect Use Protected Areas

Indirect use is allowed for the following protected natural areas. In these areas extraction and development of natural resources are not allowed, but scientific research and survey, tourism and recreation conducted under proper management and control are allowed.

- National park (Paque Nacional)
- National sanctuary (Santuario Nacional)
- Historical sanctuary (Santuario Historico)

b) Direct Use Protected Areas

Direct use is allowed for the following protected natural areas. In these areas natural resources can be utilized and developed with permission of the SERNANP and in accordance with the management plan.

- National reserve (RN: Reservas Nacionales)
- Wildlife refuge (RVS: Refugio de Vida Silvestre)
- Protected forest (BP: Bosque de Protección)
- Hunting refuge (CC: Coto de Caza)
- Communal reserve (CR: Reserva Comunales)
- Landscape reserve (RP: Reservas Paisajisticas)
- Reserved zone (ZR: Zona Reservadas)

EIA for a project within a protected natural area is required to provide assessment of the effect on the environment of the entire area including the protected natural area and buffer zone. For a power development project, the EIA submitted by the proponent is sent to the SERNANP by the DGAAE. The SERNANP performs technical review and evaluation of the EIA and decides whether or not to permit the development. Without permission of the SERNANP for the development, the DGAAE cannot approve the EIA.

c) Restrictions at Buffer Zones

The master plan has been formulated for buffer zones. Activities and development within a buffer zone are approved with the permission given by the agency in charge in accordance with the master plan.

For a power development project, the EIA submitted by the project proponent is sent to the SERNANP by the DGAAE. The DGAAE decides whether or not to approve the project within a buffer zone based on the SERNANP's opinions on the EIA.

d) Regional Reserve

In addition to national reserves, regional reserves are stipulated by law in Peru. As with the areas surrounding the national reserves, buffer zones are designated outside the regional reserves.
Development and use of natural resources are possible in the regional reserves and buffer zones around them as the same use restrictions on the protected national areas categorized as direct use areas and their buffer zones described above are applied. Likewise, approval of EIA for a project within a regional reserve is granted by the SERNANP and that for a project within a buffer zone by the DGAAE based on the SERNANP's opinions.

e) Permission Activities and Approvals EIA of ANP

Permission activities and approval EIA of the ANP in electric power development projects are summarized in Table I-4.5.2.

Table I-4.5.2 Permission activities and approval EIA of the ANP in electric power development projects

Category of ANP	Activities restrictions	Permission of EIA
Indirect use protected areas	Other than scientific research activities, etc. are not allowed.	—
Direct use protected areas	Development Activities are allowed.	SERNANP (DGAAE approves the permission of SERNANP)
Restrictions at buffer zones	Development Activities are allowed	DGAAE (based on the SERNANP's opinions)
Outside the ANP	No restriction on development activities	DGAAE

Source: by JICA Study Team

I-4.5.3 Protection of Cultural Heritage

Protection of cultural assets is provided for in Law No. 28296, General Law of the Cultural Heritage of the Nation.

This Law proclaims that assets that constitute cultural heritage of Peru and intellectual properties that are significant in the fields of Peru's archaeology, architectonics, paleontology, art, military affair, society, anthropology, tradition, religion, ethnic groups, science, and technology are protected by law.

The Ministry of Culture is stipulated by Law No. 29565 as the organ responsible for administrating the cultural heritage assets. The Archaeological Investigation Regulations (Supreme Resolution No. 044-2000-ED) provide that the Ministry of Culture is also in charge of evaluating archeological investigation results and issuing Certificates of Non-existence of Archaeological Relics (CIRA: Certificados de Inexistencia de Restos Arqueológicos).

The proponent of a development project must carry out archaeological investigation before starting development activities. Since this investigation is required to be conducted by experts after permission is obtained from the authorities, it is necessary to plan this investigation in advance and get permission from the Ministry of Culture. After the investigation, investigation report is submitted to the Ministry of Culture for approval. A CIRA is issued after the approval is granted. The CIRA certifies that there are no archaeological remains in the investigated site, or, if there are, clearly specifies the place where the remains are so that protective measures can be taken. The CIRA is valid for an indefinite period. However, in case of an encounter with unexpected relics during project activities, the work must be halted and the findings reported to the Ministry of Culture.

If implementation of the project as planned is absolutely necessary for national interests, relocation of such relics may be approved by the Peruvian government as a special exception.

I-4.5.4 Environmental Standards and Permissible Limits

Peru, as Japan, has environmental standards (air quality, water quality, non-ionizing radiations and noise) as well as regulatory values established to achieve the standards.

On the following paragraphs the environmental standards and regulatory values are described with focus on air quality, water quality and noise as being more relevant to development of geothermal projects.

(1) Air Quality (Hydrogen Sulfide)

The regulation values for hydrogen sulfide (H_2S) in the environment closely related to geothermal power plants are established in D.S. No. 003-2008-MINAM, Environmental Standards for Air Quality (Aprueban Estándares de Calidad Ambiental para Aire), as shown in Table I-4.5.3.

The environmental standard value for hydrogen sulfide control is 150 ug/m^3 (0.1 ppm, mean of 24 hours), as with the standard value in WHO guidelines.

In Japan, although environmental standard value for H_2S is not established, the H_2S level is regulated as the offensive odor source. The regulated areas in each prefecture are designated by the governor with consideration of locality. Offensive Odor Prevention Law of Japan provides that H_2S level should be regulated to the range of 0.02 ppm or less to 0.2 ppm or less. Most municipalities adopt 0.02 ppm or less as the standard.

Table I-4.5.3 H_2S (hydrogen sulfide) environmental standards

Parameter	Period	Value (μg/m^3)	Format	Analysis Method
Hydrogen Sulfide (H_2S)	24 hours	150	Arithmetic mean	UV - fluorescence (automatic method)

Source: Regulations of the Air Quality Standards-Reglamento de Estándares de Calidad de Aire, Supreme Decree Nº 003-2008-MINAM

(2) Water Quality Standards

a) Environmental Standards

National water quality standards (Aprueban los Estoindares Nacionales de Calidad Ambiental para Agua) are established under D.S No. 002-2008-MINAM as measures to manage sustainable use and conservation of water resources in Peru. D.S No. 002-2008-MINAM classifies bodies of water into the following four categories according to the characteristics of the water area and purpose of use:

Category 1: Use in inhabited area and for recreation
Category 2: Coasts and seas for use in fishery activities
Category 3: Irrigation and drinking water for animals
Category 4: Conservation of aquatic environment

As shown in Table I-4.5.4, the water quality standards for aquatic conservation are established by the water area type of ‘ponds and lakes’, ‘rivers’, and ‘coasts and marines’.

Table I-4.5.4 National water quality standards (Conservation of aquatic environment)

Parameter	Unit	Ponds and Lakes	Rivers		Coasts Marines	
			Coast and Highlands	Jungle	Estuaries	Marines
Physical and chemical						
Oils and Grease	mg/L				1	1
BOD_5	mg/L	<5	<10	<10	15	15
Ammonia Nitrogen	mg/L	<0.02	0.02	0.05	0.05	0.08
Temperature	Celsius					delta 3 ^{o}C
Dissolved Oxygen	mg/L	≥5	≥5	≥5	≥4	≥4
pH	Unit	6.5-8.5	6.5-8.5		6.8-8.5	6.8-8.5
Total Dissolved Solids	mg/L	500	500	500	500	
Total Suspended Solids	mg/L	≤25	≤25-100	≤25-400	≤25-100	3000
Inorganic						
Arsenic	mg/L	0.01	0.05	0.05	0.05	0.05
Barium	mg/L	0.7	0.7	1	1	-
Cadmium	mg/L	0.004	0.004	0.004	0.005	0.005
Free cyanide	mg/L	0.022	0.022	0.022	0.022	-
Chlorophyll a	mg/L	10	-	-	-	-
Copper	mg/L	0.02	0.02	0.02	0.05	0.05
Chromium VI	mg/L	0.05	0.05	0.05	0.05	0.05
Phenols	mg/L	0.001	0.001	0.001	0.001	
Total Phosphates	mg/L	0.4	0.5	0.5	0.5	0.031-0.093
Aromatic Total Petroleum Hydrocarbons	mg/L	ND			ND	ND
Mercury	mg/L	0.0001	0.0001	0.0001	0.001	0.0001
Nitrates ($N-NO_3$)	mg/L	5	10	10	10	0.07-0.28
Total Nitrogen	mg/L	1.6	1.6		-	-
Nickel	mg/L	0.025	0.025	0.025	0.002	0.0082
Lead	mg/L	0.001	0.001	0.001	0.0081	0.0081
Silicates	mg/L	-	-	-	-	0.14-0.7
Hydrogen Sulfide (as H_2S)	mg/L	0.002	0.002	0.002	0.002	0.06
Zinc	mg/L	0.03	0.03	0.3	0.03	0.081
Microbiological						
Thermotolerant Coliforms	MPN/ 100ml	1,000	2,000		1000	≦30
Total Coliforms	MPN/ 100ml	2,000	3,000		2,000	≦30

Source: Aprueban los Estoindares Nacionales de Calidad Ambiental para Agua .D.S N° 002-2008-MINAM ANNEX I

b) Permissible Maximum Limits for Effluents

Effluent standards in Peru are established by the industry. For the power industry, the effluent standards are provided for in R.D. No. 008-97-EM/DGAA (Aprueban niveles máximos permisibles para efluentes líquidos producto de las actividades de generación, transmisión y distribución de energía eléctrica), but the regulated items are pH, oil and SS only (Table I-4.5.5).
Monitoring of a geothermal power development project (during power plant construction and in-service periods) needs to include such items as BOD5, which is an index of the organic substances in water, and hazardous substances (arsenic, mercury). It may be necessary for the monitoring of specific hazardous substances such as arsenic, mercury of geothermal fields, it is desirable to add these items, as needed, based on the IFC (International Finance Corporation) Environmental, Health and safety Guidelines for Geothermal projects.

Table I-4.5.5 Effluent standards (for the power industry)

Parameter	Any Time Value	Annual Average Value
pH	higher than 6, lower than 9	higher than 6, lower than 9
Oil and Grease (mg/l)	20	10
Suspended Solids (mg/l)	50	25

Source: R.D. Nº 008-97-EM/DGAA.(Aprueban niveles máximos permisibles para efluentes líquidos producto de las actividades de generación, transmisión y distribución de energía eléctrica (1997-03-17))N° 008-97-EM/DGAA (March 17th, 1997)

(3) Noise

Under D.S No. 085-2003-PCM (Aprueban el Reglamento de Estándares Nacionales de Calidad Ambiental para Ruido), the environmental standards for noise (Table I-4.5.6) are established by the zone type of hospital, school, residential district, commercial district and industrial district, as well as by the time divisions of daytime and nighttime.

In Peru there are no environmental standards or regulating criteria for vibrations.

Table I-4.5.6 Environmental standards for noise

Application Zones	Values (L_{AeqT})	
	Daytime (7:01-22:00)	Nighttime (22:01～7:00)
Special Protection Zone	50 dB(A)	40 dB(A)
Residential Zone	60 dB(A)	50 dB(A)
Commercial Zone	70 dB(A)	60 dB(A)
Industrial Zone	80 dB(A)	70 dB(A)

Source: Aprueban el Reglamento de Estándares Nacionales de Calidad Ambiental para Ruido; D.S Nº 085-2003-PCM

(4) Solid Waste

Solid waste handling and management are regulated by Law No. 27314, Solid Waste General Law (Ley General de Residuos Sólidos) amended by D.L. No.1065, as well as by D.S. No. 057-2004-PCM, detailed regulations of the Solid Waste General Law (Reglamento de la Ley General de Residuos Sólidos).

I-4.5.5 Conformity with the JICA's Environmental Guidelines

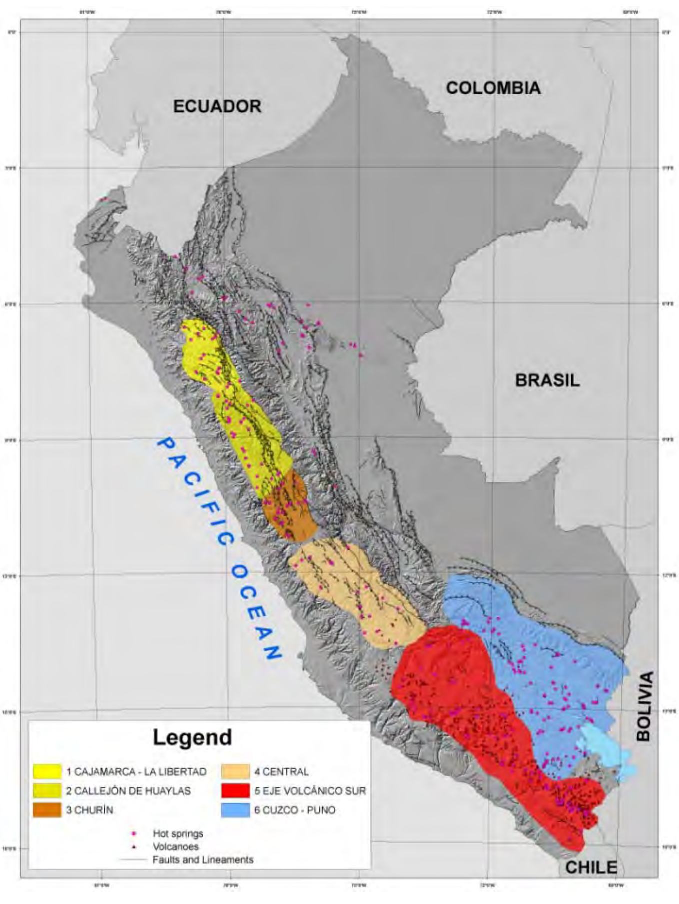
The environmental impact assessment system of the MEM in Peru adequately conforms to the spirit of the JICA environmental guidelines, and contains all the basic environmental assessment requirements for Category-A projects in the JICA classification. The JICA guidelines also require that the impact assessment be conducted pursuant to the applicable laws of the recipient country.

I-5 Status of Geothermal Development

I-5.1 Geothermal Resource Assessment

From 1970’s, reconnaissance and preliminary surveys/studies of the geothermal resource in Peru have been conducted by several Peruvian institutions including Electroperú, INGEMMET, the Proyecto Especial Tacna (PET), and the Instituto Peruano de Energía Nuclear (IPEN), with the cooperation of various international organizations (Battocletti et al., 1999). One of the most important studies is the inventory survey conducted by INGEMMET from 1997 to 2003, in which geological/geochemical samplings and analyses had been carried out for more than 500 springs with temperatures higher than 20 ºC almost all over the Peru. At present, most of the data and information obtained through the reconnaissance and surveys/studies have been collected and compiled by INGEMMET.

In order to help the management decisions to be taken on possible investments in geothermal exploration/exploitation, geoscientists in INGEMMET (Vargas and Cruz, 2010) updated the Geothermal Map of Peru (Fig. I-5.1.1) based on the previous works (Cossio and Vargas, 1979; Huamaní and Valenzuela, 2003; Fidel et. al., 1997; etc.).



Regions	*Lots*	*Areas*
1 Cajamarca – La Libertad	Cajamarca La Grama Otuzco	
2 Callejón de Huaylas	Huaraz Caraz Corongo	
3 Churín		
4 Central		
5 Eje Volcánico Sur	Arequipa Calacoa Tutupaca Challapalca	Cailloma Chivay Chachani Salinas Calacoa Tutupaca Río Maure Puquio Parinacochas Cotahuasi Coropuna Orcopampa Mazo Cruz
6 Cuzco – Puno		

Fig. I-5.1.1 Updated geothermal map of Peru (Vargas and Cruz, 2010)

The main tool to update the Geothermal Map has been the locations of hot springs and mineral springs all over the country. The boundaries of six geothermal regions have been re-defined in the updated map. The hot springs located in the northern and central Peru (Region 1, Region 2, Region 3, and Region 4) have a meteoric origin and are product of the geothermal gradients. In the southern Peru (Region 5 and Region 6), geothermal manifestations are related to active volcanism and in some cases are of mixed origin, the water from precipitations infiltrates and it is heated by a heat source at depth (Vargas and Cruz, 2010).

The study results about Region 5 showed that there are highly promising fields for power generation development such as Tutupaca, Challapalca (Borateras or Maure), Calientes, Paucarani, Calacoa, Chachani, Chivay and Laguna Salinas (Fig. I-5.1.2). In Region 5, Puquio, Parinnacochas and Orcopampa are considered to be secondary promising fields for power generation. The fields at Catahuasi, Coropuna, Caylloma and Mazo Cruz Andes are regarded as promising field next to the previously cited fields because of relatively low enthalpy of geothermal resources.

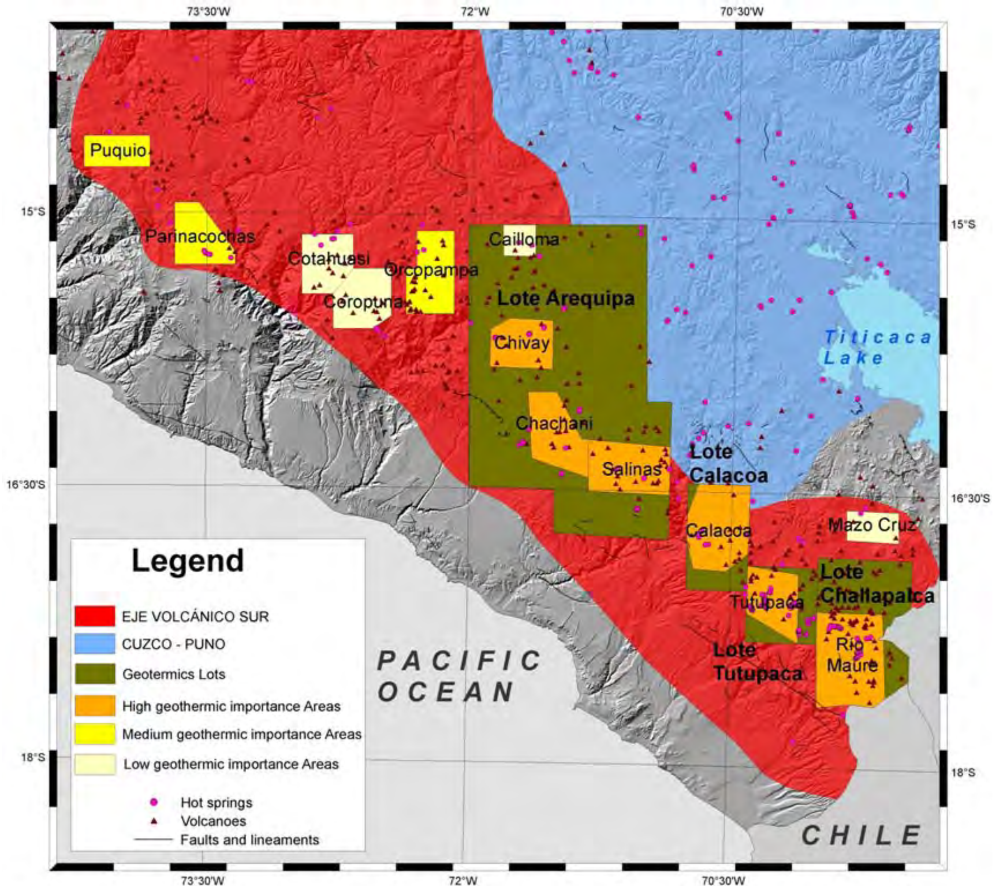


Fig. I-5.1.2 Location of the important geothermal areas in Region 5 (Vargas and Cruz, 2010)

The geothermal studies, which have been conducted so far in Peru, are regarded to be of reconnaissance and prefeasibility level. Drilling of exploratory well for geothermal exploration has never been conducted. Therefore, present data and information of any geothermal fields in Peru are not sufficient to make development program.

Only in the two fields, Calientes and Borateras, in Tacna Region, pre-feasibility study including the resource assessment with adopting MT resistivity survey was conducted for planning of geothermal power development (JBIC, 2008; JETRO, 2008). Geothermal resource potential for power generation in the two fields was estimated by the volumetric method with Monte Carlo analysis to be 100 MWe (with probability of 80%) for the Calientes and 50 MWe (with probability of 70%) for the Borateras, respectively.

Although the geothermal power potential in Peru has been estimated to be 2,990 MWe by Battocletti et al. (1999) and 3,002.7 MWe by JICA (2008 internal report), it is rough and preliminary estimation, and the detailed resource potential by the accumulation of the estimation for each geothermal field had never been calculated.

I-5.2 Current Status of Geothermal Rights Applications

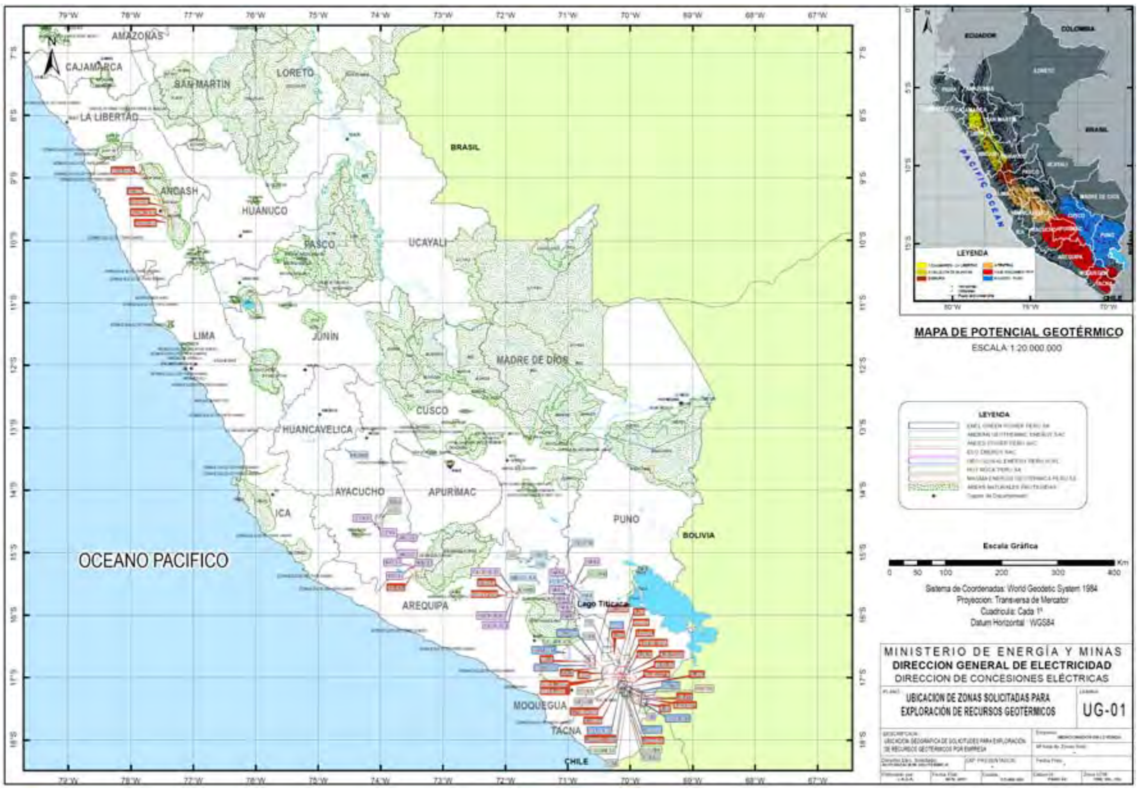
After implementation of new Regulation of the Organic Law of Geothermal Resources in April 2010, the multiple requests for authorization of geothermal rights have been presented to the MEM. Table I-5.2.1 shows the 98 projects whose applications were notified in the official newspaper up to December 2011. To date, the MEM gave authorization of 20 projects to four companies (Canadian, Australian, Peruvian and American). Although the authorizations have been given since February 2011, no application for concession has been officially made to date. Figure I-5.2.1 to Figure I-5.2.4 show the location map of the requested project for authorization. For example of the authorized project, the Tutupaca project area is shown in Fig. I-5.2.5.

Table I-5.2.1 Status of applications for an authorization request up to December 2011

No.	No. for each company	Name of applied field	Field name in the JICA Master Plan Study (Promissing field)	Company Name
1	1	Casiri	Chungara-Kallapuma	Magma Energía Geotérmica S.A.
2	2	Ticsani	Calacoa-Putina	
3	3	San Pedro		
4	4	Vilacota		
5	5	Ancoccollo	Ancocollo	
6	6	Crucero	Crucero	
7	7	Pinchollo	Chivay-Pinchollo	
8	8	Tutupaca Norte		
9	9	Suche		
10	10	Cancave		
11	11	Calientes Norte		
12	12	San Pedro Libre		
13	13	Ancoccollo Libre	Ancocollo	
14	14	Sara Sara		
15	15	Pasto		
16	16	Panejo		
17	17	Loriscota		
18	18	Huayllatiri		
19	19	Antajave		
20	20	Atarani		
21	21	Chancos	Chancos	
22	22	Olleros Sur		
23	23	Yungay		
24	24	Monterrey		
25	25	Huancarhuaz		
26	26	Olleros Norte		
27	27	Crucero Libre		
28	28	Tutupaca Libre		
29	29	Casiri Libre 1		
30	30	Pinchollo Libre	Chivay-Pinchollo	
31	31	Cancave Libre		
32	32	Vilacota 21		
33	33	Vilacota 22		
34	34	Ticsani Libre	Calacoa-Putina	
35	1	Achumani	Chivay-Pinchollo	Hot Rock Peru S.A.
36	2	Ocururane	Ancocollo	
37	3	Quellaapacheta	Calacoa-Putina	
38	4	Turu	Cailloma	
39	5	Achuco	Chungara-Kallapuma	
40	6	Rupha		
41	7	Huarajayoc		
42	8	Chocopata	(Pinaya)	
43	9	Huisco		
44	10	Ocururane Sur	Ancocollo	
45	1	Rio Calientes	Calientes	Geo Global Energy Peru SCR Ltda
46	2	Rio Maure	Borateras	
47	3	Rio Kallapuma	Chungara-Kallapuma	
48	4	Ancocollo	Ancocollo	
49	5	Tutupaca	Tutupaca	
50	6	Ticsani Oeste		
51	7	Ticsani Este	Calacoa-Putina	
52	8	Huaynaputina	Ulucan	
53	9	Ubinas		
54	10	Ccollo	Ccollo/Titire	
55	1	Hualca Hualca	Chivay-Pinchollo	Eco Energy S.A.C.
56	2	Pinaya I	Pinaya	
57	3	Pinaya II	Pinaya	
58	4	Hualca Hualca I	Chivay-Pinchollo	
59	5	Hualca Hualca II	Chivay-Pinchollo	
60	6	Umacusiri I		
61	7	Umacusiri II		
62	8	Geronta I	Puquio	
63	9	Geronta II	Puquio	
64	10	Pinaya III	Pinaya	
65	11	Pinaya IV	Pinaya	
66	12	Pinaya V	Pinaya	
67	13	Pinaya VI	Pinaya	
68	14	Rio Pararca I		
69	15	Rio Pararca II		
70	16	Rio Pararca III		
71	1	Tutupaca	Tutupaca	Andes Power Peru
72	2	Borateras	Borateras	
73	1	No.3	Calientes	Muruhuay S.A.C
74	2	Rio Calientes	Calientes	
75	3	Rio Calientes III	Calientes	
76	1	Pusa		Andean Geothermic Energy S.A.C
77	2	Pinaya	Pinaya	
78	3	Censuyo	Cailloma	
79	4	Baños del Inca		
80	5	Paclla		
81	6	Occollo		
82	7	Baños del Inca		
83	8	Coline		
84	9	Condoroma		
85	10	Atecata		
86	11	Niñobamba		
87	12	Condoroma South		
88	13	Condoroma		
89	14	Atecata		
90	15	Niñobamnba		
91	16	Baños del Inca		
92	1	Carmen	(Puquio)	Enel Green Power Perú S.A.
93	2	Chilata		
94	3	Titiri	Ccollo/Titire	
95	4	Huaylluma	Calientes	
96	5	Pilar	Chungara-Kallapuma	
97	6	Río Salado	Ancocollo	
98	7	Putina		

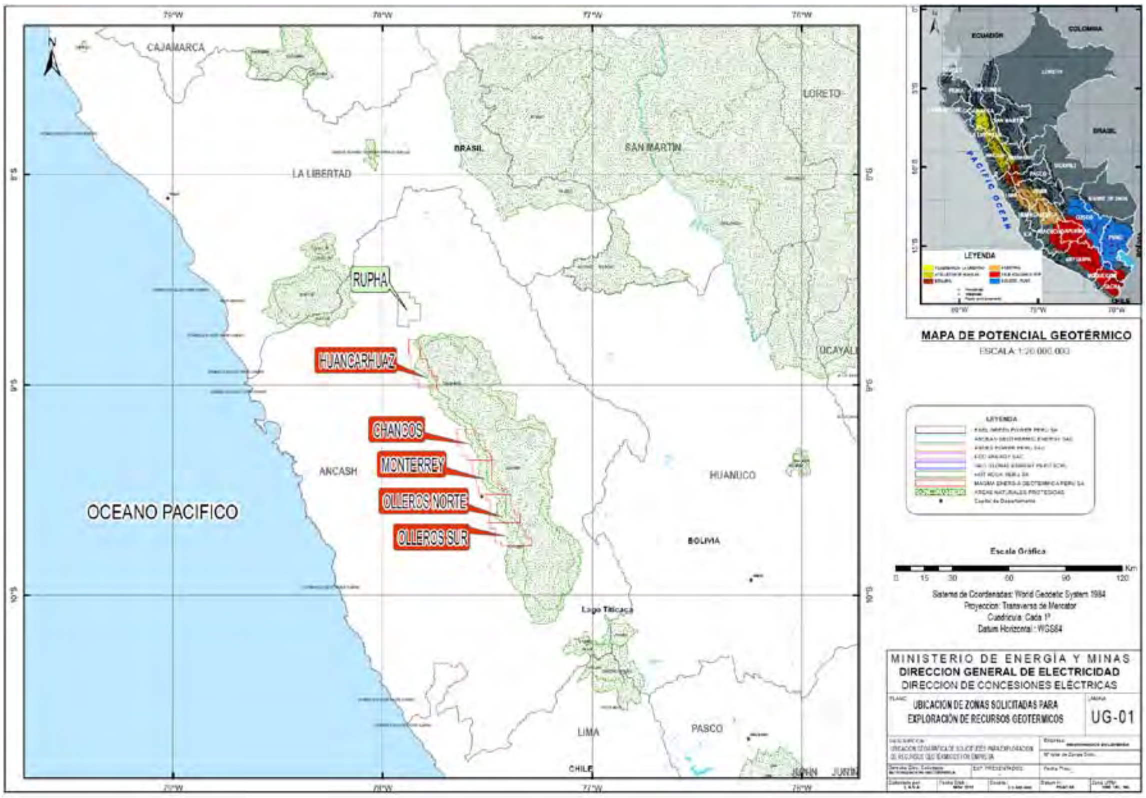
Authorized by MEM for exploration

In evaluation by MEM (or rejected)



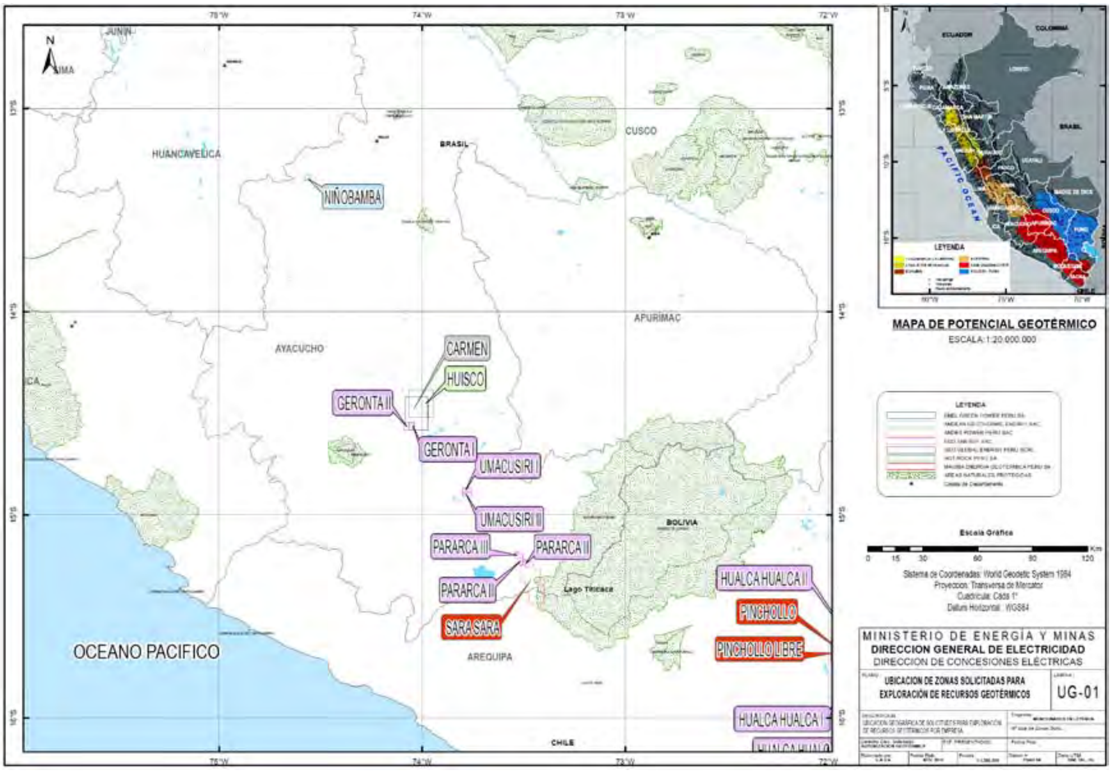
(Source: DGE, 2011)

Fig. I-5.2.1 Location map of requested project for authorization (whole Peru)



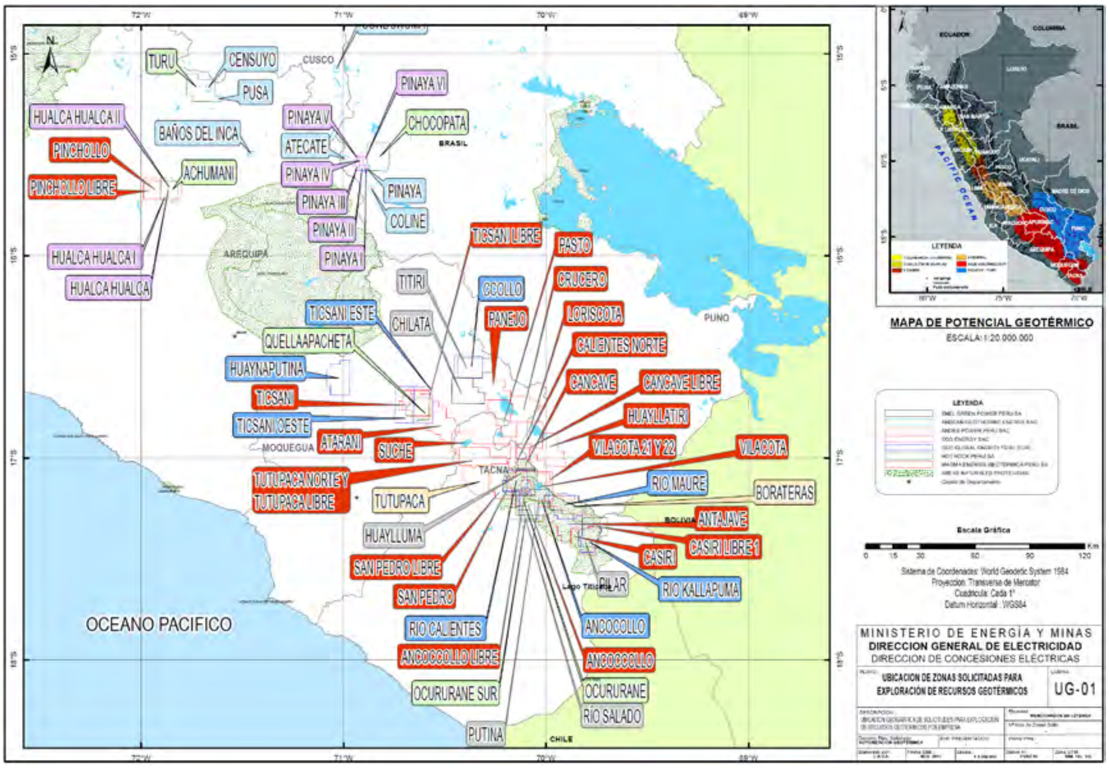
(Source: DGE, 2011)

Fig. I-5.2.2 Location map of requested project for authorization (north)



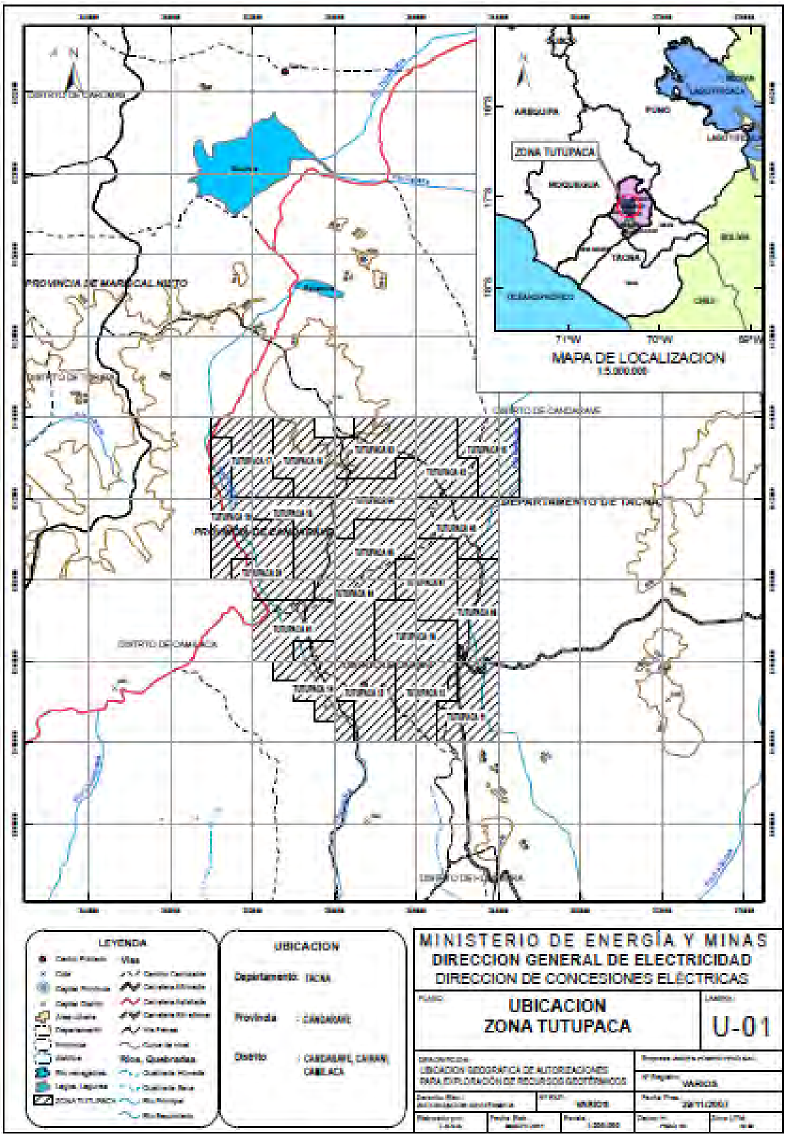
(Source: DGE, 2011)

Fig. I-5.2.3 Location map of requested project for authorization (central)



(Source: DGE, 2011)

Fig. I-5.2.4 Location map of requested project for authorization (south)



(Source: DGE, 2011)

Fig. I-5.2.5 Authorized project area of Tutupaca

I-5.3 Current Status of Geothermal Development System and Organization

I-5.3.1 Development History and Organizations Involved

First serious geothermal study in Peru was said to be launched in 1975 when Mimero Peru conducted geochemical study on Calacoa region of the Moquegua state. In 1978, INGEMMET made an inventary of the thermal activities known in the nation and clustered them geographically in six regions. From 1979 to 1980, with the financial support from OLADE, INGEMMET collaborated with Aquater of Italy for conducting the geothermal resource study in the region 5 and identified prospective geothermal fields such as Tutupaca, Calacoa, Challapalca, Laguna Salinas, Chachani and Chivay. In accordance with a technical assistance agreement with the British geological survey, INGEMMET launched a preliminary study in Cuzco-Puno, area of the Region VI and showed some reservoir in the area might have temperatures of 160°C.

On the other hand, Electroperú S.A. dispatched their engineers to geothermal specialization courses in Italy, Japan and other countries for their efforts to establish a Geothermal Investigations Unit in order to acquire a permission to explore the areas of Calacoa, Tutupaca and Challapalca, possibly with international technical cooperation. As a result, they reached an agreement of Technical and

Economical Cooperation with the Centro Studi Renzo Tassel1i (CESEN) of Italy and implemented a geothermal study including shallow well boring in the zones covering Callejon de Huaylas, 0turco, La Grama, and Cajamarca in an approximate area of 100,000 km^2 during 1982 to 1986. The study concluded the area of interest exhibited reservoir with medium to low temperature. Also in 1986, with help from IAEA, they conducted geochemical investigations in the Region V and found prospective resources in Calacoa and Calientes.

Later in 1997, Cenergia, with Mexican assistance, collected data from the past studies and made assessment on them. INGEMMET conducted nationwide survey on the hot spring inventory. Furthermore, in 2007, JBIC launched detail geothermal study in Calientes and Borateras area.

As it is described above, certain provisions were made on the expert training when implementing the series of initial geothermal studies during 1970s and 1980s. Since then, after a long absence of large scale geothermal projects, coupled with the fact that the organizations which lead the earlier studies have been restructured, the expertise on this technology has not been well maintained. Though some of the engineers who were engaged in the past projects are still active as consultants, most of them are aged. Consequently data available for the geothermal study have not been renewed for long time. In this situation, as to the group of experts in the geothermal technology, we can not expect the other than those in INGEMMET. Speaking about their resources, however, it is far from enough both in terms of personnel and equipment. Lists of experts, equipment, tools and facility related to the geothermal technology are shown in the Tables I-5.3.1 through I-5.3.3. A note should be taken that INGEMMET possesses field and laboratory equipment for water analysis, but nothing on gas geochemistry including mini-separator.

Table I-5.3.1 Experts in geothermal related technologies available in Peru (September 2011)

Area	DGE	INGEMMET	Petroperú	University	Private	Total
Geologist	0	1	0	5	100	**106**
Geochemist	0	1	0	1	30	**32**
Geophysicist	0	1	0	1	15	**17**
Reservoir Engineer	0	0	0	0	5	**5**
Drilling Engineer	0	0	0	0	10	**10**
Power Engineer	0	0	0	0	60	**60**
Environmental Scientist	0	0	0	1	100	**101**
Financial Analyst	0	0	0	0	100	**100**
GIS Scientist	1	2	0	10	200	**213**
Drillers	0	0	0	0	50	**50**
Technicians	0	0	0	0	1000	**1000**
Total	**1**	**5**	**0**	**18**	**1670**	

Table I-5.3.2 Equipment for geothermal study available at INGEMMET (September 2011)

Geological Equipment	**QTY**	**Geochemical Equipment**	**QTY**
Simple GPS	1	Simple GPS	1
Digital Thermometer	1	Digital Thermometer	1
Fluid Inclusion Heating-freezing stage	1	pH meter	1
Binocular Microscope	1	Conductivity Meter	1
Petrographic Microscope	5	Water Sampling Kit	1
X-Ray Diffractometer	1	Gas Sampling Kit	0
X-Ray Flourescence	0	AAS	1
ICP-OES	1	Ion Chromatograph (IC)	1
Mass spectroscopy for dating	0	Gas Chromatograph	0
Geophysical Equipment	**QTY**	Mass Spectrometer for stable Isotope	0
Differential GPS	1	Tritium Scintillation counter & C14 analyser	0
Simple GPS	3	**Reservoir Engineering**	**QTY**
TEM	0	Kuster gauge Tools set	0
MT	0	Logging Winch	0
Gravimeter	0	**Drilling Equipment**	**QTY**
Magnetometer	0	Complete Rig	0
Portable seismometer	6		

Table I-5.3.3 Geochemical equipment available at INGEMMET

Water Samples	Avail. or method	**Main Components**	Avail. or method	Analysis method Description
Field Laboratory	Yes	SiO_2	AA	TM – Titration, manual
Steam/Water separator	No	Na	ICP-OES/AA	CM - Conductivity meter
pH	Yes	K	ICP-OES/AA	pH – pH meter
Conductivity	CM	Ca	ICP-OES/AA	CO - Colourometry
Dissolved gases		Mg	ICP-OES/AA	AA - Atomic Absorption
CO_2	TM	SO_4	IC	IC - ICP
H_2S	No	Cl	IC	TU - Titration
		F	IC	ISE- Selective electrode
		Fe	ICP-OES	NaOH- Gas sample in NaOH solution
		Al	ICP-OES	GC-Gas Chromatograph
		B	ICP-OES	ICP-OES

I-5.3.2 Implementing Organization and System for the Geothermal Development

The authentic bodies in the government organization in Peru which are responsible for the geothermal development were described in I-4.2. Other than those mentioned, a geothermal committee (Comision Multisectorial de Geotermia) is established within the MEM, whose members consists of the academics(earth science experts) and INGMMET engineers. But, since the committee allocated small portion for the geothermal experts, its contribution to the geothermal development will be limited. Furthermore, little technical experts are present in the governmental organization in the area of resource development technologies including geothermal well drilling and geothermal power plant technology, while the capacity building program in this area is barely existent.

Meanwhile regarding the university research and education on the topics, A graduate student in the petroleum and petrochemical laboratory in Universidad Nacional de Ingeneria submitted a thesis regarding a geothermal power plant development where he dealt with various geothermal related subjects including the geothermal resource in Peru. Judging from this paper, at least some desk base study in the geothermal technology has been in place to a limited scope. Since there is no employment opportunity for this technology, their expertise will be hardly maintained. Otherwise some lecturers in Universidad Nacional “Jorge Basadre Grohmann” de Tacna and in Universidad Nacional Mayor de San Marcos have been working on the geothermal study.

I-5.3.3 Human Resource and System in the Oil and Gas Development in Peru

The industry infrastructure concerning oil and gas development in Peru including regulatory bodies, development companies, service contractors, equipemnt stock, facilities and the man power seems to be well established. Generally speaking, building a geothermal development infrustructure has many things in common with those of oil and gas. Therefore it should not pose much obstacle to build one for geothermal in case of Peru. Especially regarding the drilling related services which always pose problems when developing geothermal fields, Petrex under Italian ENI and SAXON under Schlumberger, although they are under foreign capitals, together own more than 20 drilling rigs, operating for oil and gas fields under service contracts. Since thier working fields are located in the Amazonian low lands, they need to acquire drilling knowhow and equipment pertaining to the highlands geothermal application such as air rated drilling for tackling lost circulation or cooling tower for cooling high temperature mud. None of them is anticipated to create serious obstacles either.

I-6 Status of Multi-purpose Use of Geothermal Energy

I-6.1 Worldwide Direct Use of Geothermal Energy

The direct use of geothermal heat in the world as reported in the 2010 international Geothermal Congress was 438,071 TJ/Yr (50,583 MWt) of which space conditioning (heat pumps, space heating and green house heating) represents the largest share followed by aquaculture (pond heating), agriculture/drying, industrial uses, bathing and swimming and cooling/snow melting. Table I -6.1.1 shows this distribution.

Table I-6.1.1 Direct utilization of geothermal heat in the world (per activity)

Use	**2010**	
Geothermal Heat Pumps	214,782	49.03%
Space Heating	62,984	14.38%
Greenhouse Heating	23,264	5.31%
Aquaculture Pond Heating	11,521	2.63%
Agricultural Drying	1,662	0.38%
Industrial Uses	11,746	2.68%
Bathing and Swimming	109,032	24.89%
Cooling / Snow Melting	2,126	0.49%
Others	956	0.22%
Total	**438,071**	100.00%

(Source: Direct Utilization of Geothermal Energy 2010 Worldwide Review, John W. Lund et. al., 2010, Proceedings World Geothermal Congress, Bali, Indonesia).

As for Latin America alone, it is reported that 15,301.40 TJ/Yr (862.50 MWt) of utilization (Table I -6.1.2).

Table I-6.1.2 Direct utilization of geothermal heat in Latin-American

Country	Capacita MWt	Anual Use TJ/yr	Anualice GWh/yr	Capacita Factor
Argentina	307.47	3,906.74	1,085.30	40.00%
Brazil	360.10	6,622.40	1,839.70	58.00%
Caribbean Islands	0.10	2.78	0.80	85.00%
Chile	9.11	131.82	36.60	46.00%
Columbia	14.40	287.00	79.70	63.00%
Costa Rica	1.00	21.00	5.80	67.00%
Ecuador	5.16	102.40	28.40	63.00%
El Salvador	2.00	40.00	11.10	63.00%
Guatemala	2.31	56.46	15.70	78.00%
Honduras	1.93	45.00	12.50	74.00%
Mexico	155.82	4,022.80	1,117.50	82.00%
Peru	2.40	49.00	13.60	65.00%
Venezuela	0.70	14.00	3.90	63.00%
Total Latin America	862.50	15,301.40	4,250.60	60.50%
Percentage respect world total	1.71%	3.49%	3.49%	---
World Total	50,583.00	438,071.00	121,696.00	27.00%

I-6.2 Examples of Multi-Utilization of Geothermal Resources in South America

The following is to provide reference of what it is being done in other countries of the South America continent regarding direct use and multi-utilization.

In Argentina the development of geothermal resources increased in the last few years with the discovered of new thermal areas linked to sedimentary basins that belong to the hydrothermal Conductive system, along with advanced research of high enthalpy thermal fields. This allowed the development of new therapeutic-recreational complexes that generated income for different regions of the country. During the last five years 11 new projects were started and are now in the exploration field for direct-use. These projects are being considered for recreational therapeutic facilities and to supply drinking water to nearby towns. At present there are 64 bathing and swimming development, two greenhouse sites, two fish farms, one snow melting site, and three space heating sites. The various applications of geothermal direct use are: 22.25 MWt and 295.82 TJ/yr for individual space heating; 20.44 MWt and 269.95 TJ/yr for greenhouse heating; 19.9 MWt and 252.92 TJ/yr for fish farming; 2.00 MWt and 15.14 TJ/yr for snow melting (at Copahue in the Andes); 91.36 MWt and 2,169.74 TJ/yr for bathing and swimming; 1.62 MWt and 44.62 TJ/yr for other uses (water consumption); and 149.90 MWt and 858.55 TJ/yr for geothermal heat pumps. The total for the country is 307.47 MWt and 3,906.74 TJ/yr.

In Brazil a significant number of low temperature resources (< 90^{o}C) have been identified in the continental area, but the potential for high temperature geothermal systems appears to be restricted to the Atlantic islands of Fernando de Noronha and Trindade. Most of the springs that account for the potential are located in the west central Brazil (in the states of Goiás and Mato Grosso) and in the south (in the state of Santa Catarina). The potential for large scale exploitation of low temperature geothermal water for industrial use and space heating is considered to be significant in the central part of the Paraná basin (situated at southern and southeastern Brazil), where cold winter seasons prevail under subtropical climate conditions. The various applications of direct use are: 0.9 MWt and 15.4 TJ/yr for fish farming, 4.20 MWt and 77.0 TJ/yr for an industrial wool processing plant ; 355 MWt and 6,530 TJ/yr for bathing and swimming, for a total of 360.1 MWt and 6,622.4 TJ/yr.

In Chile the geothermal energy in the country has been only utilized for recreational purposes. Current use in spa and swimming pools, accounts for all the capacity. However, there are many private thermal spas and resorts in the geothermal area, for which quantitative information regarding their use of geothermal resources is not available. In some spas, shallow wells have been drilled to obtain hot water, while in others hot water is collected rudimentary and piped to the buildings pools, through shallow drains and plastic hoses. A total of 20 bathing and swimming sites have been identified amounting to 9.11 MWt and 131.82 TJ/yr.

For Columbia no update has been reported. Thus, the figures from WGC 2005: 14.4 MWt and 287 TJ/yr for bathing and swimming at 41sites.

In Ecuador the utilization of geothermal resources in the country is restricted to direct a use only, that is, bathing resorts, balneology and swimming pools. Recently, the first use of space heating at the private Terms Papallacta Spa Resort Hotel has been commissioned, but no data are available. In addition, several projects for fish hatcheries are waiting funding for development.

For Venezuela no report on the use of geothermal resources was made available for WGC2010.Thus, the figures of 0.7 MWt and 14 TJ/yr estimated for several small spas is used.

I-6.3 Multi-Utilization of Geothermal Resources in Peru

The figures given for Peru in Table I-6.1.2 were those reported by Lund et al. (2005) for seven spas in the central-north part of Peru.

From the perspective and knowledge gained through this Master Plan study it is believed that in Peru the application of geothermal resource in uses other than power generation is possible and that can contribute to local social-economic development of communities as well as to the mitigation of the world’s climate change. Only for reference, the direct use of geothermal energy in the world as reported in the 2010 World geothermal congress contributed to energy savings amounted to 307.8 million barrels (46.2 million tonnes) of equivalent oil annually, preventing 46.6 million tonnes of carbon and 148.2 million tonnes of CO_2 being release to the atmosphere which includes savings in geothermal heat pump cooling (compared to using fuel oil to generate electricity)

I-7 Issues to be Solved for Promoting Geothermal Power Developments

As mentioned in the previous sections, the legal framework for geothermal resource development in Peru has been established with a system that postulates that the developments will be basically carried out by private sector. The application of the legal framework, however, has been just started from 2010. Thus for the developments to be actually enhanced, it is necessary for the Peruvian government to proclaim the policy and strategy for the promotion of geothermal developments. The aggressive governmental activities for the promotion are also necessary, and it is expected that flexible applications or revisions of the framework will be required according to actual situations.

The current issues to be solved for promoting the geothermal resource development in Peru can be enumerated as follows.

- Although the target for power generation by renewable energies including geothermal is set to be 5 % of the total electricity demand, the proportions to be supplied by each renewable energy sources, or a concrete development plans have not been formulated yet.
- The resource risk and risk in high initial cost, which are peculiar to geothermal, possibly prevent the progress of development by private sector. Thus it is necessary to consider options such as the improvement of the current legal system, or governmental participation to geothermal power generation project.
- The only existing incentive for promoting geothermal power generation projects is currently the fixed-price purchase system of generated electric power through the tender for renewable energy

projects. The system has not been qualified as an effective measure in promoting the developments by private sector since the purchase price (the base price in the tender) has not been examined yet.

- There are not many experts on geothermal power generation and utilization in governmental institutions. Besides, collaborative partnership and information exchange for development promotion among the related institutions are not sufficient.

The Master Plan is necessary to cope with the issues enumerated above. In this project, the Master Plan was formulated, that consists of the recommendations and action plans, the geothermal development database, and the geothermal development plans, as shown in the following chapter.

II MASTER PLAN

II-1 Recommendations and Action Plan

II-1.1 Target for Geothermal Power Development

II-1.1.1 Development Potential based on Geothermal Resource

(1) Overview of Geothermal Resource in Peru

Main land of Peru is located in the fire belt near the zone of subduction of the Nazca plate below the South American plate, which have generated tectonic movements and an intense volcanic activity that extends by million years and is still present in very recent years (Fig. II-1.1.1). The Andes, where most of geothermal fields and hot springs in Peru are situated, is a mountain belt resulting from the underthrusting of oceanic lithosphere adjacent to a continental margin. The Andes in Peru comprise two subparallel folds belts (Fig. II-1.1.2). The Western Cordillera is of Mesozoic-Tertiary age and the Eastern Cordillera of Late Paleozoic age. In southern Peru, where the fold belts diverge, they are separated by the Altiplano, which consists of a thick sequence of Tertiary molasse. The Andean Cordilleras are flanked to the east by the sub-Andean zone, which consist of continental sediments deposited on the Brazilian Shield, and to the west by the Precambrian Arequipa Massif, which may make up a large part of the Peruvian continental shelf (Kearey and Vine, 1996). Figure II-1.1.3 illustrates the generalized structure of the Andes in Peru (Kearey and Vine, 1996). Controls on the deep structure come from the interpretation of seismic refraction and gravity data, which show that the base of the crust is at 12 km below sea level beneath the ocean, at 76 km under the Altiplano and probably at 40 km beneath the Brazilian Shield.

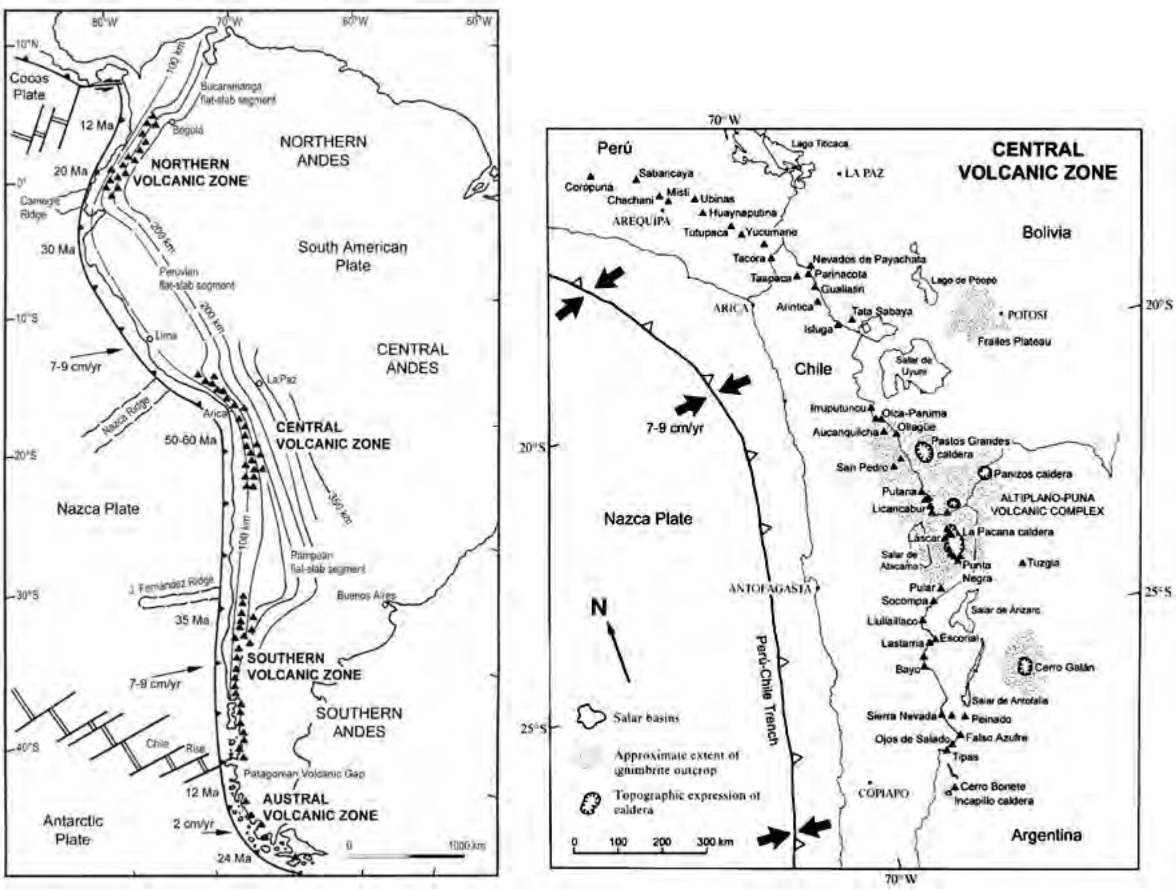


Fig. II-1.1.1 Schematic map of South America and the Pacific oceanic plates (Stern, 2004)

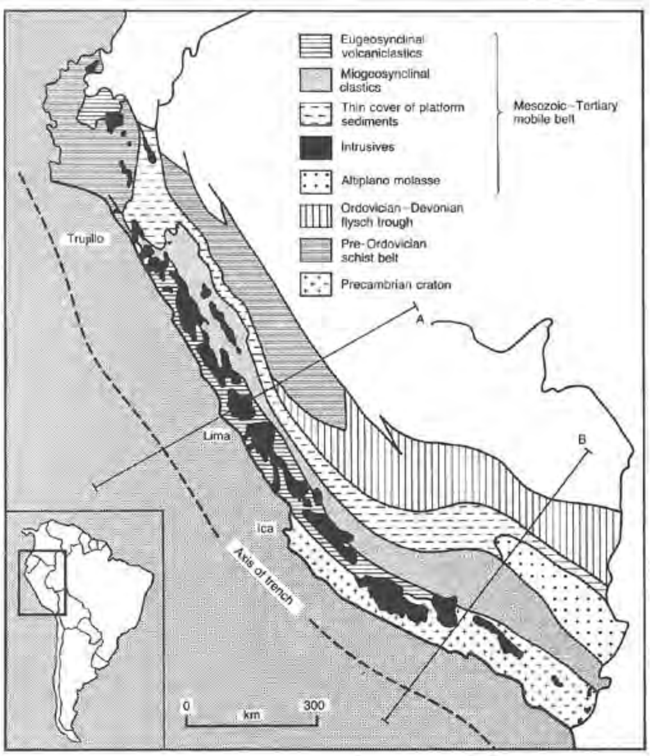


Fig. II-1.1.2 Geology of the Andes in Peru (Kearey and Vine, 1996)

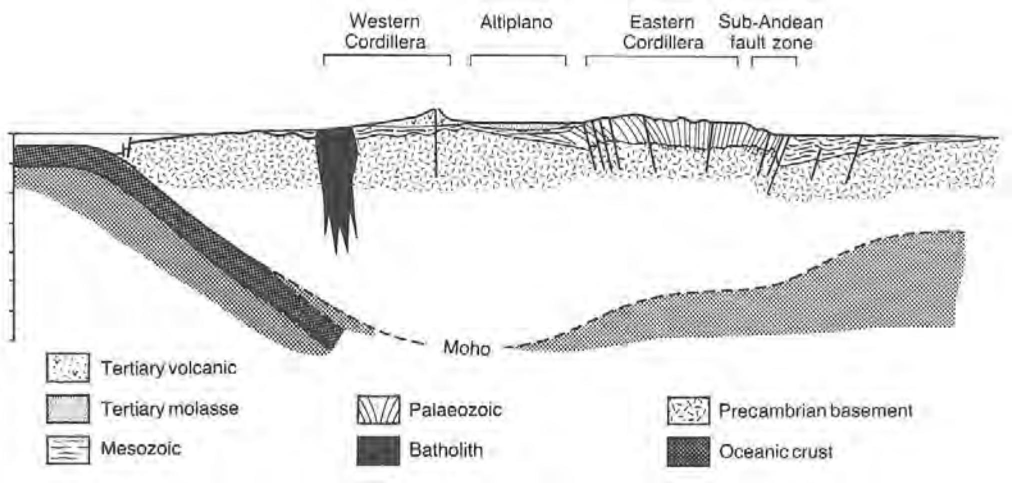


Fig. II-1.1.3 Schematic section through the Andes in Peru (Kearey and Vine, 1996)

The Andean volcanic arc is discontinuous, with gaps in active volcanism in the northern two-thirds of Peru and in north-central Chile. These gaps correspond to parts of the subducting slab that flattery beneath the overriding plate, in contrast to other parts where the slab subducts at a steeper angle of 30 deg. (Barazangi and Isacks, 1976). In central and northern Peru, there is no active volcanism. In central and northern Peru the seismic zone dips shallowly at about 10 deg. While in southern Peru the dip is 30 deg where there is Neogene and Holocene volcanism (Fig. II-1.1.4).

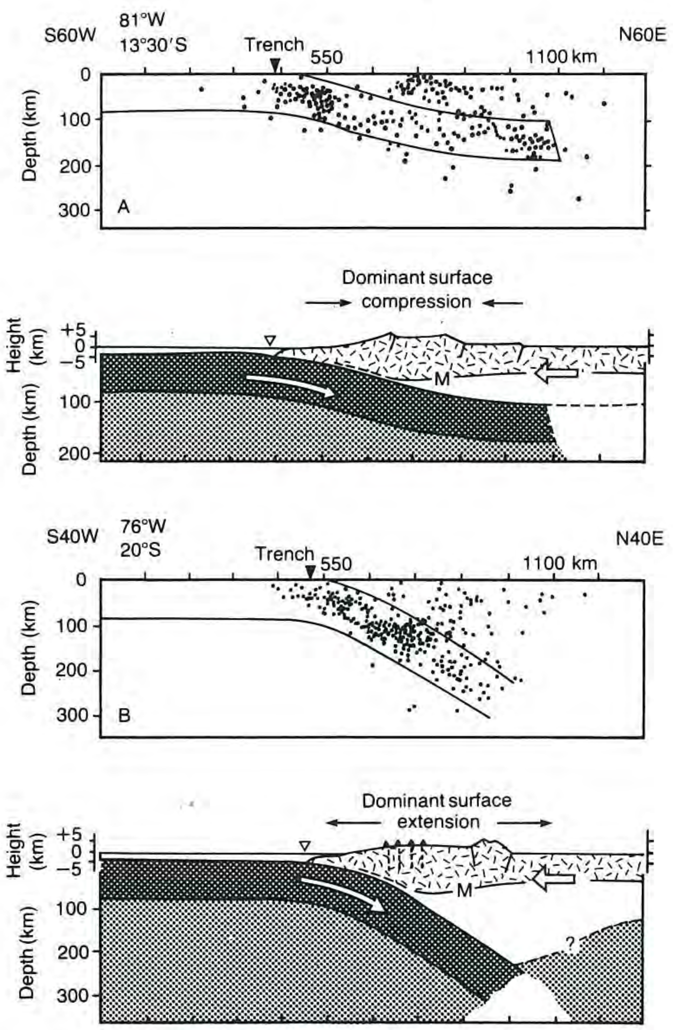


Fig. II-1.1.4 Cross sections along profiles A and B, shown in Fig. II-1.1.2 (Kearey and Vine, 1996)

An enormous amount of Cenozoic volcanic rocks are distributed in the Andes in Peru (Fig. II-1.1.5). In central and northern Peru, the volcanic rocks are distributed in a narrow zone. Active volcanoes are absent in this segment. The amount of surface outcrops of young volcanic rocks shows abrupt increase in southern Peru, coincident with the start of Altiplano. Figure II-1.1.6 shows the distribution of active volcanoes and volcanic centers younger than Miocene (Kono et al., 1989). Active volcanoes align in a single line forming a distinct volcanic front in southern Peru and northern Chile. However, in entire Neogene period, the volcanic centers are distributed almost all over the Altiplano. A wide distribution of volcanism is also consistent with high heat flow values observed not only near the Western Cordillera but in most part of the Altiplano. These imply that a much wider region has been under the influence of the volcanic activity, and a considerable amount of magmatic material should have been supplied to the crust beneath the Western Cordillera as well as the Altiplano (Kono et al., 1989). Kono et al. (1989) suggests that the volcanic activity in the Andes of southern Peru is perhaps distributed over a wide geographical extent covering most of Altiplano, and that the Altiplano corresponds roughly to the area of magma generation associated with the subduction of the Nazca plate beneath the South American plate (Fig. II-1.1.7). Presence of volcanic activity in Neogene in wide area of southern Peru implies that the occurrence of geothermal fields with high potential is expected.

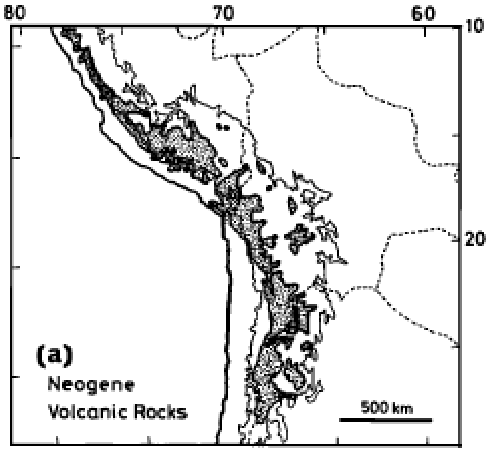


Fig. II-1.1.5 Distributions of Neogene volcanic rocks in Central Andes (Kono et al., 1989)

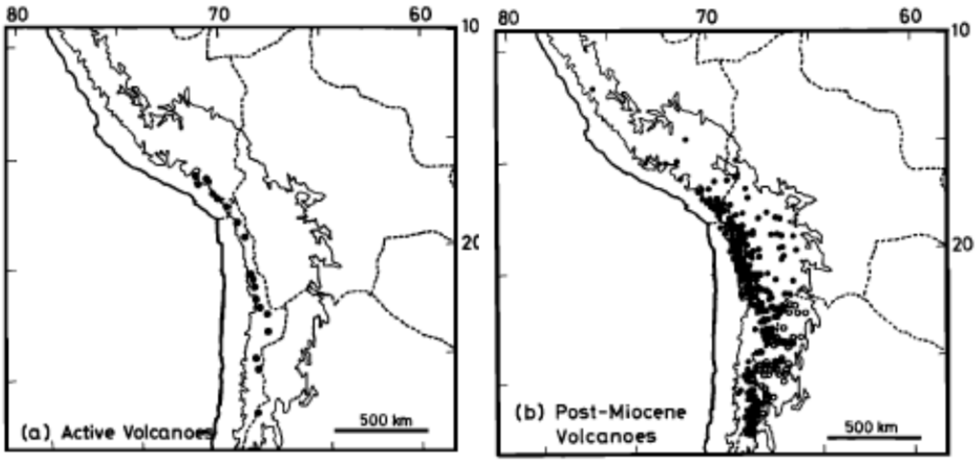


Fig. II-1.1.6 Distributions of active volcanoes and post-Miocene volcanoes in Central Andes (Kono et al., 1989)

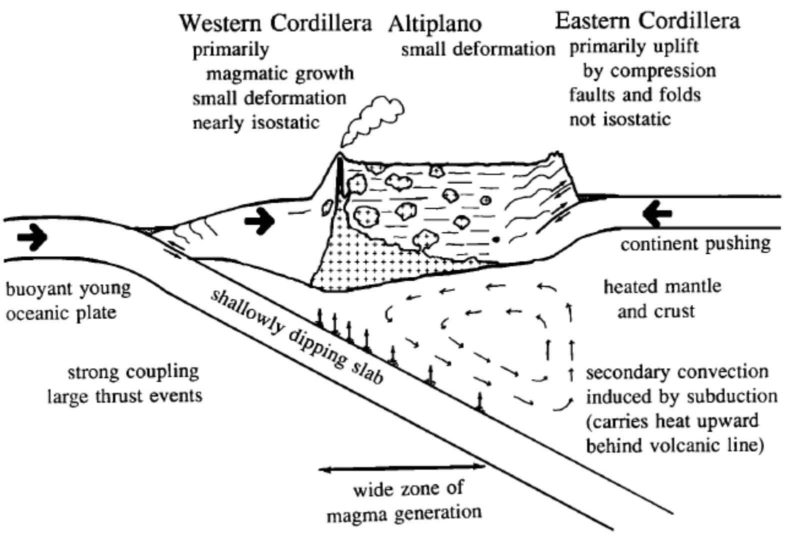


Fig. II-1.1.7 A cartoon showing the processes in the formation of the Central Andes (Kono et al., 1989)

Gravity and heat flow data in Peru also available for understanding the regional geological setting and thermal condition in Peru. Figure II-1.1.8 shows the regional Bouguer anomaly in Peru based on gravity survey data and the relation between the Bouguer anomaly and topography and distribution of crustal densities and thicknesses in southern Peru. In the Bouguer anomaly map, a remarkably low Bouguer anomaly zone elongated along the Andes is clearly recognized.

In and around the Andes, the followings are interpreted in some previous geo-scientific studies.

- Crustal thickening in the Andes has been achieved through tectonic shortening of the crust due to the subduction of the Nazca Plate below the South American Plate.
- The crustal rocks of the Andes are interpreted as driving from the melting of the downgoing slab (Nazca Plate) and overlying mantle, and the crustal thickening has resulted from an intrusion of magmatic products from this region.

These two factors is thought to be reasons to lowering the Bouguer anomaly at and around topographic high of the Andes, because the crustal rocks is considered to be consisting of lower density materials compared to more deeper materials. In addition, Cenozoic volcanic rocks in southern Peru indicate wider distribution in the east-west extent compared to those in northern Peru, and an abrupt width change of the Cenozoic volcanic rocks is observed in between these two areas (Fig. II-1.1.5). Since the distribution of the low Bouguer anomaly zone has a similar tendency to the above-mentioned distribution of Cenozoic volcanic rocks, there seems to be a strong relation between the low Bouguer anomaly and the Cenozoic volcanic rocks. This fact may suggest that geothermal activity in southern Peru is stronger than that in northern Peru.

Through the updating of geological mappings in southern and central Peru, Sempere and Jacay (2008) indicates that the western part of the Central Andes have formed by magmatic accretion, while the eastern part is indeed of tectonic origin (crustal shortening) (Fig. II-1.1.7).

However, the gravity data were acquired for estimating a large scale density structure, and thus the data cannot be utilized for deducing local structures in each geothermal field. More detailed gravity surveys in and around each geothermal field are recommendable.

According to Hamza et al. (2005), the high residual heat flow has been observed at the southern part of Peru (Fig. II-1.1.9) the heat flow data are based on the measured temperature at local wells). The area of high heat flow zone (from the southern part of Peru to the northern part of Chile) coincides with the region of active or Neogene volcanoes. This implies that the present or young volcanisms in this zone provide the high heat flow.

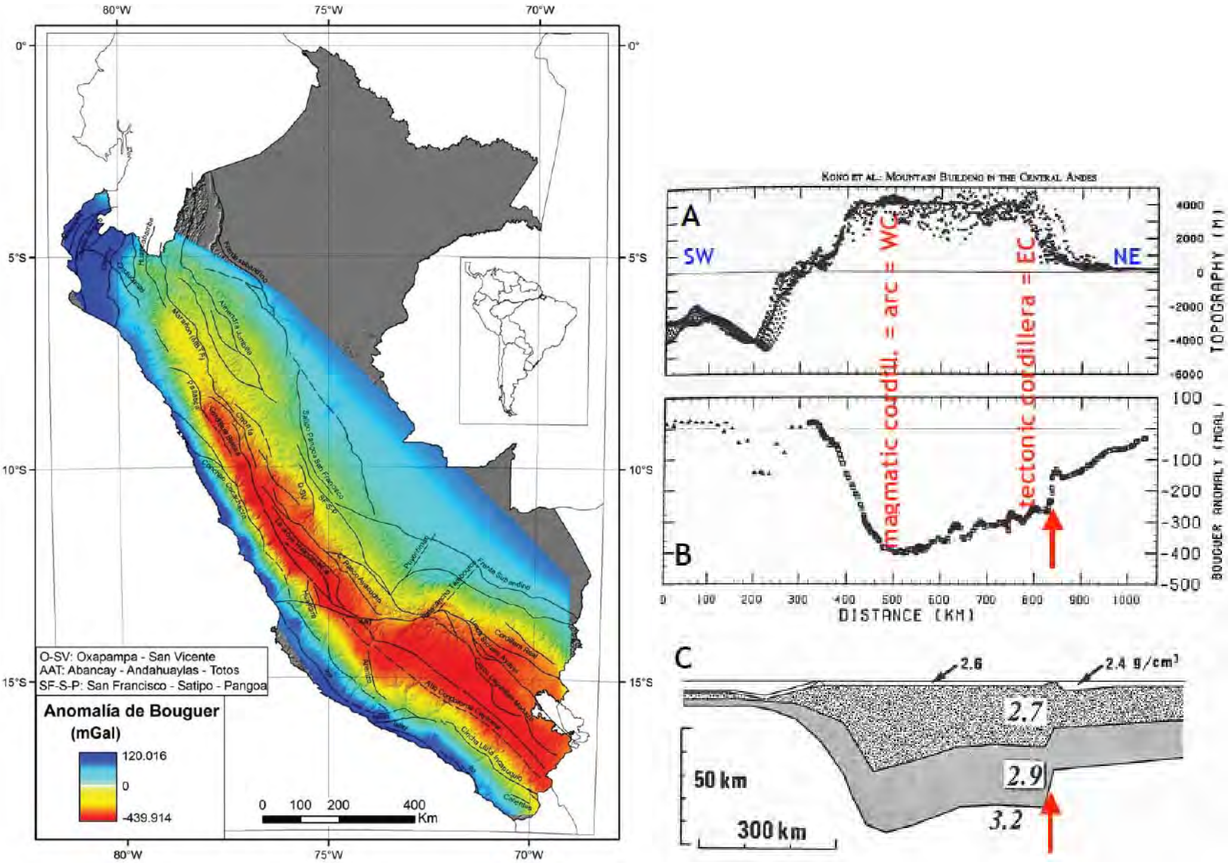
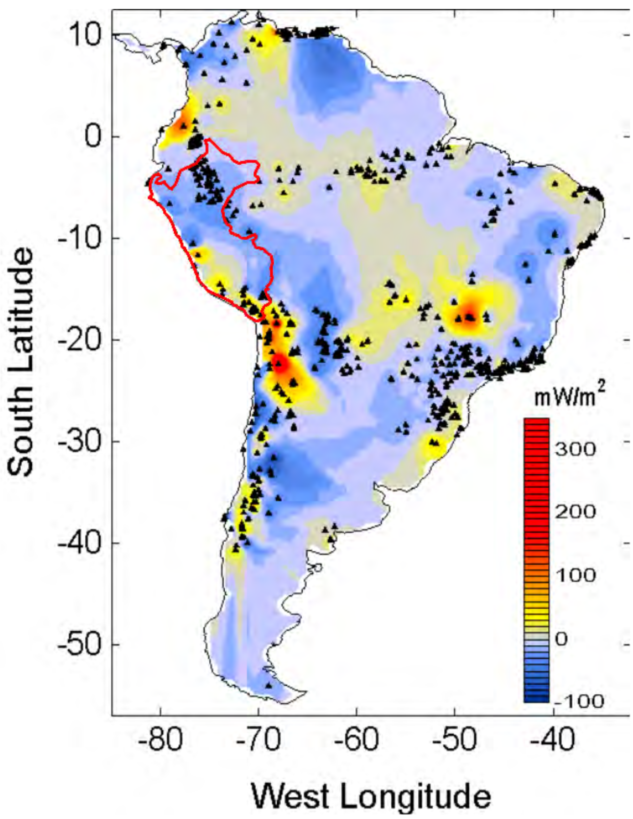


Fig. II-1.1.8 Bouguer anomaly and crustal thickness in Peru (INGEMMET; Sempere and Jacay, 2008)



Site Name	Latitude (degrees) (+N, -S)	Longitude (degrees) (+E, -W)	Elevation (meters)	Maximum Depth (m)	Heat Flow mW/m^2
RAURA	-10.4833	-76.75	4800	146	30
RAURA	-10.4833	-76.75	4800	146	17
CONDESTA	-12.6833	-76.6	450	167	24
CONDESTA	-12.6833	-76.6	450	167	35
CUAJONE	-17.0667	-70.7667	3500	120	98
CUAJONE	-17.0667	-70.7667	3500	120	57
CERRO VE	-16.55	-71.5667	2700		41
CERRO VE	-16.55	-71.5667	2700		44
CASAPALC	-11.65	-76.2333	4700	654	196
LOMITOS	-4.6167	-81.2833	200	550	35
LOBITOS	-4.45	-81.2667	200	660	28
PENA NEG	-4.2833	-81.1667	200	660	37
TOQUEPAL	-17.2667	-70.65	3100	820	66
MARCAHUI	-15.5167	-73.75	2600		44
TINTAYA	-14.9	-71.35	4100		32
LA GRANJ	-6.5833	-79.1167	2300		39
CAPAHUAR	-2.4844	-75.9347			52
CORRIENT	-3.85	-75.05	160	3832	50
PAVAYACU	-3.4	-75.3833	235	3436	53
YANAYACU	-4.9	-74.9333	145	3727	55
YURIMAGU	-5.8167	-76.1333	277	2312	55

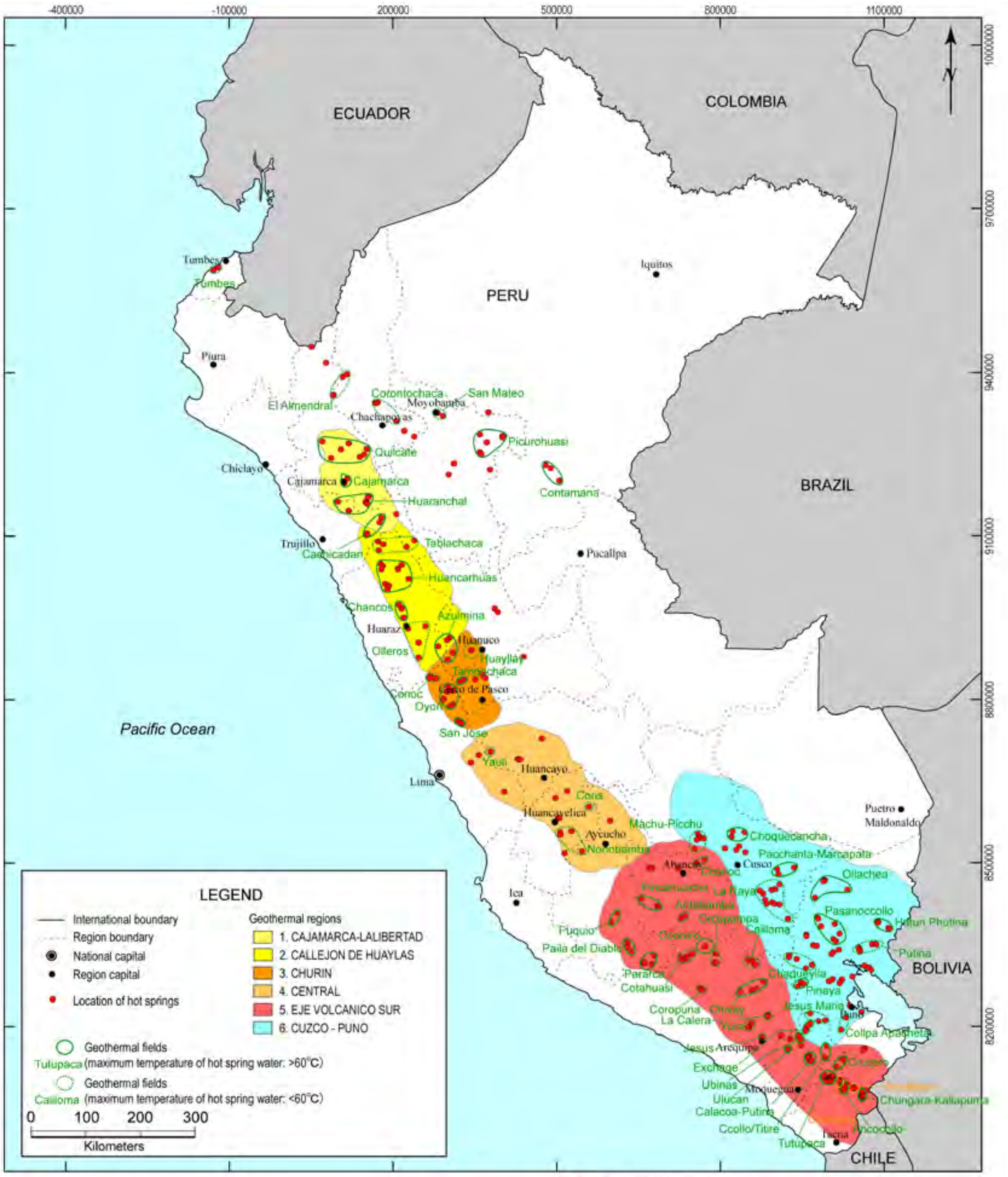
Fig. II-1.1.9 Residual heat flow density contour map of South America (Hamza et al., 2005)

(2) Geothermal Resource Potential in Peru

a) Delineation of Geothermal Fields

In the Geothermal Map of Peru updated by INGEMMET, several important geothermal areas were defined as shown in Fig. I-5.1.1. However, the geothermal (or hydrothermal) systems having the individual hydrological systems have not been delineated. In order to evaluate each geothermal field, the geothermal systems were delineated based on the spatial distribution of hot or mineral springs and topography (Fig. II-1.1.10 and Table II-1.1.1).

In the delineation work, the isolated mineral and cold springs were ignored. Sixty-one (61) geothermal fields were delineated in the whole country, but the fields more than half of them (38 fields) are within the Region 5 and Region 6. Among the 61 fields, 34 fields have one or more hot spring(s) with a discharge temperature higher than 60^{o}C.



Source: Vargas and Cruz (2010).
Simplified MAPA DE REGIONES GEOTHERMICAS DEL PERU (INGEMMET)

Fig. II-1.1.10 Location map of the delineated geothermal fields

Table II-1.1.1 List of the delineated geothermal fields

Geothermal Region	No.	Region	Field Name	Existence of Hot Spring >60^{o}C
(Northern Peru)	1	Tumbes	Tumbes	
	2	Amazonas	El Almendral	
	3	Amazonas	Corontochaca	
	4	San Martin	San Mateo	
	5	San Martin	Picurohuasi	○
	6	Loreto	Contamana	○
1. Cajamarca-La Libertad	7	Cajamarca	Quilcate	○
	8	Cajamarca	Cajamarca	○
	9	Cajamarca-La Libertad	Huaranchal	○
	10	La Libertad	Cachicadan	○
2. Callejon de Huaylas	11	Ancash-La Libertad	Tablachaca	
	12	Ancash	Huancarhuas	○
	13	Ancash	Chancos	○
	14	Ancash	Olleros	
	15	Huanuco-Ancash	Azulmina	○
3. Churin	16	Lima	Conoc	
	17	Pasco	Huayllay	
	18	Pasco	Tambochaca	○
	19	Lima	Oyon	○
	20	Lima	San Jose	○
4. Central	21	Junin	Yauli	
	22	Huancavelica	Coris	
	23	Huancavelica	Nonobamba	
5. Eje Volcanico Sur	24	Cusco-Apurimac	Cconoc	
	25	Apurimac	Pincahuacho	○
	26	Apurimac	Antabamba	
	27	Ayacucho	Puquio	○
	28	Ayacucho	Paila del Diablo	○
	29	Ayacucho	Pararca	○
	30	Arequipa	Ocoruro	○
	31	Arequipa	Cotahuasi	
	32	Arequipa	Orcopampa	
	33	Arequipa	Cailloma	
	34	Arequipa	Coropuna	
	35	Arequipa	Chivay	○
	36	Arequipa	La Calera	
	37	Arequipa	Yura	
	38	Arequipa	Jesus	
	39	Moquegua	Ubinas	○
	40	Moquegua	Ulucan	○
	41	Moquegua	Calacoa-Putina	○
	42	Moquegua	Ccollo/Titire	○
	43	Moquegua-Tacna	Crucero	○
	44	Tacna	Tutupaca	○
	45	Tacna	Calientes	○
	46	Tacna	Ancocollo	○
	47	Tacna	Borateras	○
	48	Tacna	Chungara-Kallapuma	○
6. Cuzco-Puno	49	Cusco	Machu-Picchu	
	50	Cusco	Choquecancha	○
	51	Cusco	Pacchanta-Marcapata	○
	52	Cusco	La Raya	
	53	Puno	Ollachea	○
	54	Puno	Pasanoccollo	○
	55	Puno	Hatun Phutina	○
	56	Puno	Putina	
	57	Puno	Chaqueylla	
	58	Puno	Pinaya	○
	59	Moquegua	Jesus Maria	
	60	Moquegua	Exchage	
	61	Puno	Collpa Apacheta	

b) Estimation of Resource Potential in Peru

The resource potential of 61 geothermal fields are calculated by stored-heat method to estimate roughly the whole geothermal resource potential in Peru. The resource potential calculation is carried out with classifying the 61 fields into four categories as below. The detailed procedure of resource potential estimation with the stored-heat method is described in Annex.

- Calientes and Borateras: According to the study reports of JBIC (2008) and JETRO (2008), in which the conceptual model of geothermal systems for resource potential estimation is based on detailed surface surveys including MT survey.
- Ancocollo and Tutupaca: Those two fields are selected as the most promising fields in this study, and the conceptual model for the fields for resource potential estimation is based on detailed surface surveys including MT survey.
- Eleven promising fields: The eleven fields are selected as the promising fields in this study, and the conceptual model for the fields for resource potential estimation is based on geological and geochemical surveys conducted in this study.
- Other fields (46 fields): The fields are delineated only by the special distribution of hot or mineral springs and topography. The resource potential is estimated with stored-heat method based on the rough assumption of temperature and volume of possible geothermal reservoir.

The result of resource estimation is summarized in Table II-1.1.2. The total geothermal potential in Peru is estimated to be 2,860 MWe.

It is worth noting that the each delineated field has several "sectors" inside. For instance, Chungara-Kallapuma field has five sectors (namely, Juntupujo, Chungara, Quiane, Conchachiri, and Conchachiri pozos). Two of these sectors (Juntupujo and Chungara) are considered as "Chungara-Kallapuma", as one of the 13 promising fields, with resource potential of 84 MWe. The remaining three sectors reserves 17 MWe in total. The schematic is shown in Fig. II-1.1.11.

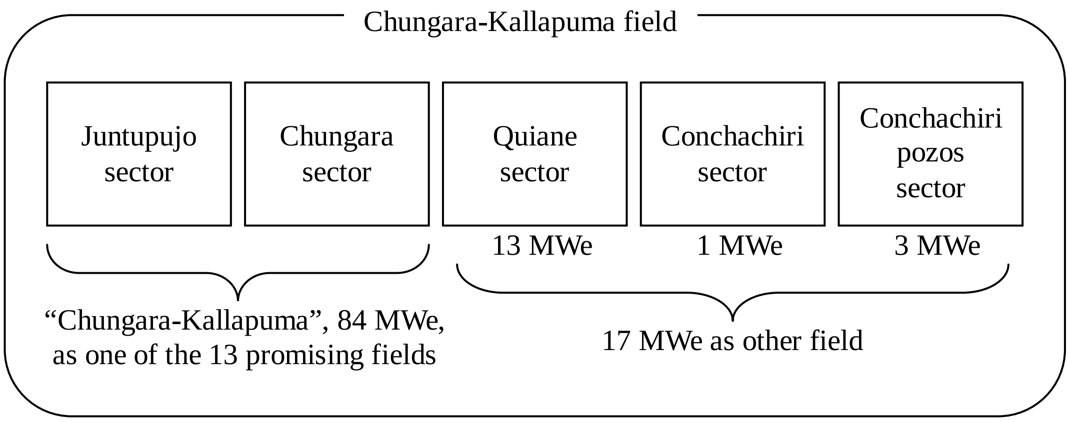


Fig. II-1.1.11 Schematic of field - sector relation and counting of resource potential (example)

Table II-1.1.2 Summary of geothermal power generation potential in Peru

Geothermal Region	No.	Region	Field Name	Resource Potential (MWe)		No. of Sector **
				Promising Fields*	Other Fields	
(Northern Peru)	1	Tumbes	Tumbes		15	2
	2	Amazonas	El Almendral		10	2
	3	Amazonas	Corontochaca		7	5
	4	San Martin	San Mateo		14	3
	5	San Martin	Picurohuasi		58	6
	6	Loreto	Contamana		48	3
1. Cajamarca-La Libertad	7	Cajamarca	Quilcate		70	7
	8	Cajamarca	Cajamarca		29	2
	9	Cajamarca-La Libertad	Huaranchal		54	5
	10	La Libertad	Cachicadan		40	3
2. Callejon de Huaylas	11	Ancash-La Libertad	Tablachaca		29	5
	12	Ancash	Huancarhuas		89	10
	13	Ancash	Chancos	15.3	21	3
	14	Ancash	Olleros		29	4
	15	Huanuco-Ancash	Azulmina		53	5
3. Churin	16	Lima	Conoc		21	3
	17	Pasco	Huayllay		10	1
	18	Pasco	Tambochaca		24	2
	19	Lima	Oyon		45	5
	20	Lima	San Jose		25	2
4. Central	21	Junin	Yauli		7	1
	22	Huancavelica	Coris		10	1
	23	Huancavelica	Nonobamba		15	3
5. Eje Volcanico Sur	24	Cusco-Apurimac	Cconoc		9	2
	25	Apurimac	Pincahuacho		25	2
	26	Apurimac	Antabamba		15	2
	27	Ayacucho	Puquio	34.3	10	1
	28	Ayacucho	Paila del Diablo		54	4
	29	Ayacucho	Pararca		31	3
	30	Arequipa	Ocoruro		23	1
	31	Arequipa	Cotahuasi		65	7
	32	Arequipa	Orcopampa		29	4
	33	Arequipa	Cailloma	9.1	26	2
	34	Arequipa	Coropuna		15	3
	35	Arequipa	Chivay	162.9	136	9
	36	Arequipa	La Calera		9	2
	37	Arequipa	Yura		15	4
	38	Arequipa	Jesus		7	2
	39	Moquegua	Ubinas		24	3
	40	Moquegua	Ulucan	27.4	0	0
	41	Moquegua	Calacoa-Putina	108.2	45	4
	42	Moquegua	Ccollo/Titire	39.7	27	3
	43	Moquegua-Tacna	Crucero	79.4	3	1
	44	Tacna	Tutupaca	113.8	29	5
	45	Tacna	Calientes	100.0	0	0
	46	Tacna	Ancocollo	98.2	55	4
	47	Tacna	Borateras	40.0	31	3
	48	Tacna	Chungara-Kallapuma	84.0	17	3
6. Cuzco-Puno	49	Cusco	Machu-Picchu		49	6
	50	Cusco	Choquecancha		43	3
	51	Cusco	Pacchanta-Marcapata		40	3
	52	Cusco	La Raya		26	5
	53	Puno	Ollachea		45	3
	54	Puno	Pasanoccollo		65	6
	55	Puno	Hatun Phutina		39	4
	56	Puno	Putina		53	6
	57	Puno	Chaqueylla		26	3
	58	Puno	Pinaya	36.8	27	2
	59	Moquegua	Jesus Maria	17.3	17	2
	60	Moquegua	Exchage		27	5
	61	Puno	Collpa Apacheta		13	2
Total				966.4	1,894	207
Grand Total				2,860		

* at 80% Confidence Level

** Excluding Borateras, Calientes and Selected 13 Fields.

In the previous studies, the geothermal power potential in Peru was estimated to be 2,990 MWe by Battocletti et al. (1999) and 3,002.7 MWe by JICA (2008 internal report). The resource potential estimated in this study is 2,860 MWe, and this result is very close to the previous estimations even though the estimation approach is different. This fact confirms the validity and the mutual complementarities of the estimations.

The distribution of calculated geothermal power potential in Peru is shown in Fig. II-1.1.12, and other statistical graphs are shown in Figs. II-1.1.13 and II-1.1.14. More than half of the total resource potential exists in the Region 5.

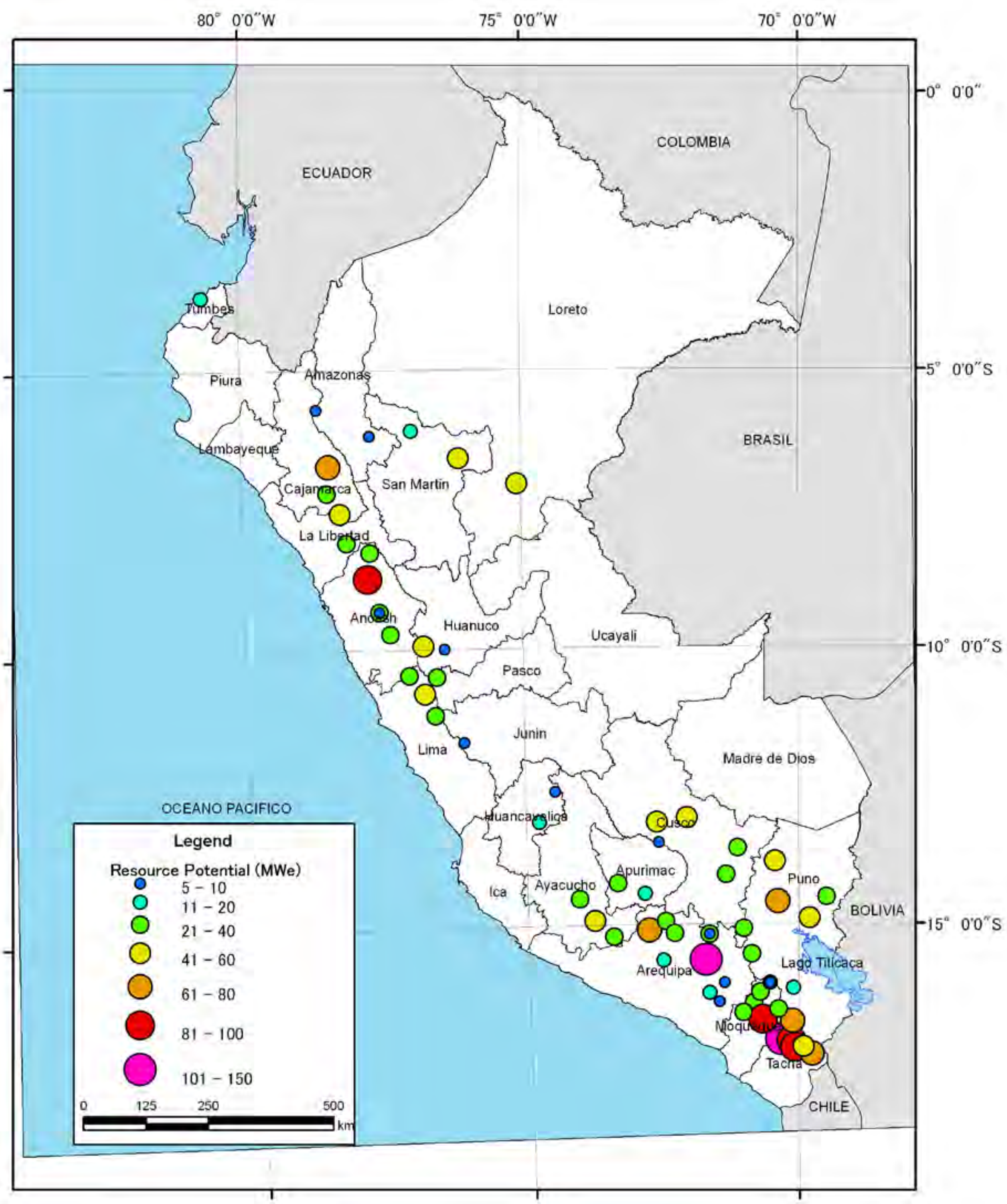


Fig. II-1.1.12 Map of geothermal power potential in Peru

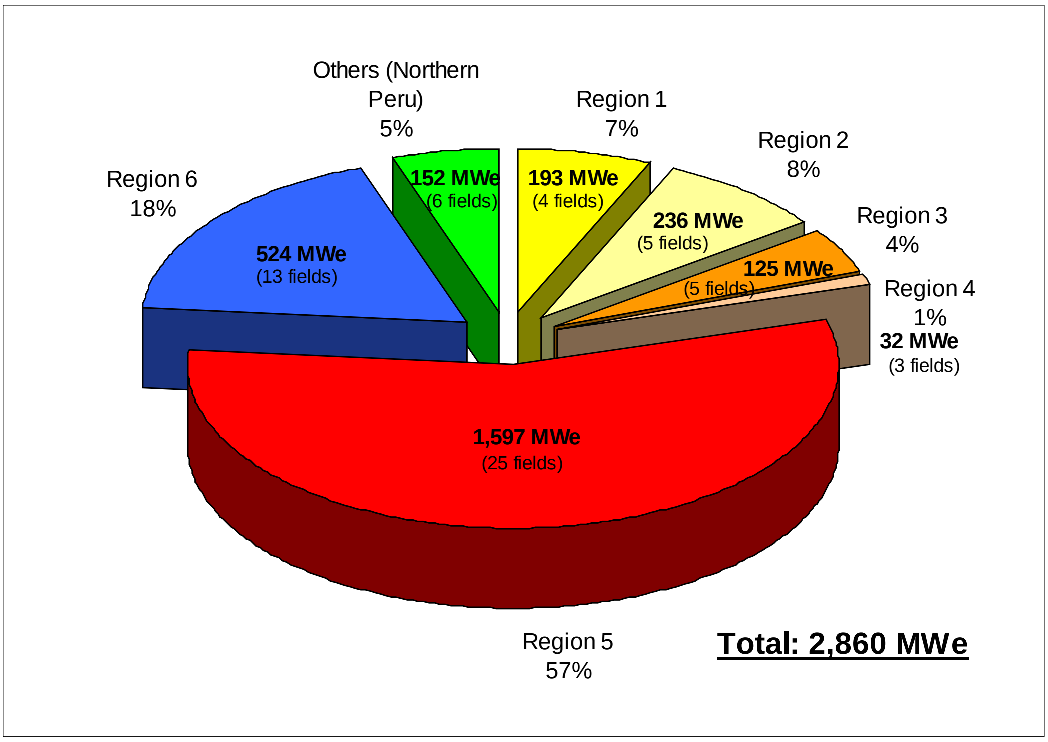


Fig. II-1.1.13 Geothermal power potential in each geothermal region

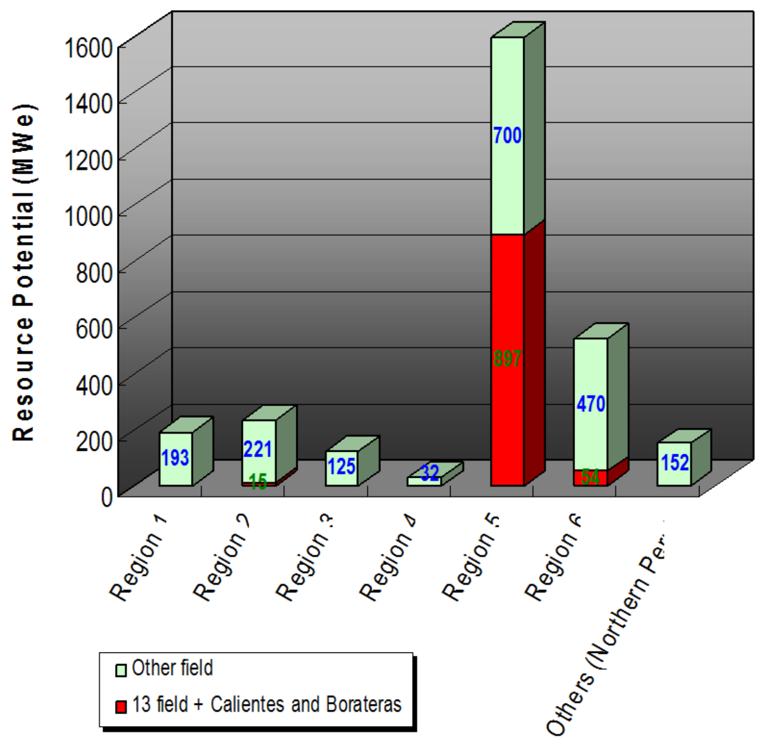


Fig. II-1.1.14 Geothermal power potential in the promising fields and the other fields

Although the significant amounts of cumulative resource potential of the other fields are presented, the potential of each sector is probably not enough for the single large-scale development. Figure II-1.1.15 shows the number of sectors against the estimated resource potential in histogram. The potential is lower than 10 MWe in most of the sectors as shown in the figure. If the geothermal system in each sector is separated, only small-scale power development is possible at the respective sector. In general, the small power development is costly for power generation compared with the large development. Since the connection and the extent of the geothermal system in the other fields are still unknown, it is necessary to conduct further resource assessment to update the estimation of resource potential.

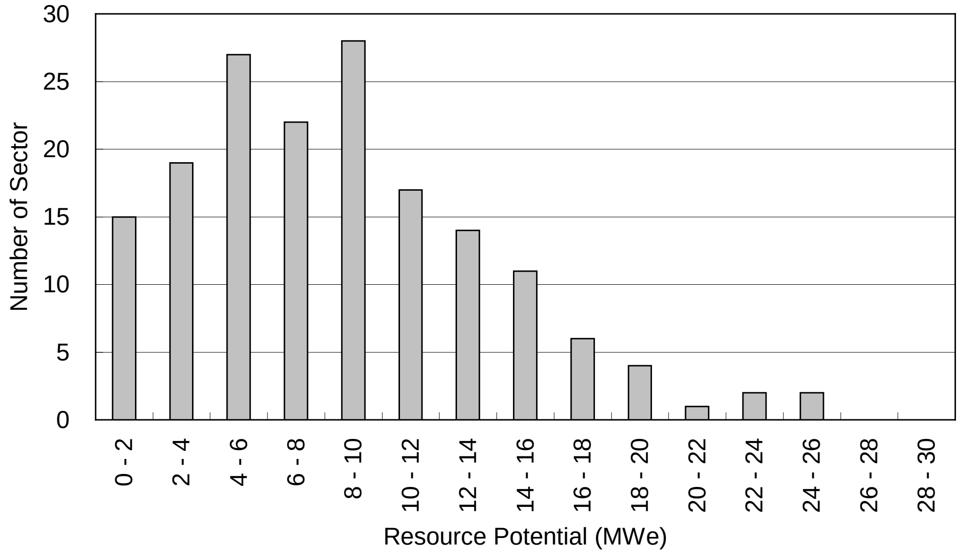
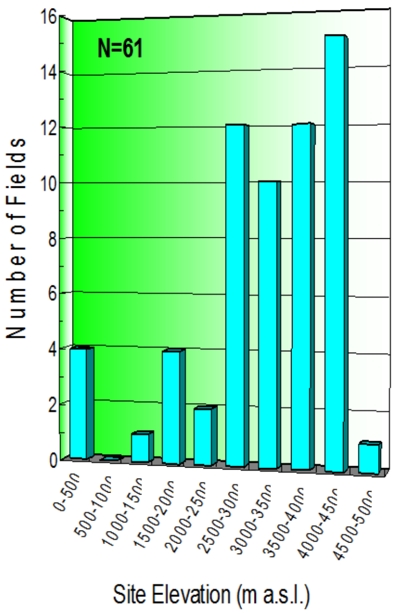


Fig. II-1.1.15 Number of sectors by estimated resource potential (excluding the promising fields)

On the other hand, some sectors of the other fields have its estimated potential of more than 20 MWe (Fig. II-1.1.15). For instance, the resource potential of Ocoruro field in Arequipa, where boiling hot springs can be observed, is estimated to be 23 MWe. Although the high resource potential possibly exists in Ocoruro, the field was not selected as the promising field because of its poor accessibility. It is desirable that the detailed geoscientific surveys are carried out in such possible high-enthalpy geothermal fields in future.

One of the major characteristics of geothermal resource in Peru is that the high-potential fields tend to be located in high elevation areas. Figure 3.6.22 shows histograms of site elevation vs. number of field and estimated resource potential. As shown in the figures, 82% of geothermal fields and 85% of estimated resource potential exist at high elevation areas of 2,500-5,000m a.s.l. Moreover, more than half (58%) of estimated resource potential is recognized at very high elevation areas of 3,500-5,000m.



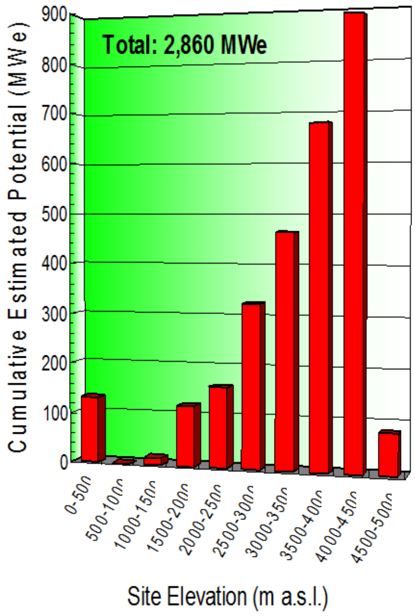


Fig. II-1.1.16 Histograms of site elevation vs. number of field and estimated resource potential

II-1.1.2 Benefits of Geothermal Energy as an Electricity Power Source

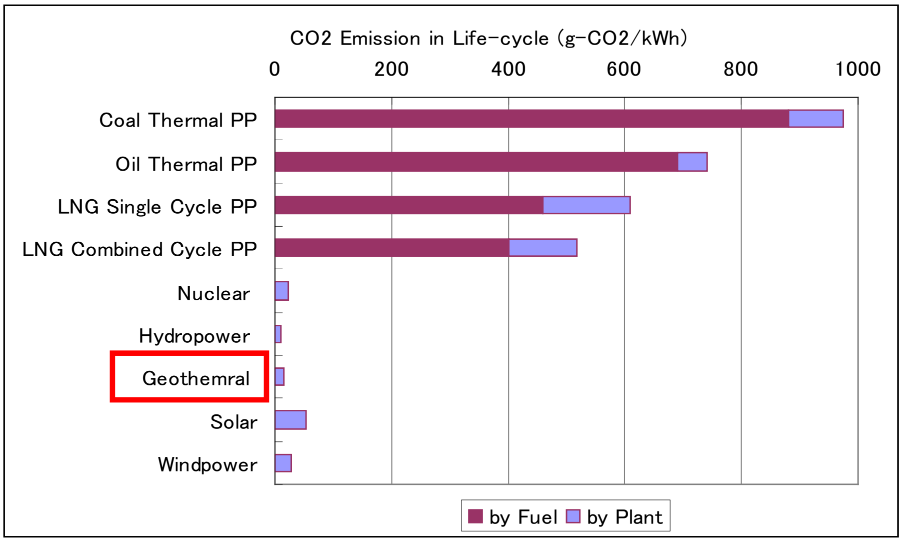
(1) Characteristics of Geothermal Energy

In general, geothermal energy is a clean reliable source of renewable energy which offers significant benefits when compared to other sources of energy:

- Environment friendly energy
- Reliable source of energy
- Indigenous source of energy
- Power generation is economically viable to some extent
- Multi-purpose use of heat is available

Environment-friendly energy

Geothermal power generation does not emit air pollutant such as sulfur oxide, nitrogen oxide, and dusts, since no combustion process is included. Furthermore, the amount of carbon dioxide emission is much smaller comparing with other kind of power generation. Therefore, geothermal power generation is an environment-friendly energy source, and it contributes to a country development without deteriorating the global warming (Fig. II-1.1.17).



(Source: Central Research Institute of Electric Power Industry, Japan; CRIEPI Review No.45, 2001 Nov.)

Fig. II-1.1.17 Life cycle CO_2 emission of various power sources

Reliable source of energy

Among other renewable resources, the points that best characterize the geothermal resource are high capacity factor and its stability, that is, it can be used throughout the year regardless to climate conditions. Thus the geothermal energy is an energy source of high supply reliability (Fig. II-1.1.18).

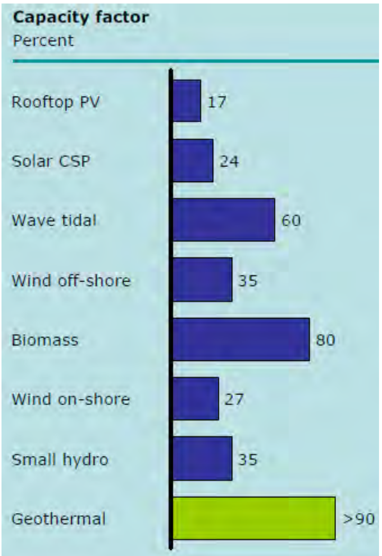


Fig. II-1.1.18 Plant capacity factors of various kinds of renewable energy

Indigenous energy source

Geothermal energy is a purely domestic source of energy. The countries without reserves of fossil fuels can reduce the amount of import of fossil fuels. Even for the countries with fossil fuels reserves and have ability of exportation, geothermal energy can replace the domestic consumption of fossil fuels. The saved amount can be displaced to export, or it can be reserved for future use.

Power generation business is economically viable to some extent

Geothermal energy development requires high initial investment at its exploitation stage. On the contrary, geothermal energy will save the operational cost since it does not consume fuel expenses. Consequently, the long-term power generation cost of geothermal energy is not expensive as that of solar power generation (Fig. II-1.1.19), and neither it is not affected by the fluctuation of the international petroleum price or exchange rate. Thus geothermal energy can be supplied at stable supply cost and the utilization of geothermal resources would contribute to stabilize national economic balance.

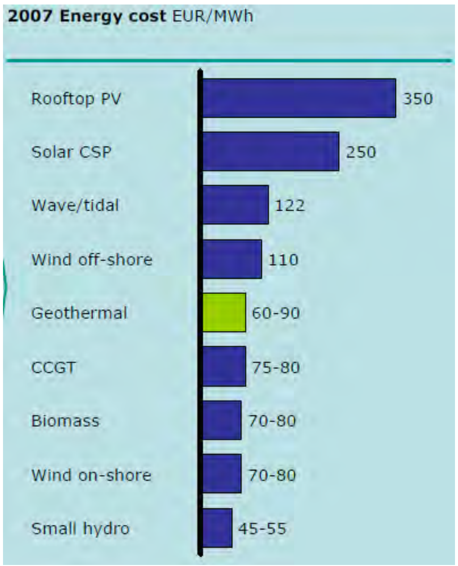


Fig. II-1.1.19 Power generation cost of renewable energies (Bertani, 2009)

Multi-purpose use of heat is available

Hot waters originate from heat source or produced as the by-product of power generation can be utilized for agriculture, fish farming, and the heat source for regional industry. Such multi-purpose use is efficient especially in the region of cold climate, and can be utilized for desiccation of woods or cereals. The steam originate from geothermal power generation can be utilized for agricultural, ranching, and drinking purposes after condensation by cooling. Geothermal energy is an energy source that can unite energy developments and regional developments.

Comparisons between geothermal energy and other renewable energies are shown in Table II-1.1.3. The benefit of geothermal resource development is not only limited to the above mentioned merits, but it also contribute to growth of regional economy.

Table II-1.1.3 Comparison between geothermal and other renewable energy sources

Power Source	Environment	Availability	Energy Independence	Commercial Balance	Multiple Utilization
Geothermal	Yes	Yes	Yes	Yes	Yes
Hydro	-	-	Yes	Yes	Yes
Wind	Yes	-	Yes	Yes	-
Solar	Yes	-	Yes	Yes	-
Biomass	-	-	Yes	Yes	-

(2) Advantage and Necessity of Geothermal Energy Development in Peru

Geothermal development in Peru is desirable especially because of the following reasons.

- Electricity power development with various kinds of energy source is necessary to cope with growing energy demand. Among various renewable energies, geothermal energy is highly expected as a promising power source since it can achieve stable supply. Fig. II-1.1.20 shows the capacity factors of power plants that had been offered in the tenders of renewable energy projects. Only a few of small-scale hydraulic power plants and biomass plants could achieve the capacity factor over 80%. In general, geothermal power plants can achieve a capacity factor of 80-95%.

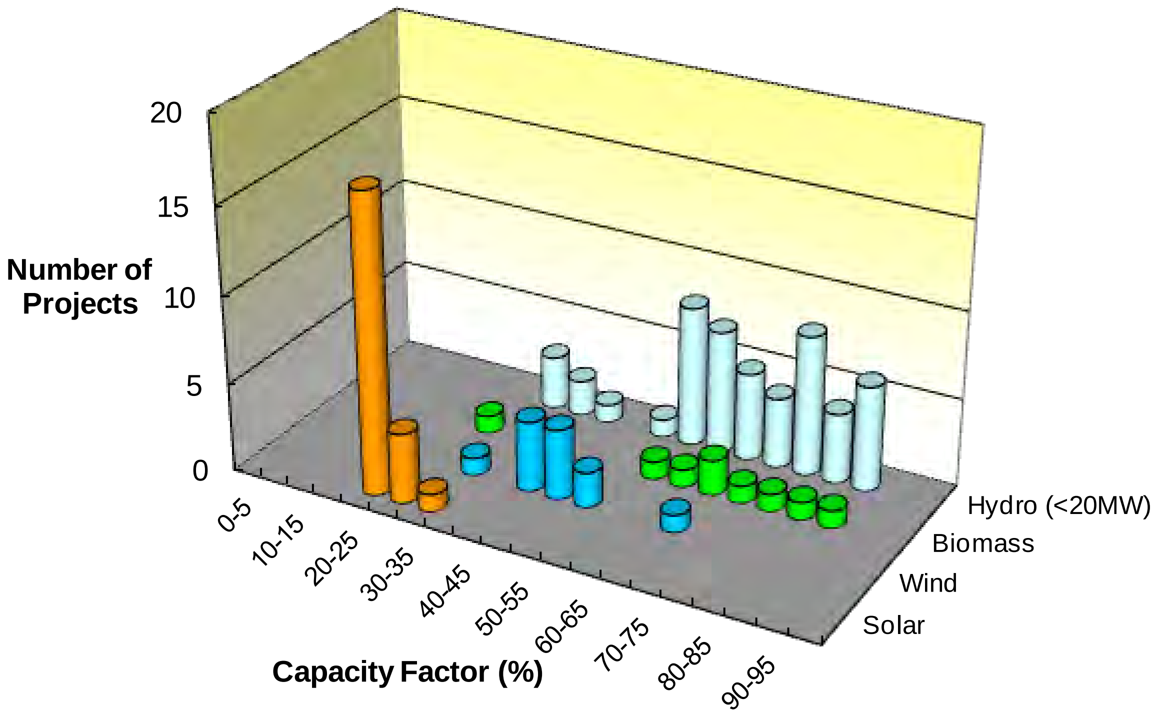


Fig. II-1.1.20 Capacity factors of renewable energy power projects offered in the tenders in Peru

- At present, natural gas fired power generations are carried out at low costs in Peru, and the power output is getting increased. Natural gases are demanded not only for power generation use but also for other purposes. Thus its domestic consumption is increasing (Fig. II-1.1.21). When geothermal power generation is realized, the consumption of natural gases for power generation use will be reduced, and the saved amount can be supplied to other purposes such as town gas demand. As natural gases are international merchandise, the saved amount can be sold to international market as LNG and the sales will bring foreign currency to Peru. (Refer to section II-1.1.3)

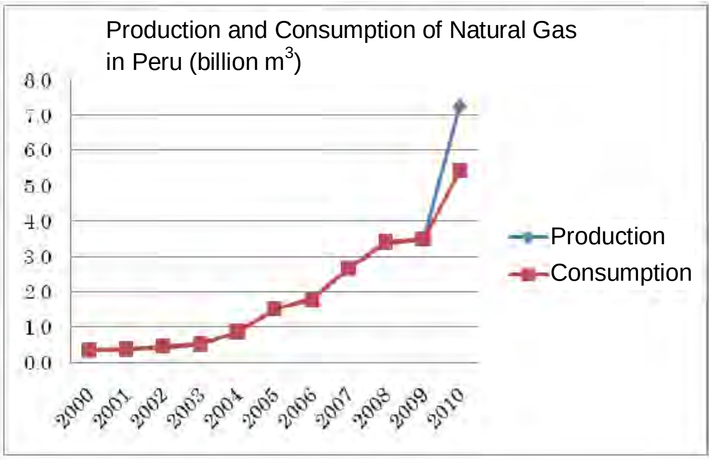


Fig. II-1.1.21 Production and consumption of natural gas in Peru (JOGMEC, 2011)

- Geothermal power generation will emit much smaller amount of CO_2 comparing with that of gas fired power generation that power supply is getting increased recently in Peru (refer to Fig. II-1.1.17). Replacement of gas fired power plants with geothermal power plants will greatly contribute to the reduction of CO_2 emission.
- There exist abundant geothermal resources in southern part of Peru. On the other hand, there are poor amount of water resources in southern part of Peru since arid region widely spread over the southern part. In addition, solar resources are relatively rich in southern part of Peru, but wind power is not available except limited area in mountainous region (Fig. II-1.1.22).

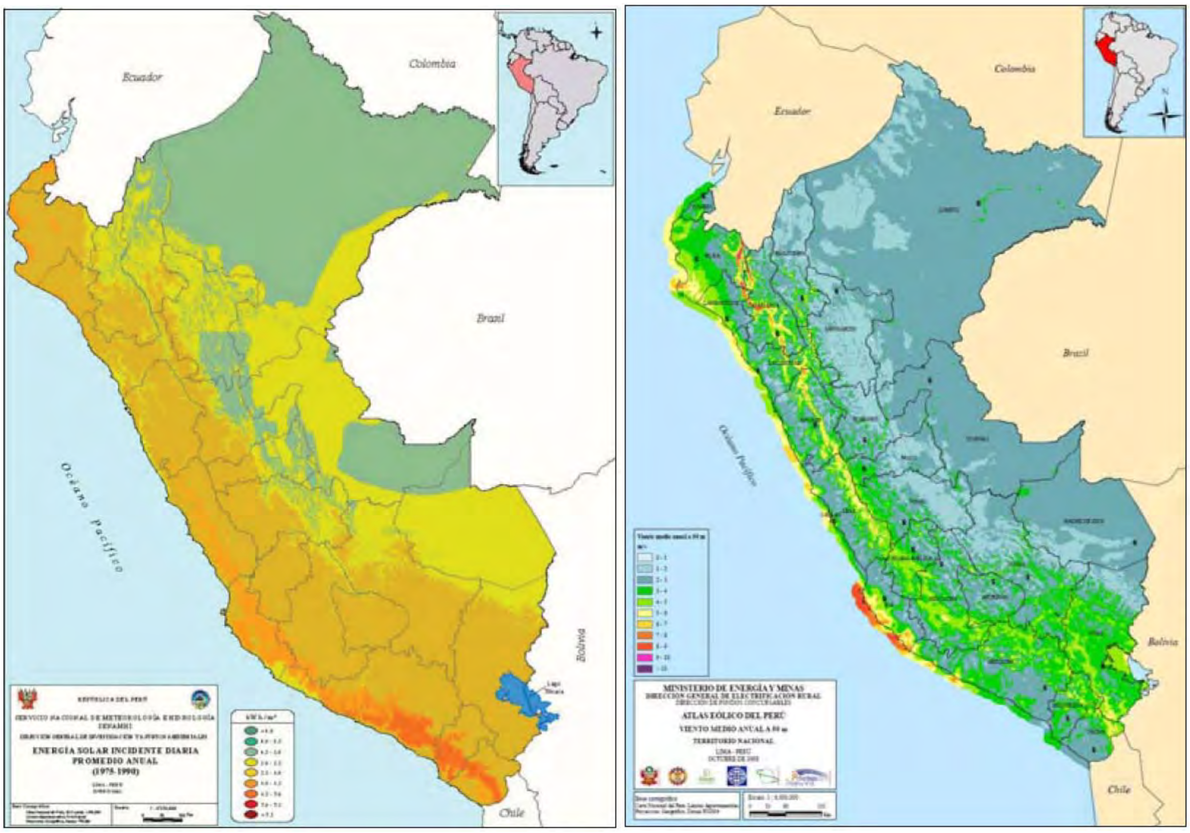
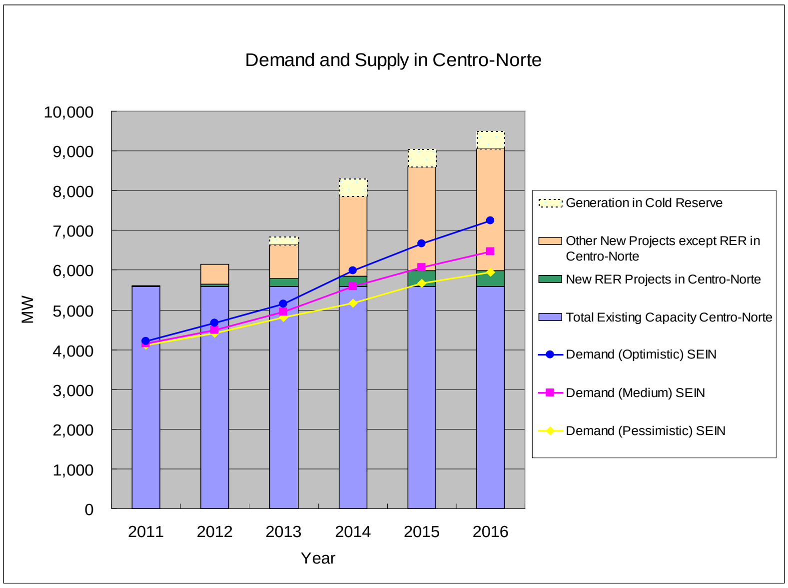
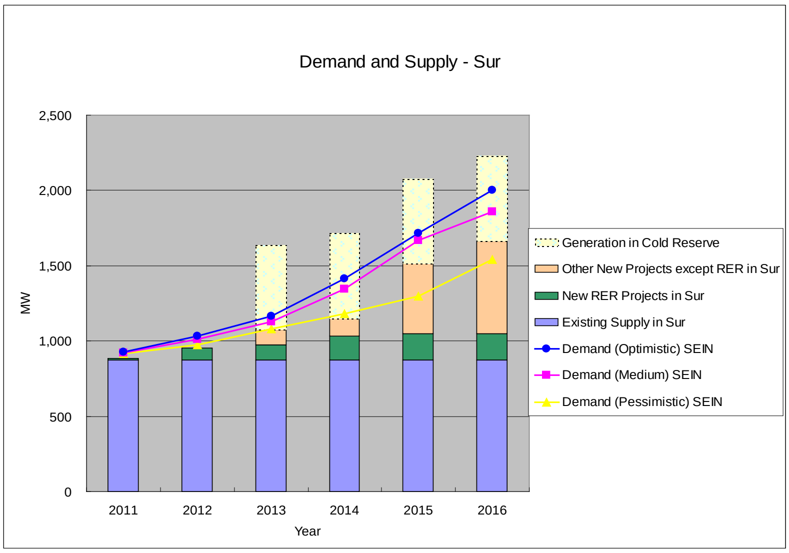


Fig. II-1.1.22 Distribution map of solar (left) and wind (right) resources in Peru

- Projections of demand and supply of electric power (up to 2016) for south area and other area (north and central) are shown in Fig. II-1.1.23. In north and central area, there will be enough supply than even optimistic demand. On the other hand, the margin of the supply in south area will be only by "cold reserve (reserva fria)" power plant, which is the lowest priority of operation among power plants, in case of optimistic and medium demand projection. In this case, power with cheaper cost may be dispatched from central area to south. Consequently, geothermal power at promising geothermal fields in south area will make southern grid (Zona Sur: Fig. II-1.1.24, Apurimac, Cusco, Arequipa, Puno, Moquegua and Tacna) stable and contribute to improvement of the transmission losses and overall system stability, as well.





(Source: MEM and COES Website)

Fig. II-1.1.23 Demand and Supply Projection (up to 2016)

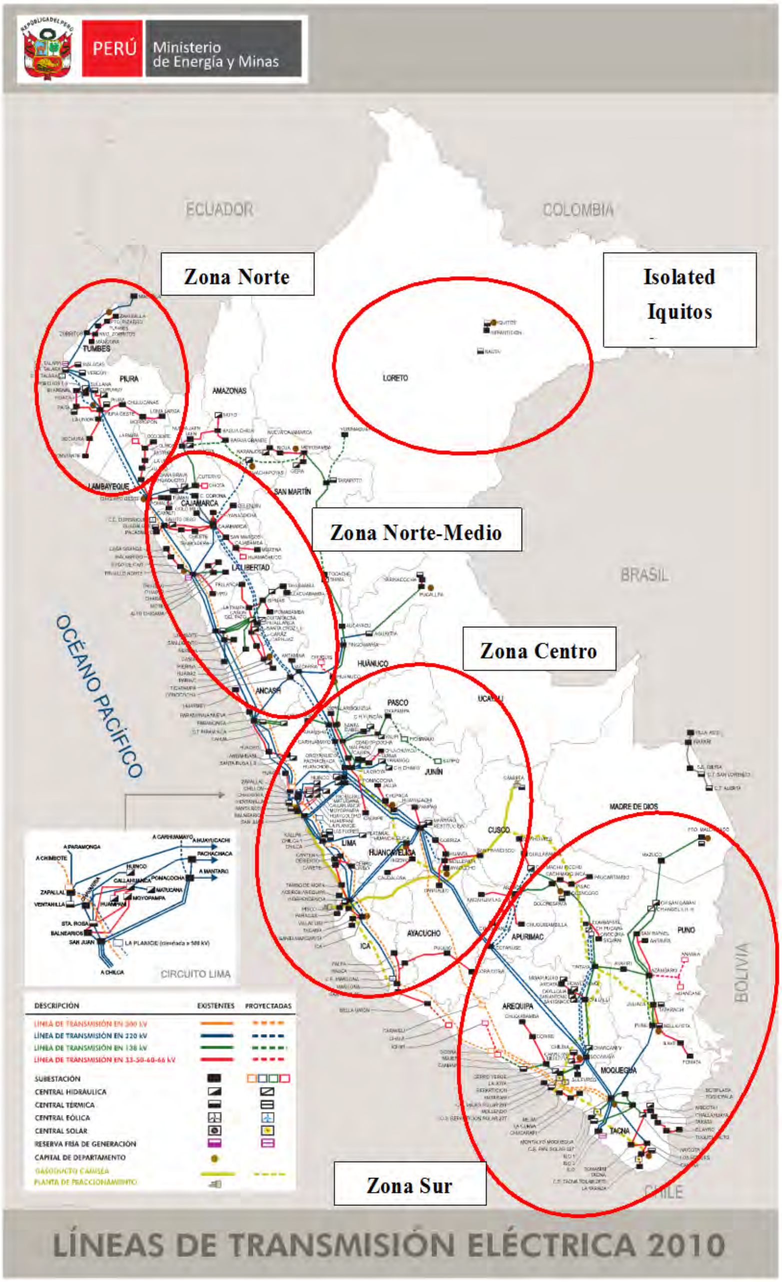


Fig. II-1.1.24 Regional zones in Peruvian power transmission system

- The regions with abundant geothermal resources in Peru are cold districts at high-altitudes. Multi-purpose use of geothermal energy including room heating can be highly expected.

II-1.1.3 Quantitative Evaluation of Benefit of Geothermal Development in Peru

(1) Economic Evaluation of Geothermal Power Project

In this study, the economy of the possible geothermal power projects is evaluated for the 13 promising fields selected in this study and for Calientes and Borateras fields where the detailed studies had been conducted previously. The details of the development plans and economic evaluation for those fields are described in the section II-3.2.1 and Annex. In the economic evaluation, the selling price of electricity that can attain 12% of the Financial Internal Rate of Return (FIRR) for the geothermal plant investors during 30-year operation period is calculated. As a result, the highest project economy is estimated for the “Field-A” with the lowest selling price of 10.5 US cent/kWh.

(2) Comparison with Alternative Power Sources (Benefit of Natural Gas Saving)

In this section, the cost competitiveness of the geothermal power project against alternative sources is studied. Natural gas (combined cycle power plant; NGCC), coal and diesel are selected as alternative sources.

Firstly, the power plant specification of alternative sources is assumed as shown in Table II-1.1.4. Oil price is assumed as 120 USD/bbl while coal price is 110 USD/ton and natural gas price is 12 USD/MMBTU (Table II-1.1.5). These prices are referred to the IEA’s "World Energy Outlook 2010", and are considered as constant during the evaluation period for the simplicity. The current price of the natural gas for power generation use in Peru is around 1.58 USD/MMBTU. However, this is a domestic price, and it is necessary to evaluate natural gas value in terms of the international price since the fuel is the internationally traded commodity. According to a report of IEA, the LNG price for 2015-2035 is forecast to be 12-17 USD/MMBTU in Asia, 7-11 USD/MMBTU in the United States and 11-14 USD/MMBTU in Europe. Therefore, 12 USD/MMBTU is taken as an average price of the three markets, and the price of 3-15 USD/MMBTU is used in the sensitivity analysis.

Table II-1.1.4 Power plant specification of alternative sources

Plant Type	Natural Gas-fired (Combined-Cycle)	Coal-fired Plant	Diesel Plant
Fuel	Natural Gas	Coal	Heavy Oil
Capacity	300 MW	300 MW	50 MW
Construction Cost (w/o IDC)	1,200 USD/kW	1,600 USD/kW	1,000 USD/kW
Construction Period	3 years	4 years	3 years
Plant Efficiency	45%	38%	38%
In-house use	3.5%	7%	4%
Capacity Factor	82.8%	85.9%	83.2%
O&M Costs	0.5 US cent/kWh	0.65 US cent/kWh	0.5 US cent/kWh
Fuel Price	12 USD/MMBTU	110 USD/ton	120 USD/bbl
Heat Value of Fuel	9,140 kcal/m^3	6,000 kcal/kg	9,800 kcal/L
Operation Period	30 years	30 years	30 years

Table II-1.1.5 Forecasted price of fossil fuels by IEA (2009 prices)

Energy	Unit	Current Policies Case					
		2009	2015	2020	2025	2030	2035
Natural Gas							
United States	USD/MMBTU	4.1	7.0	8.2	9.3	10.4	11.2
Europe	USD/MMBTU	7.4	10.7	12.1	12.9	13.9	14.4
Japan	USD/MMBTU	9.4	12.4	13.9	14.9	15.9	16.5
Crude Oil	USD/bbl	60.4	94.0	110.0	120.0	130.0	135.0
Steam Coal	USD/ton	97.3	97.8	105.8	109.5	112.5	115.0

Source: IEA, “World Energy Outlook 2010”

Based on these assumptions, the cost competitiveness against alternative thermal plants of the geothermal plants is calculated. The comparison is done to calculate the total cost difference between the case in which a geothermal plant is built and operated for 30 years and the case in which an alternative thermal power plant with the same capacity is built and operated in the same period. The comparison is expressed in terms of Economic Internal Rate of Return (EIRR). If the EIRR is larger than 12%, which is the social cost of the capital, the geothermal plant has cost competitiveness against an alternative plant. Table II-1.1.6 shows an example of the calculation.

Table II-1.1.6 Economic evaluation of a geothermal project (Alternative project is natural gas power plant with a gas price of 12 USD/MMBTU)

Table ECONOMIC INTERNAL RATE OF RETURN [Gas-fired Combined Cycle]

Field-A

EIRR = 20.1% | 12.0% disc. rate

Benefit of Geothermal (NPV) **3.53** ¢ /kWh

No.	No.	Year	PROJECT Project Cost	Capa-bitity	Capacity Factor	Annual Salable Energy	O&M Cost	Supple. Drilling Cost	Total Cost	ALTERNATIVE : [Gas-fired Combined Cycle] Alt. Project Cost	Capa-bitity	Capacity Factor	Annual Salable Energy	Effici-ency	Generation Energy	Fuel Consump.	Fuel Cost (Fuel Save)	O&M Cost	Total Cost	Cost Balance	Cost Balance (NPV)	Salable Energy (NPV)
			MM$	MW	%	GWh	MM$	MM$	MM$	MM$	MW	%	GWh	%	GWh	Mil. M3	MM$	MM$	MM$	MM$	MM$	GWh
1	#		-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	
2	#		4.07	-		-	-	-	4.07	-	-	-	-	-	-	-	-	-	-	-4.07	-3.63	
3	#		16.50	-		-	-	-	16.50	-	-	-	-	-	-	-	-	-	-	-16.50	-13.15	
4	#		5.83	-		-	-	-	5.83	-	-	-	-	-	-	-	-	-	-	-5.83	-4.15	
5	#		45.94	-		-	-	-	45.94	45.93	-	-	-	-	-	-	-	-	45.93	-0.01	-0.01	
6	#		221.07	-		-	-	-	221.07	82.67	-	-	-	-	-	-	-	-	82.67	-138.40	-78.53	
7	#		271.18	-		-	-	-	271.18	55.11	-	-	-	-	-	-	-	-	55.11	-216.07	-109.47	
8	1	1	-	150	85.0%	1,049.89	11.17	6.00	17.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	87.29	39.48	474.92
9	2	2	-	150	85.0%	1,049.89	11.17	6.00	17.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	87.29	35.25	424.03
10	3	3	-	150	85.0%	1,049.89	11.17	4.50	15.67		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	88.79	32.02	378.60
11	4	4	-	150	85.0%	1,049.89	11.17	6.00	17.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	87.29	28.10	338.04
12	5	5	-	150	85.0%	1,049.89	11.17	6.00	17.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	87.29	25.09	301.82
13	6	6	-	150	85.0%	1,049.89	11.17	4.50	15.67		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	88.79	22.79	269.48
14	7	7	-	150	85.0%	1,049.89	11.17	6.00	17.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	87.29	20.00	240.61
15	8	8	-	150	85.0%	1,049.89	11.17	-	11.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	93.29	19.09	214.83
16	9	9	-	150	85.0%	1,049.89	11.17	10.50	21.67		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	82.79	15.13	191.81
17	10	10	-	150	85.0%	1,049.89	11.17	-	11.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	93.29	15.22	171.26
18	11	11	-	150	85.0%	1,049.89	11.17	6.00	17.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	87.29	12.71	152.91
19	12	12	-	150	85.0%	1,049.89	11.17	4.50	15.67		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	88.79	11.55	136.53
20	13	13	-	150	85.0%	1,049.89	11.17	6.00	17.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	87.29	10.13	121.90
21	14	14	-	150	85.0%	1,049.89	11.17	-	11.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	93.29	9.67	108.84
22	15	15	-	150	85.0%	1,049.89	11.17	10.50	21.67		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	82.79	7.66	97.18
23	16	16	-	150	85.0%	1,049.89	11.17	-	11.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	93.29	7.71	86.77
24	17	17	-	150	85.0%	1,049.89	11.17	6.00	17.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	87.29	6.44	77.47
25	18	18	-	150	85.0%	1,049.89	11.17	10.50	21.67		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	82.79	5.45	69.17
26	19	19	-	150	85.0%	1,049.89	11.17	-	11.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	93.29	5.49	61.76
27	20	20	-	150	85.0%	1,049.89	11.17	6.00	17.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	87.29	4.58	55.14
28	21	21	-	150	85.0%	1,049.89	11.17	4.50	15.67		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	88.79	4.16	49.23
29	22	22	-	150	85.0%	1,049.89	11.17	6.00	17.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	87.29	3.65	43.96
30	23	23	-	150	85.0%	1,049.89	11.17	-	11.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	93.29	3.49	39.25
31	24	24	-	150	85.0%	1,049.89	11.17	10.50	21.67		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	82.79	2.76	35.04
32	25	25	-	150	85.0%	1,049.89	11.17	-	11.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	93.29	2.78	31.29
33	26	26	-	150	85.0%	1,049.89	11.17	6.00	17.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	87.29	2.32	27.94
34	27	27	-	150	85.0%	1,049.89	11.17	4.50	15.67		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	88.79	2.11	24.94
35	28	28	-	150	85.0%	1,049.89	11.17	6.00	17.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	87.29	1.85	22.27
36	29	29	-	150	85.0%	1,049.89	11.17	-	11.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	93.29	1.77	19.88
37	30	30	-	150	85.0%	1,049.89	11.17	-	11.17		150	82.8%	1,049.89	45.0	1,088.0	0.23	99.02	5.44	104.46	93.29	1.58	17.75
999																						
Total	Total		564.59			31,496.58	335.07	136.50	1,036.16	183.71			31,496.58			6.83	2,970.51	163.19	3,317.41	2,281.25	151.11	4,284.59

According to the above-mentioned results;

- Cost competitiveness of geothermal project against natural gas power project depends on the price of the natural gas. If the price of the gas is within a range of 10-15 USD/MMBTU, the geothermal plant in certain fields has cost competitiveness.
- Geothermal project in any fields has less cost competitiveness against coal power project. It is because the price of coal is comparatively cheap. However, it should be noted that coal power plant exhausts large amounts of CO_2 and has an impact on the global environment to some extent.
- Geothermal project in many fields has cost competitive against diesel power project. This shows the possibility that the geothermal plants can alternate diesel power plants as the power sources in the remote independent system.

This calculation shows the benefits of geothermal energy. Table-II-1.1.6 shows the cost difference between the case where a 150 MW geothermal power plant is built in Filed-A and the case where a natural gas power plant with same capacity is to be built in some area instead of the geothermal plant. According to this comparison, it is understood that the society can obtain the cost saving of USD 2,281 million by the geothermal plant through the construction and the 30 year-operation period. This cost saving turns to be USD 151 million in terms of net present value when converted by the social discount rate of 12%. This amount can be expressed as 3.53 US cent/kWh when divided by the total amount of the electricity produced by the geothermal plant[1].

(3) Increase of Tax Income

Geothermal projects need a large up-front investment and a long development time period. This characteristic greatly influences the amount of the tax payment from the geothermal generation business. Table II-1.1.7 and Fig. II-1.1.25 show the composition of the selling price of the electricity supplied by geothermal plant and natural gas power plant (NGCC). The geothermal is the case of project in Field-A and the natural gas is the case with a gas price of 12 USD/MMBTU. According to this calculations, the tax payment and royalty from geothermal project is 1.6 US cent/kWh and accounts for 15.2% of the selling price of 10.5 US cent/kWh. On the other hand, the tax payment from natural gas power project is 0.5 US cent/kWh and accounts for only 3.9% of the selling price of 12.9 US cent/kWh. There is the great difference in the tax payment of 1.1 US cent/kWh between the two projects.

Table II-1.1.7 Composition of the selling price of geothermal and natural gas power projects

Cost Item	Geothermal PP		NGCC PP	
	(Cents/kWh)	(%)	(Cents/kWh)	(%)
Initial Capital Cost	4.1	(39.1%)	1.4	(10.9%)
Additional Capital Cost	0.3	(3.3%)	-	-
Fuel Cost	-	-	9.4	(73.0%)
O&M Cost	1.1	(10.5%)	0.5	(4.1%)
Interest	0.9	(8.6%)	0.3	(2.3%)
Tax	1.5	(14.2%)	0.5	(3.9%)
Royalty	0.1	(1.0%)	-	-
Return for Investment	2.5	(23.3%)	0.7	(5.7%)
TOTAL (Selling Price)	10.5	(100.0%)	12.9	(100.0%)

1 The electricity production is also converted to the net present value using 12% discount rate.

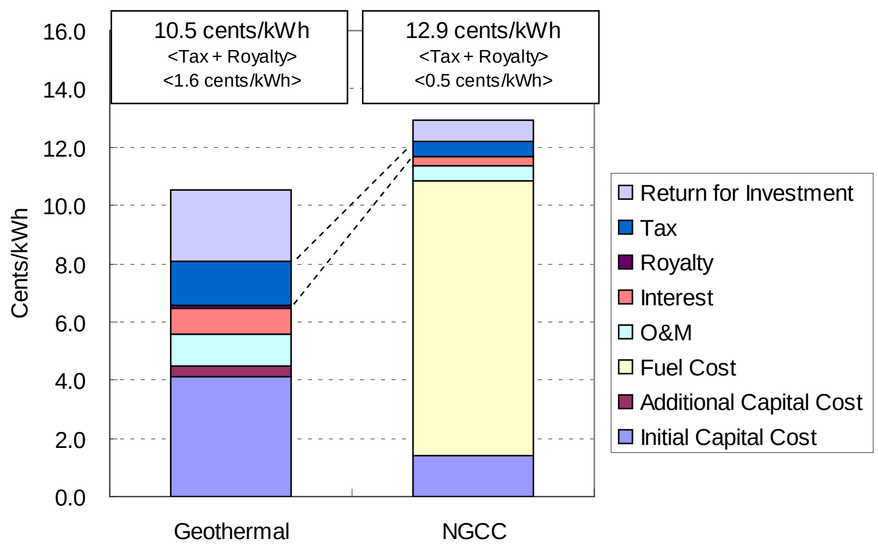


Fig. II-1.1.25 Composition of the selling price of geothermal and natural gas power projects

The less tax load of natural gas power project is due to the fact that the fuel expense which is the main cost factor of natural gas generation can be treated as a cost and can be subtracted from the sales profit. On the other hand, the investment return of geothermal project, which corresponds to the fuel cost of natural gas generation and is the main cost factor, is treated as profit in business operation. Therefore it is taxed and the tax amount becomes large in geothermal project compared with a same sale natural gas project. In this respect, California Energy Commission (1996) also reports that the tax load of geothermal projects is 2.8 times heavier than that of the alternative thermal power projects.

The phenomenon that the tax load of geothermal project is higher than that of alternative natural gas project means that geothermal project can bring benefit of tax increase for the government. If geothermal plant were constructed instead of natural gas power plant, the government would be able to obtain more tax income. Although the government can use this tax income for any fiscal expenditure, it is highly desired that the government should decrease the tax ratio from geothermal business or use this tax benefit for the various incentives to promote geothermal energy development in Peru.

The incentives to promote geothermal energy development need their costs. However, if these incentive costs are less than the tax income increase, the net government benefit remains plus. Even if the net governmental benefit becomes minus when incentive costs become large, the incentives might be justified when the other social benefits of geothermal energy, including the benefit of fuel saving and environmental quality improvement, is taken into the consideration.

II-1.1.4 Target of Geothermal Power Development

As described in previous sections, the total resource potential in Peru can be approximately estimated to be 2,860 MW reserved in 61 geothermal fields, according to the results of the Master Plan study. In addition, a development of 735 MW electric power in total could be possible in the 13 geothermal fields that were selected as promising fields in this study. The evaluation results of national resource potential and development strategies proved that Peru is endowed with abundant geothermal resources. Moreover, since the geothermal developments in Peru will bring plenty national benefits including natural gas saving and others as described above, successful utilizations of geothermal energy as a renewable energy source is strongly desired.

The expectation to the growth of geothermal power generation is getting increased all over the world. According to the outlook for the power supply by geothermal energy forecasted by the International Energy Agency (IEA) in 2011, a worldwide growth of geothermal energy developments are expected in the coming decades (Fig. II-1.1.26).

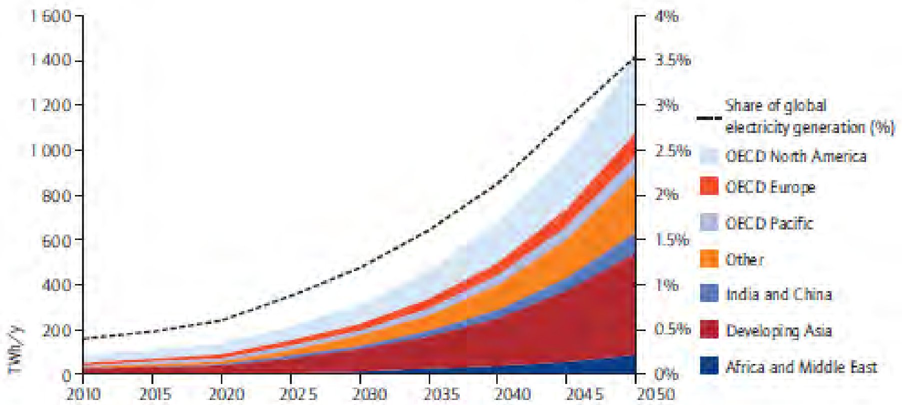


Fig. II-1.1.26 Outlook of world's power supply by geothermal resources

The concrete numeric target for power developments by renewable energies including geothermal resources has not been decided yet since "the National Plan for Renewable Energies" has not been formulated and is not open to public. However, the law for promoting power generation by renewable energies states that the power purchase with fixed price is guaranteed for up to 5% of total power demand (excluding hydro/micro-hydro power generations), and this could be regarded as the practical target for power generation by renewable energies. If the target for renewable energy power generation will be remained unchanged as 5% of the total power demand, it can be expected from the bidding results for renewable energy projects that the power generation by various renewable energies other than geothermal will cover the targeted amount of power demand (Fig. II-1.1.27). Thus it is desirable to increase the numeric target of power generation by renewable energies in future.

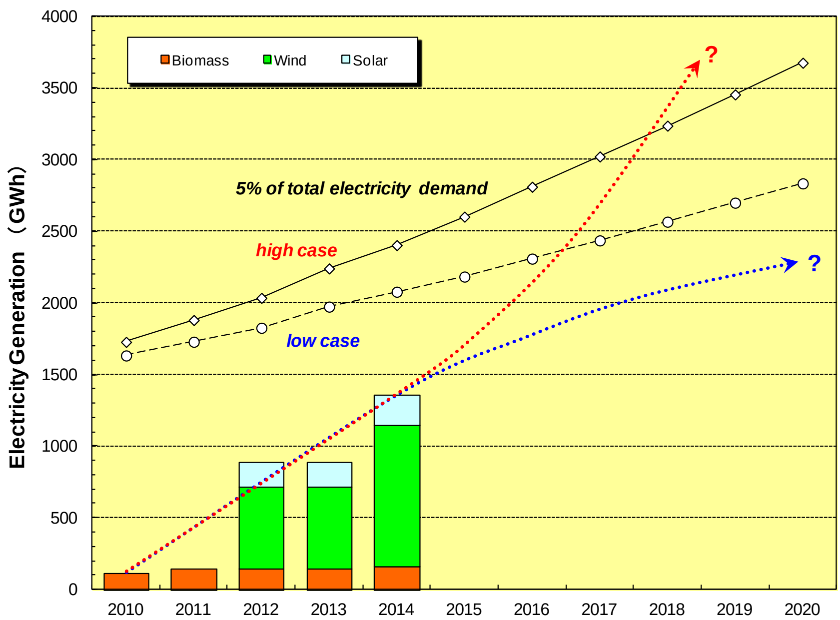


Fig. II-1.1.27 Prediction of growth in power generation by renewable energies other than geothermal

It is desirable to increase the target power generation by renewable energies to be 10% of the total electricity demand. The amount of the target power generation will be revised in every five years, and the next revision will be made on 2014. Thus it is expected to increase the target amount of power generation to be increased to 10% of total electricity demand in 2014. In the Republic of Chile, the neighboring country, a target goal was determined so that the amount of power generation by non-conventional renewable energies to achieve 10% of national power demand, by the year of 2024.

It is desirable to set the target goal of the power output by geothermal energy to be 50% of power generation by renewable energies, that is, the goal should be set as to supply 5% of total national power demand by geothermal energy. In this case, forecasting the growth of demand according to an optimistic scenario, and assuming the load factor of a geothermal power plant to be 85%, the target of power generation capacity by geothermal energy in 2030 will be 1,000 MW. This numeric target of development, that is, to newly develop 1,000 MW in the coming 18 years, is not impractical, considering that the total resource potential in 13 promising fields is 735 MW as previously described, and considering that there are other fields to be exploited in the near future.

➩ It is longed for geothermal resources to be developed as much as possible for power generation and other heat utilization purposes, as indigenous energy resources in Peru. The development will be started with resource exploration and will take rather long time. However, to develop 1,000 MW geothermal power by 2030 is desired from the viewpoint of mid/long-term energy mix strategy.

II-1.2 Legal and Organization Framework for Geothermal Power Development

II-1.2.1 Recommendations on Legal Framework

(1) Organic Law of Geothermal Resources

In Peru, there exists the Organic Law of Geothermal Resources and its Regulation, which establish the framework for the promotion of geothermal development by the private sector. Under this framework, a number of requests for exploration right (authorization) have been requested. However, the grant of authorization by MEM is just beginning and most of them are still in the process of evaluation. Therefore, it is still early to judge how effectively this legal framework may promote the geothermal development principally by the private sector. Currently, the authorization holders have the mandatory payment of small right fee of ever year as prescribed by the Article 62 of the Regulation of the Organic Law of Geothermal Resources. And in case of that the authorization holders do not advance their activities as planned, the guarantee (5% of the budget) presented by them for the phase II of exploration period will be executed as prescribed in the Article 17 of the Regulation of the Organic Law of Geothermal Resources. However, for the phase I for the exploration period, there is no penalty even though the authorization holders do not proceed their activities as planned. Therefore, if the authorization holders consider difficult to develop the project as private business, it may happen the case that they don’t develop the fields but keep holding the authorizations. If this situation occurs in practice, it requires for the MEM to strengthen their supervision on whether or not the exploration activities are being proceeded as planned.

On the other hand, if the authorization holders cannot proceed their exploration activities due to the high risks on resources, it is recommend that the governmental institution or other state-own enterprises participate on the exploration activities. In such case, the options such as the drilling by the public entity or the project implementation through the Public-Private Partnership should be considered.

(2) Law for Electricity Generation with Renewable Energies

This Master Plan study recommends the realization of the renewable energy resources auctions for geothermal generation projects in accordance with the law for electricity generation with renewable energies. However, in Peru, geothermal development is still in the phase of exploration, and so, the auctions for geothermal power generation have not been realized yet. In case of other renewable energy resources projects, since the development period is short, comparing to the geothermal projects, it is not required to get the concession right to participate on the auctions. However, in case of geothermal projects, it takes a long period for development, some measures should be considered to secure the power generation within certain years after the awarding. For example, to get the concession right must be a precondition for the participation on the auctions.

On the other hand, in the renewable energy resources auctions, the bid price must include the investment cost for transmission lines necessary for the connection to SEIN. However, in case of geothermal generation, the installed capacity is generally much larger than other renewable energy resources generation and most of geothermal potential is concentrated in the same area of southern part of the country. Therefore, it is not realistic either economically or technically for each geothermal developer has to construct their transmission line to be connected to the systems. So, in case of geothermal power generation projects, the investment for transmission lines should be considered separately from the bid price for the renewable energy resources auctions, and the law for electricity generation with renewable energies should be modified accordingly.

Finally, according to the Article 11 of the law, the MEM would elaborate the National Plan of Renewable Energies. However, it has not been announced up to now. The elaboration of this plan is essential in order for the country to achieve the best mix of electricity generation sources. Furthermore, the composition of renewable energy resources sources in the auctions in the future will take into account this plan. In this sense, it is very important to incorporate the result of this Master Plan to the National Plan of Renewable Energies.

- Any major problem does not been identified in the present legal and regulatory framework for geothermal development. However, in case of that it is revealed that the geothermal resource development only by the private sector is difficult, it is recommended to review and modify accordingly the related laws. The possibility of participation of the government or the public company for exploration stage and construction stage must be evaluated in order to reduce the resource risks and the investment burden for the private sector.

II-1.2.2 Development System and Organization

It is expected that the power utility business in Peru will primarily evolve under private initiatives. In principle, so will be the geothermal development once it acquires certain momentum. Though it may follow such development path, those government bodies under DGE which are responsible for the power sector policy and the supervision of IPP must retain and develop wide range of technical experts related to the geothermal technology, including the legal and economical issues, so that they will be able to enact appropriate policies on the geothermal concession, to determine proper price level under FIT system or to provide proper supervision and guidance on the private developers during each stage of their activities such as exploration study, plant construction and its operation. Proper capacity building will not be realized if it consists of just sending bright young engineers to overseas training course. They need to go through actual projects in order to accumulate experiences. As the experts in the supervising organization gain more experience and knowledge in the geothermal technology, they shall bring more benefits to the country since they are capable to implement better judgment, policy and control on the development and use of the geothermal resource which is one of the precious assets of this country.

In the past, there have been some attempts initiated by several government agencies as they tried to exchange information with the others or even tried to form alliances between them by setting up geothermal committees or some other way. But in order to deal with the actual issues they face during geothermal development, it will be necessary to reinforce mutual coordination and network among those organizations. Furthermore the implementation of the policies proposed under this geothermal Master Plan requires extensive use of the database developed under this study, which consequently asks for establishing an appropriate structure in terms of the operation of the databases, for its effective utilization as well as for the rigorous implementation of the data update in order to maintain its usefulness.

As more fundamental issues to be addressed before discussing future prospect, private developers have to face difficult business decision when embarking geothermal project, as it requires high initial investment cost such as for drilling geothermal wells and for constructing fluid system on top of the power plant construction, while resource risk is not eliminated. Consequently the development tends to get longer as it has to accumulate detail knowledge of the field in order to mitigate the project risk. It will not be easy to attract private investors for geothermal project, even if lucrative return on investment is offered for the purpose of promoting their appetite.

Because geothermal development depends on exploration of underground resources, development involves various risks. For example, development difficulties due to the geographical characteristics of the explored field easily lead to cost overruns in development. Other cost overruns may occur, depending on the success rate of exploration wells, the depth of the reservoir, the steam productivity of the reservoir, the chemical characteristics of the geothermal fluid, the amount of non-condensable gas in the steam, and so on. Additionally, even in the operating stage, performance may be reduced due to a decline in steam production and increase in the numbers of necessary make-up wells and so on. The factors determining these cost overruns cannot be predicted during the desk planning stage, and can only be found as a result of actual development.

For example, Fig. II-1.2.1 shows the distribution of production well depths for geothermal power plants in Japan, and Fig II-1.2.2 shows the distribution of average steam productivity per single production well. The depth of production wells and the average production capacity are critical values in the design of a geothermal power plant, and business profitability depends largely on these values. Both Figs II-1.2.1 and II-1.2.2 show that these numbers are never the same for different geothermal power plant sites. Design of a geothermal power plant involves many unknown factors in addition to these values on which profitability largely depends, and the fate of a geothermal generation project depends on these factors, which become clear only after actual field development is completed.

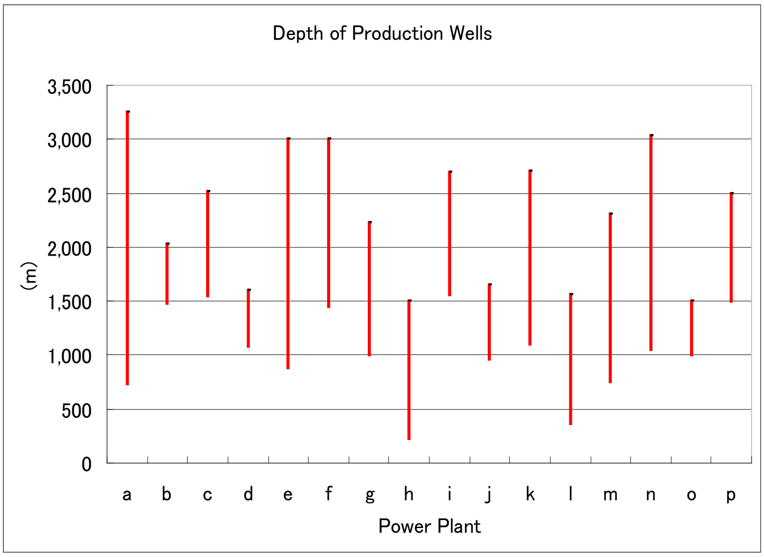


Fig. II-1.2.1 Distribution of production well depth of geothermal power plants in Japan
(Source: "Geothermal Development Master Plan Study in Indonesia" JICA, 2009)

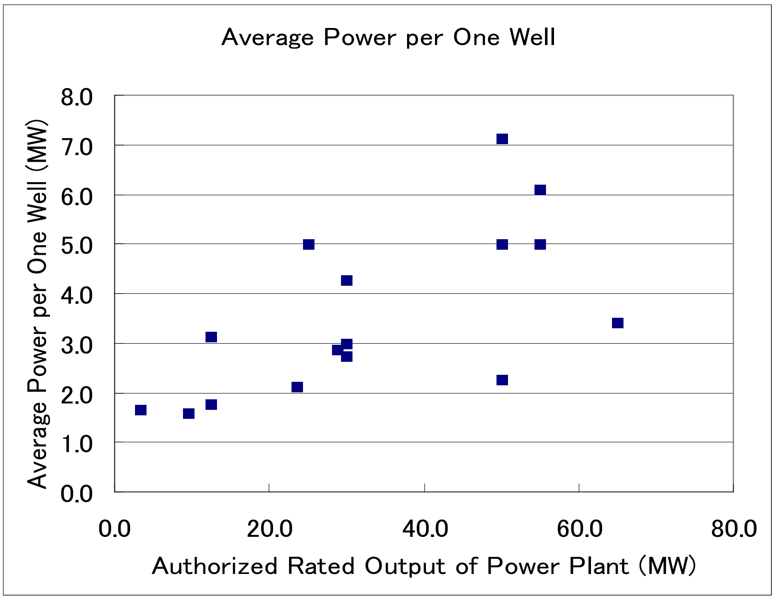


Fig. II-1.2.2 Distribution of productivity of geothermal power plants in Japan
(Source: "Geothermal Development Master Plan Study in Indonesia" JICA, 2009)

Under such circumstances, those developing countries which have been successfully introduced geothermal power plants, at least during the initial stages, opted a way that their public instruments undertook the projects, because they could absorb larger resource risk and they could utilize financial aid from bilateral and multilateral donors, thus the development cost can be reduced.（Refer to Table II-1.2.1）. During the early stage of the geothermal development in these countries, they also faced mounting problems including those for confirming resource quality and those on capacity building. Even after the construction of the first pilot plant, things did not go smoothly as they were encountered by numerous problems. In a way, these experiences showed difficulty of geothermal development, which makes private investors hesitating from entering green field development and in return proves the necessity for involvement of the public instruments. In case of Peru, as public entities which could undertake geothermal development are the state owned companies such as, 1), INGMMET which has accumulated long experience in the geothermal study, 2), Perupetro S.A. which has knowledge on the drilling sector which also plays important role in geothermal development, 3), Electroperú S.A. which was in past engaged in the geothermal study and can handle downstream side of the project. They could be reinforced with help from Universidad Nacional de Ingeneria when it comes to the technology pertaining to the geothermal power plant.

Table II-1.2.1 Examples of geothermal development promoted by government-owned entities

Country	Resource development / Steam supply	Power Plant	Project examples / Remarks
Indonesia	PGE (PERTAMINA Geothermal Energy)	PLN	Kamojang : 200MW, Lahendong : 60MW As to Kamojang unit 4, PGE undertakes both resource development and power plant operation.
Philippines	PNOC-EDC (Philippines National Oil Company-Energy Development Company)	NAPCOR	Bac-Man : 150MW, Mindanao : 106MW Northern Negros : 49MW Southern Negros : 192.5MW Leyte : 700.9MW PNOC-EDC was privatized and sold in 2007. NPC has been selling its assets upon the enactment of Electric Power Industry Reform Act in 2001.
Turkey	MTA (General Directorate of Mineral Research & Exploration)	TEAS (Turkey's Electricity Generating & Transmission Corporation)	Kizildere : 20MW Kizildere GPP was later sold to a private company as the power generation sector is now under IPP market. The private geothermal developers have been very active in recent years. MTA, however, retains strong influence as they are given special status on the concession right and also undertake geothermal exploration for private developers.
Mexico	CFE (La Comisión Federal de Electricidad)	CFE	CerroPrieto:720MW LosAzufres:188MW LosHumeros:35MW LasTresVirogenes:10MW
Costa Rica	ICE (Corporativo del Instituto Costarricense de Electricidad)	ICE	Miravalles : 133MW Las Pailas : 35MW Government-owned power electric corporation which covers 80% of generation and monopolies transmission/distribution of the country.
El Salvador	LaGeo	LaGeo	Berlin : 100MW, Ahuachapan : 95MW When Berlin III was developed, Italy's ENEL acquired 20% of La Geo share.
Kenya	KENGEN	KENGEN	Olkaria I,II and IV, total 127MW Regarded as having least power development cost, development priority on geothermal is fueling rapid growth. State owned GDC was created which is responsible for the resource development and the steam supply with an intention that the state takes care of upstream sector while private developers take care of the downstream sector. Meanwhile privatization of KenGen is ongoing as they had IPO in 2006.

As geothermal development initiated by the public sector achieves success, it is expected that experience on the unique technical conditions pertaining to Peruvian environment such as those caused by high altitude (low atmospheric pressure and temperature) accumulates and a group of experts in this technology develops, which should enhance capacity of the governmental organizations who are responsible for supervising, controlling and advising the private developers as well as for setting the development policy.

➮ It is desirable that, while the governmental organizations such as DGE and INGEMMET streamlines their organizations and promote capacity building in order to promote geothermal energy, the others expected to be involved directly such as Electroperú S.A. should start building geothermal task team in their organizations.

II-1.3 Recommendations on Assistance and Incentives for Promotion of Geothermal Development

II-1.3.1 Feed in Tariff (FIT) System

As mentioned in Section I-3.2, the current legislation in Peru gives the incentive of "Feed-In-Tariff" to the private companies selected through the tender process to develop renewable energy resources for power generation, including geothermal energy. Under this system, it is important for the government to determine the Base Price at reasonably high level to motivate the private companies to invest for the power generation projects with renewable energy sources.

Figure II-1.3.1 shows the price level for FIT systems for geothermal power generation in other countries. In many cases it is around 10 US cent/kWh. However, there are some countries where the price for geothermal power generation is set above 15 US cent/kWh.

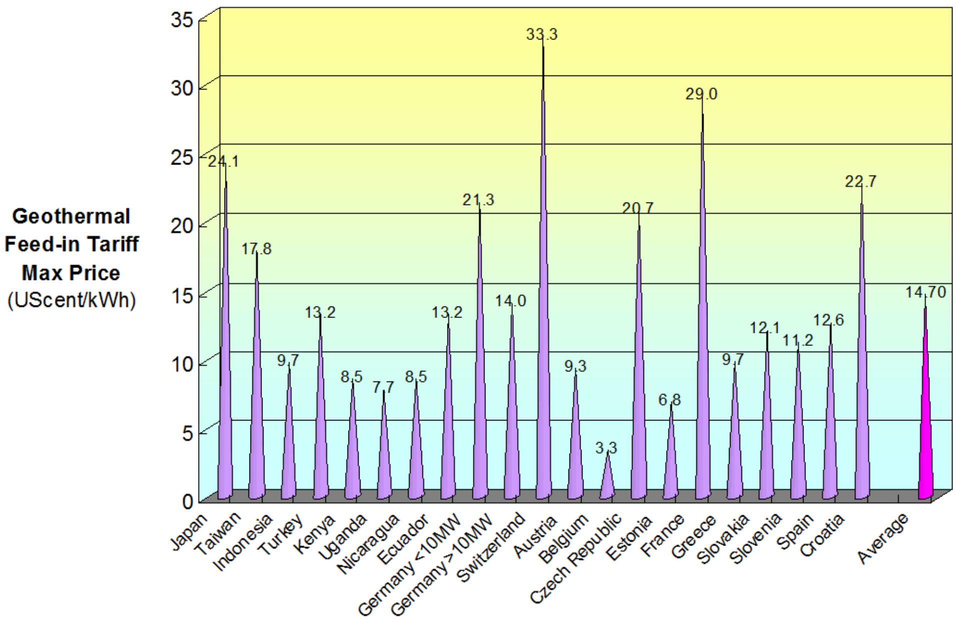


Fig. II-1.3.1 Price for FIT of geothermal power generation in the world (maximum price)

However, the cost to sustain the FIT system (premium to cover the difference between the fixed price and the market price) is borne by the users as the tariffs for electricity consumption. Thus, the higher the price level of FIT becomes, the burden to the consumers becomes larger.

Therefore, it is desirable for the government to provide some additional support for the promotion of geothermal development other than the current FIT system so that the direct impact on the electricity tariff for consumers can become relatively small.

➮ To promote geothermal development through the current FIT system inducing the private investments, it is desirable to set the base price as high as possible. However, it means that the impact on electricity tariff for consumers may become significant. To avoid that, it is desirable to implement other means of assistance and incentives.

II-1.3.2 Financial Support, Tax Incentive and Fiscal Assistance

(1) Financial Support (low-interest loans for construction costs)

The main characteristic of geothermal power generation are its relatively large initial investment cost compared to thermal power generation cost and its long lead-time for development. Thus, the loan interest for the initial investment has a significant impact on the electricity selling price. Figure II-1.3.2 shows the impact of loan interest on electricity selling price for the natural gas-fired power generation and geothermal power generation, with the assumption of that 70% of the investment cost would be financed by loan. In this case, the project assumed for the geothermal power generation is the one in the Field-A and as for the natural gas-fired power generation, the assumed natural gas price is 10 USD/MMBTU. As the figure shows, in the case of the natural gas-fired power generation, the impact of interest rate of loan for the construction costs on electricity selling price is not significant. This is because the initial investment cost is relatively small for the natural gas-fired power generation project, and most of its generation cost comes from the fuel costs. In contrast, geothermal power generation project requires a large initial investment, in which the impact of loan interest for the construction costs on electricity tariff is significant. It means that if the low interest financing is provided for the geothermal power generation project, electricity price may lower significantly comparing to the case of financing with the normal interest rate. In this sense, the financial support for geothermal development may bring a significant effect.

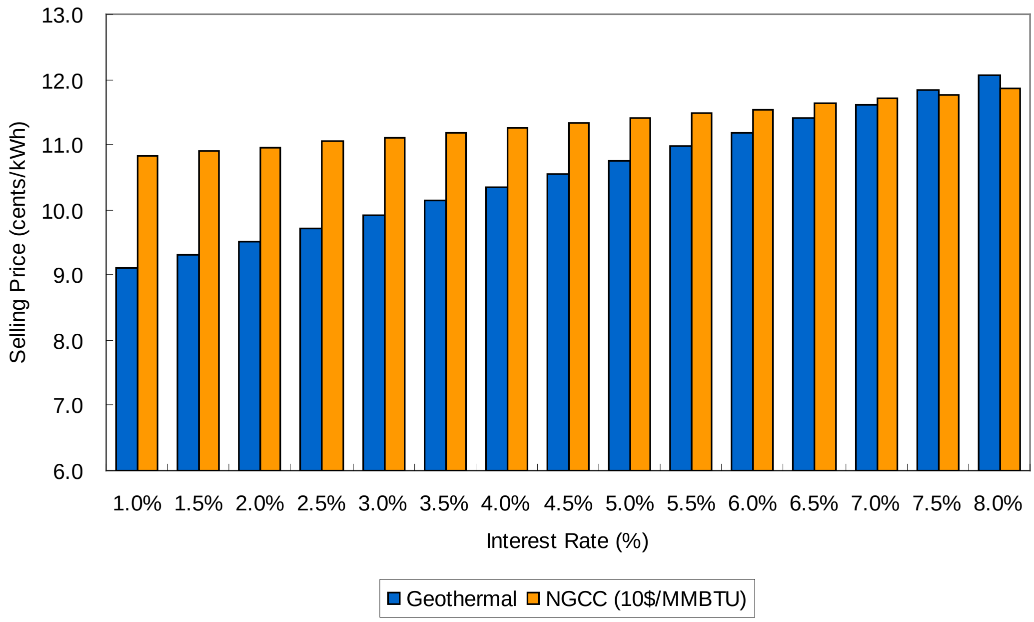


Fig. II-1.3.2 Impact of low interest loan for the construction costs on electricity selling price (comparison between a natural gas-fired thermal project and a geothermal project)

In the economic evaluation conducted for the promising geothermal projects, the following conditions are assumed; 70% of construction costs are financed with a loan on conditions of 4.5% of interest rate, 3 years of grace period, 12 years of repayment period (15 years of loan period). The electricity price of 10.5 US cent/kWh for the Field-A project is calculated under these conditions. The calculations of electricity price on the different financial conditions for the same field are also conducted, in the interest rate is decreased down to 1.0% with 3 years of grace period and 17 years of repayment period (20 years of loan period). Table II-1.3.1 and Fig. II-1.3.3 shows the results of these calculations.

Table II-1.3.1 Effect of low-interest financing for construction costs on reduction of electricity selling price

Case	Steam Dev. Section Interest Rate (%)	Steam Dev. Section Loan Period (yrs)	Power Plant Section Interest Rate (%)	Power Plant Section Loan Period (yrs)	Const. Cost ($/kW)	Selling Price (cents/kWh)	Effect (cents/kWh)	Incentive Cost (cents/kWh)
Base Case	4.5%	12	4.5%	12	3,940	10.5	-	-
IPP-1	4.0%	12	4.0%	12	3,920	10.3	▲ 0.2	0.14
IPP-2	3.5%	12	3.5%	12	3,900	10.1	▲ 0.4	0.28
IPP-3	3.0%	12	3.0%	12	3,880	9.9	▲ 0.6	0.41
IPP-4	2.5%	12	2.5%	12	3,860	9.7	▲ 0.8	0.54
IPP-5	2.0%	12	2.0%	12	3,840	9.5	▲ 1.0	0.68
IPP-6	1.5%	12	1.5%	12	3,820	9.3	▲ 1.2	0.80
IPP-7	1.0%	12	1.0%	12	3,800	9.1	▲ 1.4	0.93
IPP-8	4.5%	17	4.5%	17	3,940	10.5	▲ 0.0	▲ 0.17
IPP-9	4.0%	17	4.0%	17	3,920	10.3	▲ 0.3	▲ 0.01
IPP-10	3.5%	17	3.5%	17	3,900	10.1	▲ 0.5	0.15
IPP-11	3.0%	17	3.0%	17	3,880	9.9	▲ 0.7	0.30
IPP-12	2.5%	17	2.5%	17	3,860	9.7	▲ 0.9	0.45
IPP-13	2.0%	17	2.0%	17	3,840	9.5	▲ 1.1	0.60
IPP-14	1.5%	17	1.5%	17	3,820	9.3	▲ 1.2	0.75
IPP-15	1.0%	17	1.0%	17	3,800	9.1	▲ 1.4	0.90

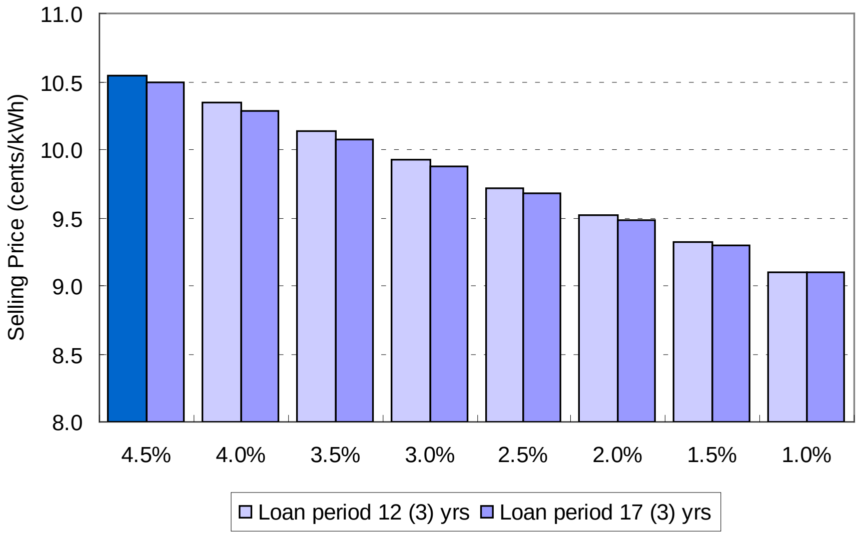


Fig. II-1.3.3 Effect of low-interest financing for construction costs on reduction of electricity selling price

According to the results of those calculations, the effect of low-interest financing for the construction costs on electricity price is large. For example, when the loan with the interest rate of 2.0% is provided, the electricity price decreases by 1.0 US cent/kWh (9.7% reduction). Also, the extension of loan period can, even slightly, contribute to the reduction of electricity price.

When the loan with preferential interest is provided to the private companies, its cost will be borne by the financial institutions (the government). Here we assume two [2] values, (A) the present value of interest rate to be repaid by the developer financed by a loan without a preferential interest rate, and (B) the present value of interest rate to be repaid by the developer financed by a loan with a preferential interest rate. When the difference (A-B) is divided by the amount of power generated during 30 years, it can be considered as the cost per kWh of this financial support[3]. Table II-1.3.1 also shows the cost of support in each case. In case of the 2.0% interest rate with the repayment period of 17 years (Case IPP-13), the electricity price can reduce by 1.1 US cent/kWh (10.1% reduction), while the financial cost for this remain in 0.6 US cent/kWh.

2 Converted to the net present value using 12% discount rate.

3 The generated power energy is also converted to the net present value using 12% discount rate.

Consequently, if financial assistance for geothermal power generation is provided in Peru, it is recommended to establish a scheme in which the governmental financial institution such as COFIDE (Corporación Financiera de Desarrollo, SA) provides the Two Step Loan (TSL) etc. to the private sector, utilizing the low-interest financings such as ODA loans.

(2) Tax Incentive

Due to the fact that geothermal power generation does not require the expenses for fuel but the large initial capital investment, the tax burden of geothermal power generation is large compared to thermal power generation. Therefore, a measure to reduce this burden for geothermal energy power generation through tax incentives can be a powerful measure to promote geothermal development.

As an example, the impact on required electricity selling price for a project in the Field-A is calculated by applying various tax incentives in place of the current tax rate of 30%. The results are shown in Table II-1.3.2 and Fig. II-1.3.4. In case of tax holiday, the tax holiday for 5 years brings little effect on the reduction of selling price. This is because the most of this period (5 years) is in the deficit, thus the amount of tax is small. In case of 10 years of tax holiday, the selling price declines to 9.9 US cent/kWh (reduction of 0.7 US cent/kWh or 6.3%).

Table II-1.3.2 Impact of tax incentives on the reduction of electricity selling price

Case	Tax Rate (%)	Tax Holidays (yrs)	Const. Cost ($/kW)	Selling Price (cents/kWh)	Effect (cents/kWh)	Tax (cents/kWh)	Incentive Cost (cents/kWh)
Base Case	30%	0	3,940	10.5	-	1.9	-
T-1	30%	5	3,940	10.5	0.0	1.6	0.00
T-2	30%	7	3,940	10.2	▲ 0.3	1.3	0.23
T-3	30%	10	3,940	9.9	▲ 0.7	1.0	0.51
T-4	30%	12	3,940	9.7	▲ 0.8	0.8	0.65
T-5	30%	15	3,940	9.5	▲ 1.0	0.6	0.80
T-6	25%	0	3,940	10.3	▲ 0.3	1.3	0.21
T-7	20%	0	3,940	10.0	▲ 0.5	1.1	0.41
T-8	15%	0	3,940	9.8	▲ 0.7	0.9	0.60
T-9	10%	0	3,940	9.6	▲ 1.0	0.6	0.77
T-10	5%	0	3,940	9.4	▲ 1.2	0.4	0.94
T-11	0%	0	3,940	9.2	▲ 1.4	0.2	1.10

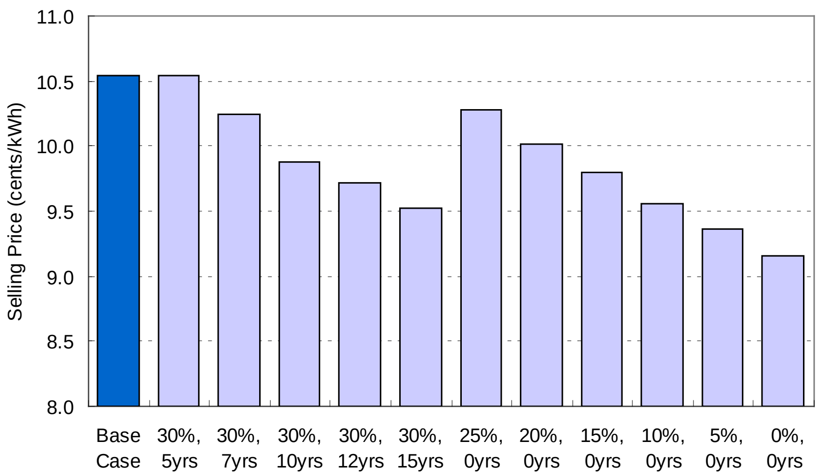


Fig. II-1.3.4 Impact of tax incentives on the reduction of electricity selling price

For natural gas-fired power generation, tax amount is about 0.6 US cent/kWh. In order that the tax burden of geothermal power generation could be equal to the one of natural gas-fired power generation, it is required to implement tax holiday for 15 years, maintaining the current tax rate (Case T-5) or to reduce the tax rate to 10% without tax holiday (Case T-9). In this case, the selling price results in 9.5 US cent/kWh (Case T-5) or 9.6 US cent/kWh (Case T-9), which means the price reduction of around 1.0 US cent/kWh.

Furthermore, it is possible to combine the financial support described above with tax incentives. Table II-1.3.3 and Fig. II-1.3.5 show the calculation result of the impact in electricity selling price of geothermal project in the Field-A by the simultaneous application of financial assistance of the loan with 2.0% of interest for construction, 3 years of grace period and 17 years of repayment period (20 years of loan period) and tax holiday during 10 years. According to this calculation, electricity selling price declines to 8.9 US cent/kWh (reduction of 1.7 US cent/kWh or 15.7%).

Table II-1.3.3 Impact of the simultaneous application of financial assistance and tax incentives on electricity selling price

Case	Financial Incentive		Tax Holiday	Const. Cost	Selling Price	Effect	Incentive Cost
	Interest Rate (%)	Loan Period (yrs)	(years)	($/kW)	(cents/kWh)	(cents/kWh)	(cents/kWh)
Base Case	4.5%	12	0	3,940	10.5	-	-
Financial Incentive (r=2%)	2.0%	17	0	3,840	9.5	▲ 1.1	0.60
Tax Incentive (T.H=10yrs)	2.0%	17	10	3,840	8.9	▲ 1.7	1.08

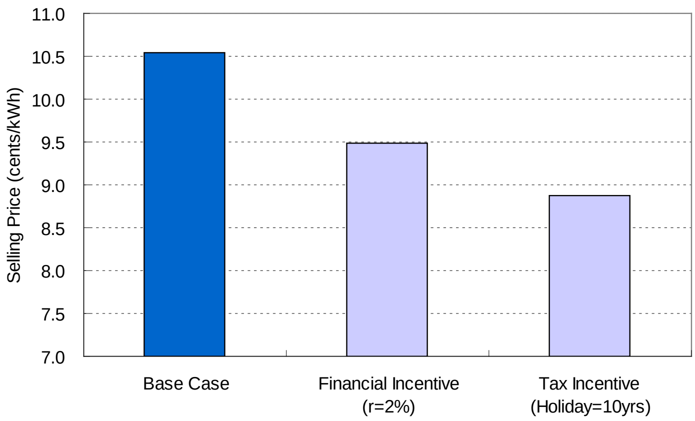


Fig. II-1.3.5 Impact of the simultaneous application of financial assistance and tax incentives on electricity selling price

From the above, to promote the geothermal development, the application of the combined measures of financial assistance described above and the tax incentives such as tax holiday for around 10 years.

Many countries have adopted tax incentives for renewable energy development. For example, the government of USA has the Production Tax Credit (PTC) scheme. In 1992, the government of USA enacted the “Energy Policy Act”. By this act, when power is generated from wind or biomass, a “Production Tax Credit” of 1.5 US cents per kWh counts toward corporate taxes for 10 years. This tax credit is adjusted for inflation. This scheme expired in 1999, but has been revived several times since[4], and the latest tax credit for geothermal energy is 2.2 US cent/kWh for 10 years.

[4] EIA Report *Non-hydraulic renewable energies promotion policy in USA and major countries* (Feb., 2005)

Countries other than USA also have a tax incentive system for renewable energy. For example, in Guatemala the corporate tax rate is 31%, but it has been the case since 2003 that renewable energy development can enjoy a tax exemption for 10 years. In Nicaragua, an exemption from the 30% corporate tax has been granted for 7 years for renewable energy development. In Panama as well, from 2004, corporate tax is exempted up to a total of 25% of total investment for renewable energy power plants of less than 20 MW. In Asia, the Philippines enacted the Renewable Energy Act in December 2008, and introduced this kind of tax credit system to promote renewable energy.

(3) Fiscal Assistance

Term “fiscal assistance” is used in a narrow sense and refers to direct government expenditure. In other words, government can provide subsidies for renewable energy developers and reduce their up-front investment burden to promote renewable energies. Also the government itself can carry out some activities to promote renewable energies, such as a nation-wide survey of the geothermal energy inventory. Many countries provide this kind of fiscal assistance.

In case of Peru, one example of this kind of fiscal assistance may be the construction of transmission line by the government. If each private geothermal developer has to construct the transmission line independently to connect the geothermal power plant to the national grid, it may cause the double investment or congestion in the transmission. From the viewpoint of national economy as a whole, it is not efficient. To avoid such an economic inefficiency, it is recommended that the government will be in charge of constructing the transmission line in the geothermal potential area, based on the geothermal development plan of the private developers, based on the advance promising geothermal areas. In that way, the government can assist and promote the geothermal power generation by the private sector.

Table II-1.3.4 shows the effect of the fiscal assistance for the project in Field-A, by which the transmission line is constructed by the government. Since the investment in transmission lines is not large compared to the investment in resource development and power generation, the effect of such incentive is limited. However, the construction of transmission lines by the government is significant in terms of that it can prevent the overlapping investment. However, in the actual law of electricity generation with renewable energy defines that the construction of transmission line for the connection with the existing grid is a responsibility of each IPP developer. Thus, the law should be modified accordingly so that the construction of the transmission line for geothermal power generation projects will be managed by the government.

Table II-1.3.4 Impact of the construction of transmission lines by the government on electricity selling price

Case	Land costs (M$)	T/L costs (M$)	Const. Cost ($/kW)	Selling Price (cents/kWh)	Effect (cents/kWh)	Incentive Cost (cents/kWh)
Base Case	0.28	9.31	3,940	10.5	-	-
Without T/L	0.0	0.0	3,870	10.4	▲ 0.2	0.10

The other form of fiscal incentive, which requires the further commitment of the government, is the direct participation of public company (state-owned enterprises) to geothermal development projects. There are principally two benefits on the participation of public company; one is the access to the concessional loan provided by the World Bank, the Inter American Development Bank, JICA, etc. As mentioned above, financial assistance at low interest rates bring relatively large effect. The other benefit is the accumulation and integration of knowledge and experience of geothermal development in the public company. Instead of relying on foreign companies for geothermal development, the creation of public entity, where knowledge and experience of geothermal development will be accumulated, can make it possible to develop geothermal resources increasingly in an economic and efficient manner.

Currently, in Peru there is no public entity which is able to implement geothermal resource development itself. However, if we assume that the state-owned generation company such as Electroperú can be the entity in charge of geothermal development, there may be two possible forms of participation;

(a) Joint development between private sector and Electroperú (Public Private Partnership)

Development through Public Private Partnership (PPP); Electroperú will be responsible for up-stream development (steam development) and the private sector will be responsible for down-stream development.

(b) Consistent development by Electroperú

Electroperú will be engaged in all the stages of geothermal development and power generation.

The participation of the public entity on geothermal development may reduce the resource risk of geothermal development. However, it is difficult to quantify such reduction. Instead, the effect of participation of public entity in geothermal development can be evaluated, assuming that such entity can access the concessional ODA loan. Table II-1.3.5 shows the impact on electricity selling price for two cases, (a) Electroperú develop geothermal resources, using the concessional loan (0.6% of interest, 10 years of grace period, 30 years of repayment period (40 years of loan period)) and the private company generates the electricity (a case of PPP), and (b) Electroperú is in charge of all the stages from resource development to power generation, using the concessional loan (a case of 'All Public'). The assumed project is the project in Field-A. Figure II-1.3.6 shows the effect of direct participation of public sector in geothermal development.

According to the results, in case of (a: PPP), the selling price is 9.9 US cent/kWh, which means decline of 0.7 US cent/kWh (6.5% reduction), compared to the case in which a private company is in charge of all the stages. In case of (b: All Public), the electricity price is 8.9 US cent/kWh, which means decline of 1.6 US cent/kWh (15.5% reduction), compared to the case in which a private company is in charge of all the stages. This is the effect of using low-interest financing.

Table II-1.3.5 Effect of the participation of the public company on geothermal development

Case	Steam Dev. Section		Power Plant Section		Const. Cost	Selling Price	Effect	Incentive Cost
	Interest Rate (%)	Loan Period (yrs)	Interest Rate (%)	Loan Period (yrs)	($/kW)	(cents/kWh)	(cents/kWh)	(cents/kWh)
Base Case	4.5%	12	4.5%	12	3,940	10.5	-	-
PPP	0.6%	30	4.5%	12	3,870	9.9	▲ 0.7	0.42
All Public	0.6%	30	0.6%	30	3,790	8.9	▲ 1.6	0.95

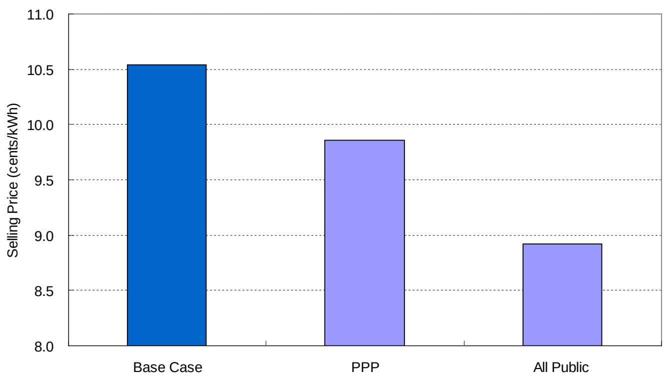


Fig. II-1.3.6 Effect of participation of the public company on geothermal development on electricity selling price

The good example of the PPP is Philippines' case. In Philippines, in the late 1990s the public company PNOC-EDC developed steam and then let the private companies generate electricity. In this case, since there was no risk taken by the private sector in steam development, many companies participated on generation, thus the country has made a significant progress on its use of geothermal energy.

Finally, the effect of public participation on geothermal resource exploration (including drilling of deep exploratory wells) is evaluated. This measure not only provides the fiscal incentive, but also contributes a lot to reduce the resource risk for private companies. As shown in Fig. II-1.3.7, this measure reduces the risk for the private sectors, but also contributes on (i) reduction of the exploration (well drilling) cost and (ii) reduction of lead-time for development. Therefore, it is also effective in reduction of electricity selling price.

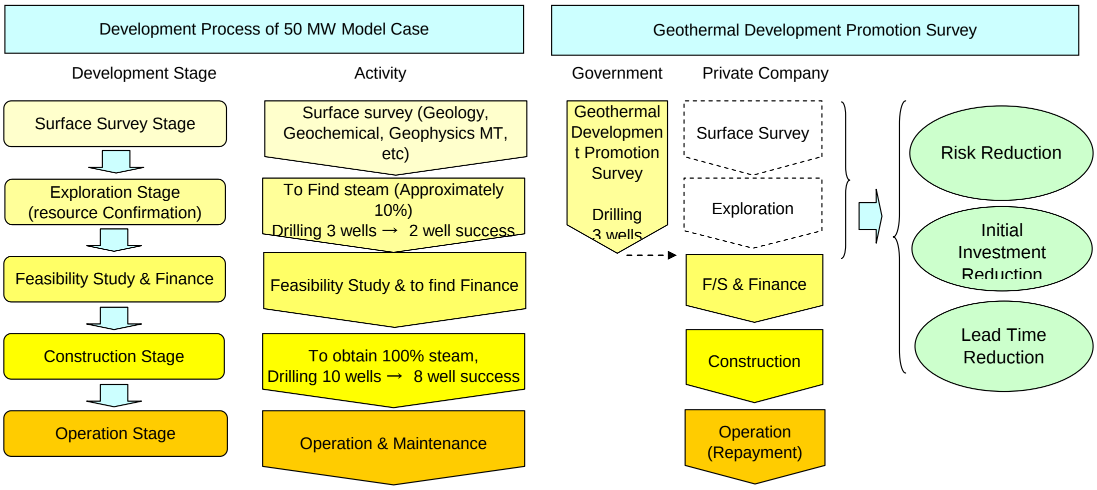


Fig. II-1.3.7 Effect of resource exploration by the government

The result of calculation of this effect in Field-A is shown in Table II-1.3.6 and Fig. II-1.3.8. If the government conducts the exploration study and drills three exploratory wells, the electricity selling price becomes 9.7 US cent/kWh, which means decline of 0.8 US cent/kWh (7.8% reduction), compared to the case of development only by the private sector. The cost for this measure is small enough at 0.25 US cent/kWh, which is calculated by dividing the initial investment cost by the amount of power generated during 30 years.

Table II-1.3.6 Effect of execution of resource exploration by the government

Case	Initial Survey Support (%)	Const. Cost ($/kW)	Selling Price (cents/kWh)	Effect (cents/kWh)	Incentive Cost (cents/kWh)
Base Case	0%	3,940	10.5	-	-
Gov't Survey	100%	3,770	9.7	▲ 0.8	0.25

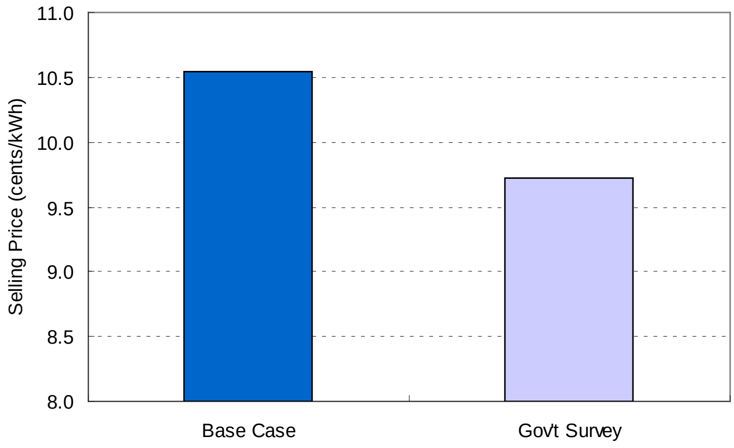


Fig. II-1.3.8 Effect of execution of resource exploration by the government on electricity selling price

- In case of geothermal development only by the private sector, it is recommended to provide them with the financial assistance through Two Step Loan to COFIDE, etc. , for example, utilizing the concessional loan. Additionally, tax incentives such as tax holiday can also work to promote geothermal development principally by the private sector.
- However, in many cases, the geothermal development only by the private sector is difficult. In such a case, it is recommended to evaluate, in early stage, the possibility of Public Private Partnership utilizing the ODA concessional loan for the portion of investment by the public company.
- It is desirable that the government conducts the resource exploration as a part of fiscal assistance. This contributes to reduce the resource risk, development cost and lead time for development for the private companies.

II-1.4 Environmental and Social Considerations Preservation for Geothermal Power Development

II-1.4.1 Issues of Organizational Capacity and Laws for Enforcement of Environmental and Social Considerations with respect to Geothermal Power Development Projects

(1) Implementation structure of Environmental Impact Assessment (EIA)

With no history of geothermal power development in Peru, the Directorate General of Energy Related Environmental Affairs (Dirección General de Asuntos Ambientales Energia: DGAAE), which is responsible for reviewing and approving EIAs for geothermal development, has no experience with EIAs for geothermal projects. In fact, nobody in the DGAAE has first-hand experience with EIAs in geothermal power generation projects. It is thus essential to educate and develop a human resource pool in the DGAAE that is qualified to evaluate and review EIAs for geothermal power generation projects.

(2) Environmental Impact Assessment system

Under the Peruvian Law of Electricity Concessions and Regulations (Law No. 25844), an EIA is required for power development projects with 20 MW or greater energy output capacity. In addition, though an EIA is required under the Law of Geothermal Resources (Law No. 26848) for the development of geothermal resources, the law provides no regulations or details. Since geothermal resource development precedes power plant planning, the situation urgently requires the preparation of guidelines for geothermal resource development, defining the scales of projects for which an EIA is required, full details of the scope to be covered in the EIA, and detailed process, contents and implementation methods for the EIA.

II-1.4.2 Issues for EIA of Geothermal Power Project

According to the past cases and experiences of problems in the process of EIA for hydropower development, the particular attention should be paid to the following in implementing the EIA for geothermal power development in Peru.

(1) Issues

- Most of the possible geothermal power development areas in Peru are located in a high mountain region with limited industry. The talk and implementation of such a project will generate high hopes with the local residents for increased job opportunities and improvements in their way of life.
- The project site is possibly located near a reserve or natural area with no human intervention. In such a case, the local residents and NGO groups may have concerns over impact on the natural environment.
- Since places of geothermal manifestation are often tourist attractions, the local residents and interested parties may have concerns over impact on tourism.

(2) Improvement Measures

- To disclose information to the local residents in each stage prior to, during and after the EIA survey, incorporate their requests, and present accurate and truthful information
- To prepare detailed documentation and give explanations to the local residents in terms that they can understand
- To prepare documents and make contacts with the local residents before beginning the field survey of the EIA to notify them in advance
- To check the contents of all documentation to ensure accuracy and no mistakes
- To build a good solid relationship with the local residents and win their trust
- To employ local residents
- To carry out the project to the final completion, and not to implement it for speculative purposes

II-1.4.3 Experience in the EIA Approval Process for Renewable Energy Projects

Renewable energy project that currently has its EIA under evaluation and which did not participate in the auction of renewable energy resources projects, is the project: "Choca Hill Windfarm of 260 MW and 60 kV Transmission Line" of the company NORWIND S.A.C. The assessment of its EIA was initially declared inadmissible by DGAAE, because they did not undertook public participation workshops before and during the preparation of the EIA; later, a reconsideration motion was filed by the proponent and the EIA continues, currently being at the process of observation solving.

It is also important to note that in accordance with that established in the Ministerial Resolution N° 223-2010-MEM/DM (Guidelines for citizen participation in electricity activities) and in accordance with Supreme Decree N° 002-2009-MINAM (Transparency Rules, public access to environmental information and citizen participation and consultation in environmental matters), as part of the preparation and approval of environmental studies, it is required to present a Citizen Participation Plan (CPP) in which it must specified the mechanisms for citizen participation to be applied before, during the preparation of the EIA, as well as during its evaluation process

II-1.4.4 Non-thermal (such as Hydroelectric or Wind-power) Projects at Odds with Environment Groups, Indigenous Peoples or Other Such Groups, as Well as Areas of the Projects Concerned

According to the DGAAE, there are four power development projects currently facing opposition from local residents, indigenous peoples, NGOs, or other such groups in the project areas. As outlined in Table II-1.4.1, all these four projects are hydropower development projects.

Table II-1.4.1 Hydroelectric development projects at odds with environment groups, indigenous peoples or other such groups

Project Name	Location	Scale (MW)	Progress of EIA	Opponents	Reason for Objection
Inambari	MADRE DE DIOS	1,500	With objection during workshop prior to EIA, EIA has not been implemented (2009).	Local residents and NGO groups	Resettlement of around 5,000 residents
Paucara	CUSCU	130	EIA was completed (2001).	Local residents	Land acquisition and water
Pakizapango	JUNIN	1,200	Survey for EIA has not started.	Local residents and NGO groups	Protection of the living area of the indigenous people
Veracuruz	AMAZO NAS	730	EIA has been submitted.	Some people not related to the area	No specific reason

(Source: JICA Study Team)

II-1.4.5 Geothermal Development in the Regional Conservation Area Vilacota-Maure (ACRVM) of Tacna Province

In 2009 Vilacota-Maure Regional Conservation Area (ACRVM: Area de Conservación Regional Vilacota Maure) was established around the northern part of Tacna Province, in southern Peru, where promising geothermal fields are concentrated. Up to now, although some applications for geothermal resource exploration rights have been presented for those geothermal fields inside the ACRVM, SERNANP concludes that the exploration activities are not compatible in relation to those objectives of creation of ACRVM. However, if the adequate measures of environmental and social considerations are taken, it can be assumed that in some geothermal fields the development activities can be implemented without ignoring the objectives of ACRVM. In this section, the environmental impacts which may be caused by the geothermal development activities within ACRVM are evaluated based on the matrix of critical threats in ACRVM determined in the Master Plan of ACRVM (2009-2014) elaborated by the Regional Government of Tacna (Table II-1.4.2 and Table II-1.4.3).

Table II-1.4.2 Matrix of Critical Threats in the Regional Conservation Area Vilacota-Maure (ACRVM)

Classification	Threats	Source	Element subject to impact	Location within the ACRVM
Hydrological network: Maure-Uchusuma Basin and high basin of the Caplina, Santa and Locumba rivers	Streams deviations	Agriculture activity of the low and medium altitude valleys - Mining activity	Lakes and wet lands	High Andes Palaca, Tarata, Ticaco and Susapaya
	Water reservoirs	- Impact the landscape - Noise and dust pollution - Increasing agro and cattle industry - Increase in power demand - Increase in social demand	Lakes	Palca Ticaco Tarata
	Snow melting	Global warming Impact on Flora and Fauna associated to streams	High elevation mountains with snow	Barroso cordillera and other snow covered picks in the ACRVM
Flora and Fauna	Displacement of Wild Fauna	Introduction of exotic species	Wild flora and fauna species (Rhea, Vicuna, North Andean Deer)	All ACRVM
	Shrinking of population of Wild Fauna	Furtive hunting and illegal catch of Wild animals	Wild mammals and birds (North Andean Deer, Vicuna, Felines and Rhea)	All ACRVM
	Shrinking of population of Wild Fauna	Picking of eggs	Rhea, wild Ducks, Chocas, etc.	Nesting areas within the ACRVM
	Fragmentation of Habitats and displacement of wild species	Construction of infrastructure	Vicuna, North Andean Deer , Vicuna, Felines	All ACRVM
	Loss of vegetation area	Logging Firewood Over extraction of fauna and bushes	Wild fauna	All ACRVM
	Deforestation	Expansion of the farming frontiers	Scrubs (related to Fabiana stephani)	Candarave (CPM of Santa Cruz)
	Degradation of “wetlands”: Reduction of the offer of habitat to wild Fauna	Excessive livestock farming	High Andes lands wetlands grasslands of The ACRVM	All ACRVM
	Loss of the vegetation area	Illegal logging of forestry	Qennoales, Tolares	All ACRVM
Geomorphology	Landscape alteration	Infrastructure construction (Camps, canals, dams, roads, etc.)	Geomorphology of the ACRVM	All ACRVM

	Reduction of water volume	Exploitation of the water resource (streams *rerouting*)	Lakes, wetlands, waterfalls, water springs	All ACRVM
	Alteration of the landscape	Mining exploitation	All geomorphology of the ACRVM	All ACRVM
	Natural Phenomena	Global warming	Barroso Cordillera and other snow covered picks	All ACRVM
Cultural Manifestations	Deterioration of archeological site	Insufficient budget of the concerned institutions	Archeological sites within the ACRVM	Vilacota, Mamuta, Inca Moqo
	Depredation of archeological sites	Lack of surveillance and control programs	Archeological sites within the ACRVM	Vilacota, Mamuta, Inca Moqo
	Loss of traditional scenic harmony of towns of rural areas	Urban plans not considering the traditional architecture and landscape	All type of constructions within the ACRVM	All ACRVM
	Loss of cultural identity	New customs assimilation	Live culture	All ACRVM

Table II-1.4.3 Prediction and evaluation of the impact of geothermal development in the ACRVM

Classification	Impact components	Environmental fact	Extent of impact	Possibility of avoidance and mitigation the impact
Hydrological network: Maure-Uchusuma Basin and high basin of the Caplina, Santa and Locumba rivers	- Intake of water for well drilling work and effluents - Extract geothermal fluid and reinjection hot water - Intake of water for power plant and effluents	- Decrease in river flow - Water level lowering of lake and wet lands - Polluted water	- Intake water will be small, depending on the intake water sources amount, the affected extent of change. - Hot water will be reinjected deep underground through reinjection wells, there will not be any hot water released into the rivers, lake and wetland. - Use drilling water will be recycled, not outflow out of the system. - Effluents during the in-service period of the power plant may have an impact water body.	- Conducted a survey of the intake water source amount, consider less affected by the intake of the intake water source. - To comply with effluent standards and Installation of wastewater treatment facilities.
Flora and Fauna	- Geothermal resources survey (E.g. drilling well) - Construction of power plants and related facilities	Important species and noteworthy habitats	- If there is a important species and noteworthy habitats are considered significant impacts. - Depending on the planning of the power plant, may cutting of trees and plants.	- The conducted a survey, if there are important species and habitats, consider change of the plans. - Develop a plan to minimize the cutting of trees and plants.

Geomorphology	Landscape alteration	- Geothermal resources survey. - Establishment of land and power plant construction site.	Topography and geological	Depending on the planning of the power plant, may affect the planning power plant area.	Conducted important Topography and geological survey, Consider the minimization and avoidance of significant impacts due to the topography plan.
	Reduction of water volume	Intake of water for well drilling work, power plant and domestic use	Decrease in river flow, water level lowering of lake, wet lands and ground water.	Intake water will be small, depending on the intake water sources amount, the affected extent of change.	Conducted a survey of the intake water source amount, consider less affected by the intake of the intake water source.
	Alteration of the landscape	Alteration topography and the presence of the facilities.	Landscape resource and main landscape view.	Depending on the location of the power plant, the presence of facilities and steam from the power plant may affect the landscape in the immediate area.	- Conduct a landscape survey and these results reflect the project plan. - Examine the location and design that takes into consideration the landscape.
	Natural Phenomena	- Power plant constriction - Power plant operation	Greenhouse gas (CO_2)	- During construction work, greenhouse gases generated during the operation of construction machinery and during the transportation of materials in and out of the construction sites are assumed to be minimal, and the impact of these emissions is assumed to be temporary and minor. - During the in-service period of the power plant, the CO_2 component of NCG (Non Condensable Gas) will be released, the considerably reduced amounts of greenhouse gas emissions as compared with other power generation methods.	No action is required.
Cultural Manifestations	Deterioration of archeological site	- Power plant constriction - Power plant operation	Archeological site	The impact on these archaeological sites will depend on the exact location of the project	Conduct surveys to confirm the archaeological sites, avoid planning the project location in the archaeological site.
	Depredation of archeological sites			Impacts are not expected	

	Loss of traditional scenic harmony of towns of rural areas	Power plant and surrounding facilities	Landscape	Depending on the location of the power plant, the presence of facilities and steam from the power plant may affect the landscape in the immediate area.	- Considering the design characteristics of the region. - Consider the traditional architecture and landscape in location planning.
	Loss of cultural identity	- Power plant constriction - Power plant operation	Life and culture	Temporary impact is expected during the construction stage of hiring power plant construction workers from outside the area. In addition, the expected impact of improve access road and power plant workers from outside.	- Employ local workers to the fullest extent possible. - Consider a program to protect the tradition, culture and life of the region.

II-1.4.6 Study of Alternative Plans For Electric Power Development Policies And Programs

(1) Electric Power Development Policies

Regarding the electric power policies of Peru, the following plans and targets have been set for power development and renewable energies:

- The capacity increase of power generation facilities to be achieved by 2019 is planned to consist of hydropower at 49% and natural gas-fired power at 49%.
- It is set as a national goal to supply 5% of electric energy consumption by renewable energies within the next five years.
- The power generation by using renewable energies necessary for accomplishment of the goal in the next five years is set to be 500 MW.

Biomass, wind, solar, geothermal, and ocean energies as well as hydropower of 20 MW or less are defined as renewable energy resources (Recursos Energéticos Renovables: RER).

Since the power supply structure of Peru is characterized by excessive dependence on hydropower generation and growing utilization of natural gas, it is important for the national energy security to facilitate energy mix by introducing renewable energies. Under such circumstances of the country, development of renewable energy power sources is expected to increase.

(2) Setting Alternative Plans

In the Peruvian power policies, no concrete programs to implement the plans and achieve the goals have been indicated, nor have been specified targeted output capacity to be developed for each type of natural resources.

The electric energy estimated in this Master Plan study to be produced by geothermal power generation at the 13 promising fields is 735 MW. With addition of two sites, Calientes and Borateras, the capacity will increase to 885 MW, which accounts for more than 10% of the national total of electric power generation, 7,300 MW.

For study of alternative plans for the electric power policies in Peru, power source development scenarios will be compared, for which the following two scenarios are considered to be appropriate subjects:

- Scenario 1: 800 MW geothermal power development
- Scenario 2: Hydropower development, instead of 800 MW geothermal power development

The major environmental and social impacts are compared between hydropower development and geothermal power development by the projects studied in this master plan, and the comparison is summarized in Table II-1.4.4.

In comparison of negative impacts, Scenario 2 is expected to have greater impact on involuntary resettlement, fauna, flora and biodiversity, and others on which magnitude of impact is determined by site location, as well as water contamination, while Scenario 1 is predicted to have greater impact on items related to air pollution, waste and other contamination.

Table II-1.4.4 Comparison of alternative electric power policy

Impacts	Scenario 1 (800MW of geothermal power development)	Scenario 2 (800MW of hydro power development)
Involuntary Resettlement	Minor	Significant (Creation of a Reservoir)
Local Economy	Minor	Significant (Creation of a Reservoir)
Land Use and Utilization of Local Resources and Water Usage	Moderate (Well drilling and geothermal power plant construction)	Significant (Creation of a Reservoir)
The Poor, Indigenous and Ethnic people	Minor	Significant (Creation of a Reservoir)
Cultural heritage	Minor	Significant (Creation of a Reservoir and Storage of water)
Infectious Diseases (HIV/AIDS)	Moderate (Not require large-scale civil engineering works and the number of construction workers will smaller)	Significant (Long construction period, the long-term inflow of construction workers into construction sites)
Hydrology and Hydrological Situation	Minor	Significant (Modification of river morphology and Changes in river flow by Storage of water)
Flora, Fauna and Biodiversity	Minor	Significant (Creation of a Reservoir, Floras and faunas such as the habitat loss by storage of water and impact and impact aquatic organism by changes in river flow)
Air Pollution	Significant （H_2S emissions）	Minor
Water Pollution	Minor	Significant (Deterioration of water quality by storage of water)
Topography and Geographical Features	Moderate	Significant (Creation of a Reservoir and Storage of water)
Waste	Moderate (Generation of industrial waste)	Minor

Note 1: Significant, Moderate and Minor indicates relative plan between the two scenarios.
Note 2: Items in brackets are main cause of adverse impacts

Source: JICA Study Team

II-1.4.7 Monitoring Plan

The Environmental Monitoring Plan to implement at the different phases of the project must take into account the characteristics of each project and the environmental situation of the area where the project would run. This plan is a technical mechanism for environmental control in determining and assessing the parameters to carry out monitoring of the quality of different environmental factors, as well as the control systems and measurement of these parameters (Table II-1.4.5).

Table II-1.4.5 Environmental monitoring plan

Item	Parameter	Exploration, drilling and construction	Operation
Air Quality	H_2S	Location: 2-4 points in the surroundings of the drilling fields and 1 point in nearby house or each community. Frequency: Monthly Methods of measurement and standard: D.S. Nº 003-2008-MINAN	Location: 2-4 points in the surroundings of the plant and drilling fields and 1 point in nearby house or each community. Frequency: Monthly. Methods of measurement and standard: D.S. Nº 003-2008-MINAN
	PM_{10}, $PM_{2.5}$, NO_X	Location: 2-4 points in the surroundings of the plant construction site and 3 points in accesses roads. Frequency: Quarterly. Methods of measurement and standard: D.S. Nº 003-2008-MINAN and D.S. Nº 074-2001-PCM	-
Noise	Noise level	Location: 4 points in the surroundings of the plant construction site and 1 point in each sensitive area (nearby house or community). Frequency: Quarterly. Methods of measurement and standard: D.S. Nº 085-2003-PCM	Location: 4 points in the boundary of the plant site and 1 point in each sensitive area (nearby house or community). Frequency: Quarterly. Methods of measurement and standard: D.S. Nº 085-2003-PCM
Surface Water Quality	Parameter of (D.S. Nº 002-2008-MINAN)	Location: Surroundings the plant construction site upstream and downstream of rive and lakes. Frequency: Quarterly. Methods of measurement and standard: D.S. Nº 002-2008- MINAN.	Location: Surroundings the plant upstream and downstream of rive and lakes. Frequency: Quarterly. Methods of measurement and standard: D.S. Nº 002-2008- MINAN.
Groundwater Quality	Parameter of (D.S. Nº 002-2008-MINAN), groundwater and high altitude wetlands (*bofedales*) levels	Location: 1-3 points in the surroundings of the project area (if there are well and lakes or wetlands) Frequency: Quarterly (water quality), Level (monthly). Methods of measurement and standard: D.S. Nº 002-2008- MINAN.	Location: 1-3 points in the surroundings of the Plant and wells pad (if there are well and lakes or wetlands) Frequency: Quarterly (water quality), Level (monthly). Methods of measurement and standard: D.S. Nº 002-2008- MINAN
Effluents quality	Water temperature, pH, SS, BOD_5 and Oil and Grease	Location: Temporary grit chamber outlet Frequency: Monthly. Methods of measurement and standard: R.D. Nº 008-97-EM/DGAA.	Location: Plant and domestic effluents outlet Frequency: Quarterly. Methods of measurement and standard: R.D. Nº 008-97-EM/DGAA.
Hot spring	Temperature, pH, EC, Na^+, Ca^{2+}, Cl^-, SO_4^{2-},etc. and volume.	Location: Hot spring in the surroundings of the project area. Frequency: Monthly (before drilling started 3 months and exploration, drilling period). Evaluation method: Comparative analysis of survey results.	Location: Hot spring in the surroundings of the plant and well.pad. Frequency: Quarterly period). Evaluation method: Analysis of survey results over time.
Subsidence	Ground elevation	Location: 4-6 points in the surroundings of the plant and well.pad.and 2-4 point in settlement site Frequency: Annually. Methods of measurement: Land elevation of the point from leveing. Evaluation method: Comparative analysis of survey results	

Item	Parameter	Exploration, drilling and construction	Operation
Flora, Fauna (If rare species are there)	Flora, Fauna (including birds) and diversity of flora and fauna.	Location: EIA baseline survey sites. Frequency: Twice a year (Rainy and dry seasons during the construction period)	Location: EIA baseline survey sites. Frequency: Twice a year (Rainy and dry seasons)
Hydrobiology	Plankton and benthos and the relative abundance in the case of fauna.	Location: Surroundings the plant construction site upstream and downstream of rive and lakes. Frequency: 2 Twice a year ((Rainy and dry seasons during the construction period)	Location: Surroundings the plant site upstream and downstream of rive and lakes. Frequency: Twice a year (Rainy and dry seasons)
Archeological	Effect of archaeological sites and cultural heritage	Location: Archeological and cultural heritage sites Frequency: 2 Twice a year ((Rainy and dry seasons during the construction period)	Location: Archeological and cultural heritage sites Frequency: 2 Twice a year ((Rainy and dry seasons during the construction period)

II-1.4.8 Environmental Improvement Effect of Geothermal Projects

The expected emission reduction of CO_2 which will be derived from the substitution of thermal power plant to geothermal power plants to be constructed in the selected promising 13 geothermal field (735 MW in total) is estimated.

(1) Methodology

a) Preconditions

- The calculation is carried out considering the amount of crude oil which will be saved by the geothermal project. (energy saving (or energy substitution) effect)
- Concerning greenhouse gases other than CO_2, multiply by an index which is determined according to the type of gas.
- In cases where the cause of reduction in greenhouse gas emissions is not only due to energy saving or substitution, use the formula established by the Intergovernmental Panel on Climate Change (IPCC) for that portion.

b) Calculation Formula

In cases where the cause of reduction in greenhouse gas emissions is due to energy saving or substitution only;

Reduction of CO_2 emission =

estimating consumption of crude oil (ktoe/y) x 42.62 x 20 x 0.99 x 44/12

Energy saving (or substitution) effect (estimating consumption of crude oil (ktoe/y)) A

- 10,000 kcal/kg as convert number from crude oil to calories
- 2,646 kcal/kWh as convert number from electricity to calories

Conversion into energy unit per unit of crude oil (calorific value (TJ)) B

B = A x 42.62 TJ/kt (energy conservation factor)

Conversion into carbon exhaust per energy unit C

C = B x 20 t C/TJ (carbon emission factor)

Correction of incomplete combustion portion D

D= C x 0.99 (fraction of carbon oxidized)

Conversion into carbon dioxide E

E = D x 44/12 (Molecular weight ratio)

(2) Calculation of CO_2 emissions reduction effect

a) Preconditions

- Capacity of new power plant: 735MW
- Capacity factor: 85%

b) Calculation of CO2 Emissions Reduction Effect

Consumption of crude oil

2,646 kcal/kWh/10,000 kcal/kg=264.6 kg/MWh

Conversion into calorific value (TJ)

264.6 kg/ MWh ×42.62 TJ/kt= 11.277 $\times 10^{-3}$TJ/MWh

Conversion into carbon exhaust

11.277 $\times 10^{-3}$TJ/ MWh ×20 t-C/TJ = 0.226 t-C/MWh

Correction of incomplete combustion portion

0.226 t-C/ MWh ×0.99 =0.224 t-C/ MWh

Conversion into carbon dioxide

0.224 t-C/ MWh ×44/12 = 0.821 t-CO_2/ MWh

Annual power generation

Annual power generation (MWh/year) =735 (MW) x 24(h/day) x 365 (day) x 0.85 (%)＝5,472,810 MWh

Annual CO_2 emissions reduction effect

Annual emission reduction (kt-CO_2/year) = 5,472,810×0.821=4,493 kt-CO_2/year

(3) CO_2 Emissions Reduction Effect

Thus, when geothermal power plant (735 MW) is completed, it is expected that CO_2 emission will be reduced by 4,493,000 tCO_2 per year.

II-1.5 Suggestion on Multi-purpose Use of Geothermal Energy

II-1.5.1 Multi-purpose Use of Geothermal Energy

The use of the geothermal fluids been usually regarded useful to generate electricity only, however depending on the temperature of the resource at surface or after the process to generate electricity; geothermal fluids can be utilized in multiple ways. Figure II-1.5.1 lists the possible utilizations of geothermal fluids depending on its temperature.

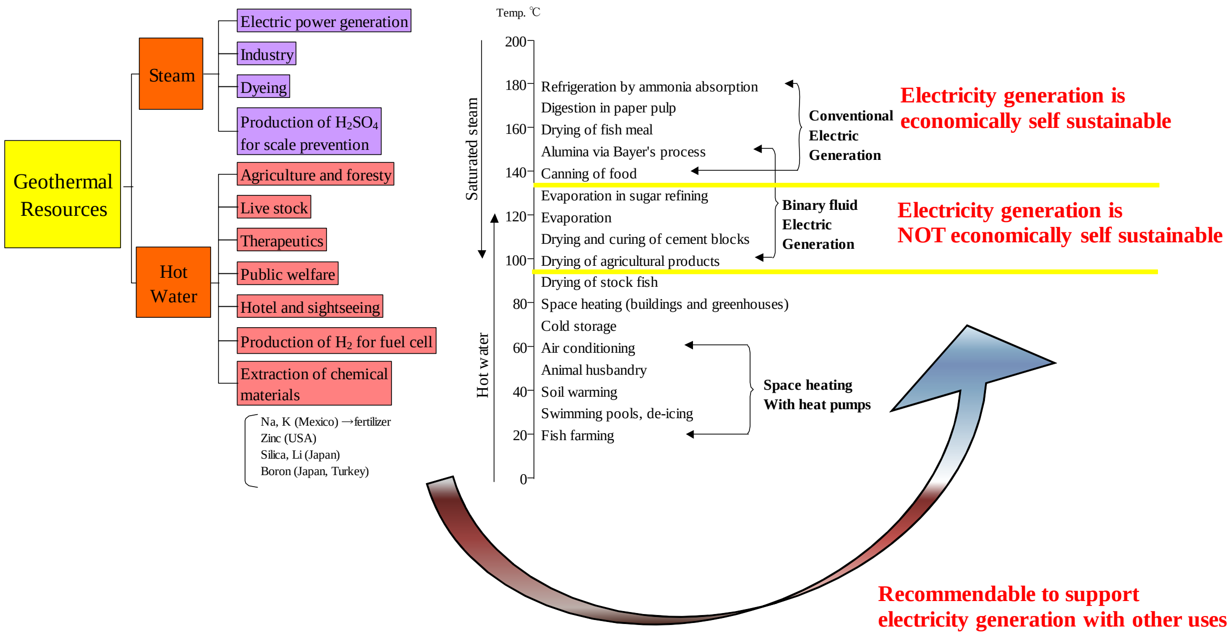


Fig. II-1.5.1 Application of geothermal resources depending on temperature

It is common sense that lower temperature geothermal resources are more widespread than high temperature geothermal resources. These resources can provide useful energy for heating buildings and spaces to be used in animal or plant farming or in industrial processes. Such heat can also be available as a by-product of geothermal power generation projects or as a by-product of other industrial process that starts using the geothermal resource at high temperature to subsequently utilize the heat in a cascade fashion (Fig. II-1.5.2).

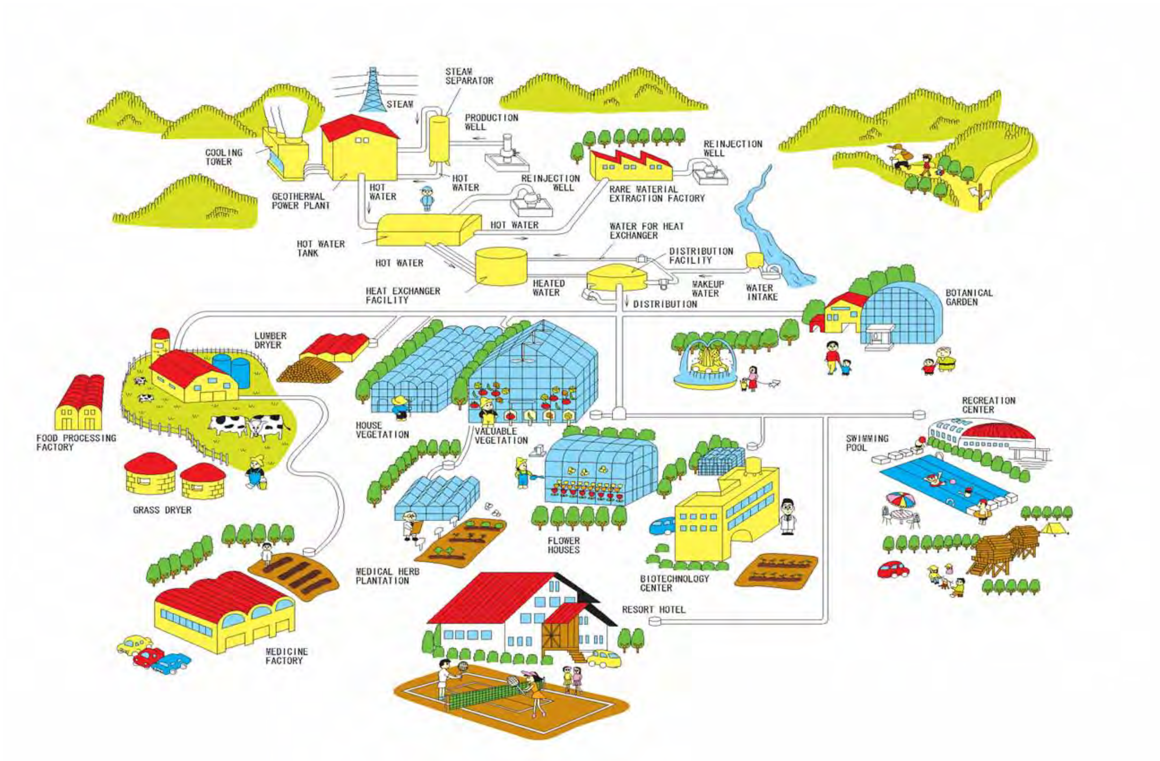


Fig. II-1.5.2 Schematic representation of a cascade utilization of geothermal resources

II-1.5.2 Kind of Multiuse Applications to the Geothermal Areas of Peru

The term geothermal heat direct use may differ from the applications that can be available for the case of Peru. In the case of Peru due to the location of most of the geothermal resources in very high lands of dry to very dry climate and where daily ambient temperatures varies from 20^{o}C to -20^{o}C the application would be more to the use of hot fluids in combination to other exploitation such as power generation. Therefore, of the applications listed above; space heating, agriculture, aquaculture, recreation, mineral recovering, would be appropriate.

What application will suit the most will depend on the type of current economic activity of the area, which in turn will depend on the uses of land the kind of existing industry, soil, type of animal farming and population. Nevertheless, once a pole of social-economic development is started other application can be implemented as the need of the region changes.

Due to edaphic and climatic characteristics of Ancoccollo, Chungara - Kallapuma, Tutupaca, Crucero, Pinaya, Ccollo Titire and Caylloma study areas, the lands are used only for grazing purposes. In the fields of Calacoa Putina, Ululan, Chivay Pinchollo and Chancos the soils are used for agricultural purposes and in a lesser extent for livestock breeding. The population is mostly dispersed (low population density) with the exception of Chivay-Pinchollo, Chancos and Ulucan.

Animal farming: The main economic activity of Ancoccollo, Tutupaca, Crucero, Pinaya, Jesús María, Ccollo Titire, Caylloma and Puquio, is extensive animal farming of South American Camelids, as well as sheep and cattle.

Agriculture: Nearby the fields of Chivay-Pinchollo, Calacoa Putina, Ullucan and Chancos the main economic activity is agriculture and in lesser extent animal farming. It should be noticed that in Chivay-Pinchollo (Cañon Del Colca) touristic activities are also in practice as in Chancos (Callejón de Huaylas) but to a lesser extent.

Trading: In most of the areas of geothermal interest this activity agriculture and animal farming is supplementary by the trading of their raw materials.

Mining: In Tutupaca there is possibility of exploiting environmentally passives Sulfur and in Ccollo-Titire there is gold and silver mine exploitation.

However in general terms the geothermal areas covered in this study had animal farming of South American camelids (Vicuña, Alpaca, Llama, and Guanaco) as a common element. These animals feed themselves of Brown grass, Alfalfa or Corn Silage which is a natural product. The Llama and Alpaca are only known domesticated South American camelids. The Guanaco and Vicuña are wild, the former being endangered. The vicuña lives in herds on the bleak and elevated parts of the mountain range bordering the region of perpetual snow, amidst rocks and precipices, occurring in various localities throughout Peru some of which are bestowed with geothermal resources. The fiber of their hair is extremely delicate and soft, and highly valued for the purposes of weaving, but the quantity which each animal produces is minimal. The most commercially valuable of the Camelids is the Alpaca.

Therefore a cascade type application can be designed to social and economic development of communities living nearby and around areas of geothermal development. In generic terms what geothermal energy can do from up-stream to down-stream for these poles of social development is summarized in Fig. II-1.5.3. Electricity from the geothermal resource can be applied for water pumping, food preservation, illumination and small industry that will enhance the human resource quality of the communities; will improve their health, the possibilities to education and the security of their towns. These elements will provide a human resource with capacity to utilize more efficiently their natural resources in plant and animal farming to produce raw materials for their industry or other processing industry and basically to produce food security for human and animal use. Then these raw materials in turn can be the supply for the communities own small-medium industry or be preserved (using heat from geothermal resources for refrigeration or heating) to be sent to external markets for procession. All this process ends up with income to the local community and improvement of their life standards.

In Peru, since most of the field is in very high and dry lands, water is an essential element. Soil tends to be good because of its volcanic origin which makes it full of nutrients to the vegetation that can co-exist under the climatic conditions and exposed to winds and solar radiation of the high Andes. Shall water be available a prosperous agriculture can be put in practice and specially that kind of agriculture that will feedback other industry such that of animal farming. Therefore, production of water that can be used for human and animal consumption as well as for irrigation is of high priority. Water from geothermal fluids after being utilized in power generation is of two types; one, is a brine resulting from the separation of steam from the geothermal fluids and the other is water resulting from the condensation of steam after passing through the power generation facilities. The brine and condensed water can deliver heat; brine before reinjection and water before treatment for animal/plant farming or human use. An example of a cycle to produce water for the case of power generation using binary power plants is presented in Fig. II-1.5.4. Water can also be produced for power facilities operating steam cycles (water collected in the cooling tower pool). Since in Peru there are many low temperature geothermal resources, for this small power project, binary cycle will be applicable.

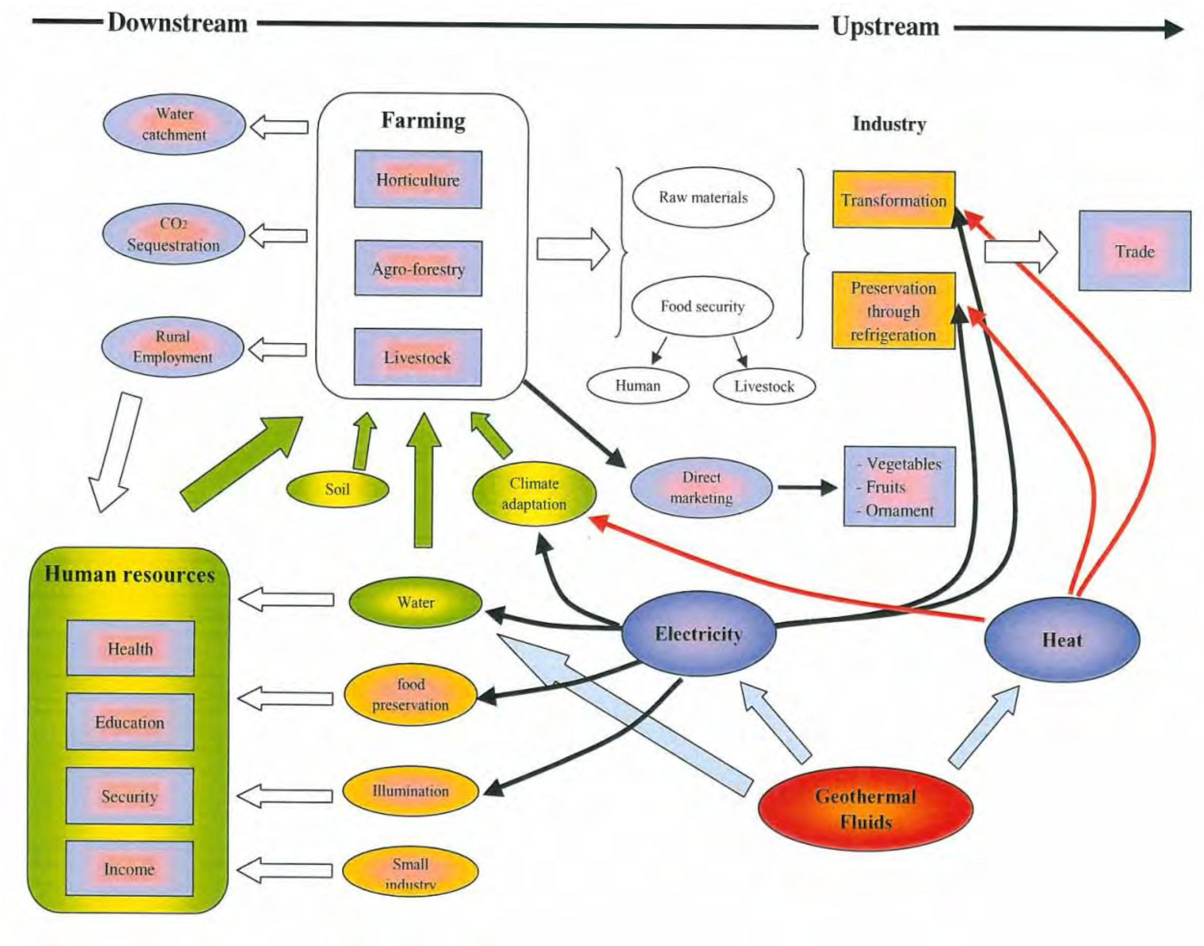


Fig. II-1.5.3 Hypothetical participation in the socio-economics of a region

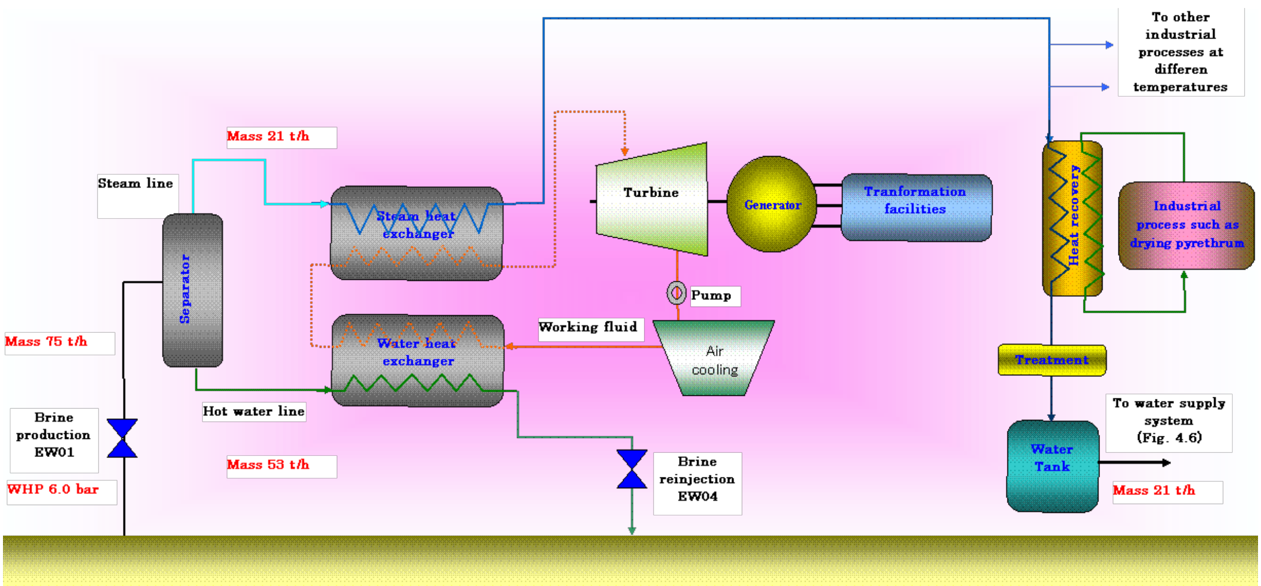


Fig. II-1.5.4 Utilization of water byproduct of a geothermal power application (binary case)

II-1.5.3 Suggested Pilot Project for Multi-use Applications of Geothermal Energy in Peru

(1) Objectives

This pilot project should serve the purpose of demonstrating:

- The feasibility of cascade utilization of geothermal resources
- Applicability in the promotion of socio-economic development

(2) Place

Ancocollo for a pilot project for an animal farming base socio-economic development

(3) Product to develop

As the product to develop, Alpaca is suggested. There is no existing extensive agriculture because the place is over 4300 m.a.s.l. and because there is deficiency in water supply. There are approximately 1800 heads of Alpaca and 400 Llamas. The livestock is 30% for self-consumption and 70% for trading. The price of one standing animal (Alpaca or Llama) varies according to the size and weight between S/. 80 and S/. 150; the price of meat varies between S/. 5.00 and S/. 8.00, and that for wool fiber, the pound varies between S/. 4.00 and S/. 6.00 (white wool) and between S/. 2.00 and S/. 4.00 (colored wool). The livestock farming is extensive and practiced at family base. Only traditional technology is used with very limited technical assistance.

(4) Problems to solve

a) Poverty

There are two barriers to overcome to fight poverty; one is the middle man that takes the product at very low price and raises the price to the market. The way of eliminating the middle man is to provide the farmers with means for them to preprocess the wool of their animals to sell yarn (thread) or even final product such apparel. The main element of geothermal to help the solution is electricity from the power plant to operate the spinning machines and apparel factories.

b) Reduce mortality of new born or young animals

This problem is due to the low ambient temperatures that reduces the survival rate of young animals. The main element of geothermal to help the solution is heat from either the geothermal brine or steam condensate. Shelters shall be constructed and space conditioned for the animals to spend nights at milder temperatures.

c) Improve the quality of animal fibber

The quality and it is the price of the fiber depends on color and softness (silkiness). This in turn depends on the kind and quality of the nutrients in the pasture the animals eat. These again in turn depend on the quality and quantity soil and water. The main element of geothermal to help the solution is heat and water than can be provided form steam condensation and or heat extracted from geothermal brine prior reinjection. Salts and minerals can be extracted from brine to improve nutritional contents in pasture.

(5) Pilot project contents

- Geothermal power plant to provide electricity to the grid and to feed local the community; their illumination and electricity to power their wool procession shops.
- Treatment of steam condensate and pipeline network to space condition

- Treatment of steam condensate to improve nutrition contents
- Pipe network for water supply and for irrigation.

(6) Project organization and barriers to overcome

For the project to successful it requires the coordination of following several institution of the government.

- MEM and the DGE, currently in charge or planning and overseeing the execution of power generation. This institution shall be the center in promoting coordination with the respective public institutions for the proper legislation and enforcement of rule for the multi-utilization of geothermal resources.
- INGEMMET: TO be in charge of the creation and maintenance of the database for geothermal resources and technological assistance to developers of geothermal sites and of multi-utilization projects.
- MDA-ANA (Ministry of Agriculture - Autoriddad Nacional del Agua, ANA): in charge of the exploitation and disposal of the underground water resource. This institution shall establish the way water has to be exploited and utilized at surface prior to its disposal.
- MEM-DGAAE: In charge of the regulatory and enforcement of the dispositions to protect the environment impacted by power development activities.
- MINAM-SERNANP: In charge of the regulatory and enforcement of dispositions to protect the environment impacted by activities for the multi-utilization of geothermal resources.
- MINCENTUR (Ministry of External Trade and Tourism): In charge of promoting trading of local products and to promote tourism.
- MEF-Proinversion-Cofide: that shall take responsibility the promotion of future investments in the multi-utilization of geothermal resources
- Universities: To take charge of the preparation of necessary human resources to oversee and or execute geothermal projects and their multi-utilization.
- Geothermal Multi-sectorial Commission: To be in charge of assisting MEM-DGE in the coordination of all ministries and institutions.

➩ Regarding the multi-use of geothermal energy, development of legal system for the geothermal resource development and exploitation regarding is required considering the combined use with power generation purpose. In addition, governmental support such as subsidy, preferential tax system, etc. for multi-use project is required. To validate the feasibility of the multi-use project, implementation of a government-led pilot project is recommended.

II-1.6 Action Plan for Geothermal Development

In this section, the study team proposes the action plan relating with all areas (legal framework, system/organization, supporting/assistance by the government and multipurpose use) for promoting geothermal developments in Peru, based on various recommendations described in the previous sections. The yearly schedule of the action plan is shown in Table II-1.6.1, and the action plan that are wanted to be executed by related organizations are shown in Table II-1.6.2.

In the yearly schedule shown in Table II-1.6.1, each action to be taken is classified into two groups, one of which is desired to be achieved in a short term, and the other is the actions to be continuously taken for medium or long term. As for the short-term objectives, first of all, the basic policy to promote geothermal developments should be clearly proclaimed. Secondly, proper management and appropriate instructions should be given steadily for the geothermal exploration and exploitation activities carried out by private sector. The items relating with the management or direction of the development activities by private sector are enumerated in the short-term objectives. In addition, the necessary items to prepare for the governmental direct participation (for example by a state-owned enterprise) to geothermal power generation projects are also listed in the short-term objectives. It is assumed that the short-term objectives shall be achieved within three years, since the resource exploration activities in the fields of whish exploration rights granted in 2011 will be basically completed in 2014 (exploration period of three years). The items such as actions to realize geothermal developments by state-owned enterprises, continuous capacity building for various organizations, additional resource potential study at unexplored area, are listed in the mid or long-term objectives.

Table II-1.6.1 Action plans for each areas and yearly schedule

	Short-term Target		Long-term Target							
	2012	2013	2014	2015	2016	2017	2018	2019	2020-	Note
Revision of targeted RE participation			▼					▼		present status: 5% of total energy demand
Tender for RE projects		▼		▼		▼		▼		every two years
Legal Framework										
- Enactment of policy										National Plan for RE etc.
- Revision of Geothermal Law (as necessary)										Management of development by private sector, etc.
- Revision of RE Law (as necessary)										
- Guideline for natural and social environmental considerations										
System/Organization										
- Capacity building to develop. management										DGE･INGEMMET
- Network for promoting geothermal										MEM Geothermal Committee
- Database updating system										
- Organization in state-owned utilities										Electroperú, etc.
- Capacity building of the public sector for their participation in geothermal										
Support from the Government										
- Development finance system (TSL, etc.)										COFIDE etc.
- Establishment of PPP scheme										Financing at low interest, etc.
- Exploration by the public sector										
- Upgrade knowledge of geo-potential										INGEMMET
Multi-purpose Heat Use										
- Management of hot water resources										
- Legal framework for multi-purpose use										
- Establishment of subsidy system										
- Public demonstration project										

Table II-1.6.2 Action plans for each organizations

	Legal Framework	System/Organization	Support by the Govt.	Multi-purpose Heat Use
MEM-DGE	- Proclamation of policy - Revision of Geothermal Law - Revision of RE Law - Guideline for natural and social environmental considerations	- Capacity building for develop. management - Network for promoting geothermal - Database updating system - Organization in state-owned enterprise	- Development finance system (TSL) - Establishment of PPP scheme - Exploration by public sector	- Management of hot water resources - Legal framework for multi-purpose use - Establishment of subsidy system - Pilot project by public sector
MEM-DGAAE	- Guideline for natural and social environmental considerations	- Capacity building for develop. management - Network for promoting geothermal - Database updating system		- Management of hot water resources (water pollution)
MEM-Multisectoral Geothermal Committee	- Proclamation of policy	- Network for promoting geothermal (as pivotal element of the network)	- Exploration by public sector - Continuous study in unexplored fields	- Management of hot water resources - Pilot project by public sector
MEM-INGEMMET		- Capacity building for development management - Network for promoting geothermal - Database updating system - Organization in state-owned enterprise - Capacity building of public sector for project participation	- Exploration by public sector - Continuing studies of unexplored fields	- Management of hot water resources - Pilot project by public sector
OSINERGIMIN	- Revision of RE Law	- Network for promoting geothermal	- Establishment of PPP scheme	
COES-SINAC		- Network for promoting geothermal		
University, etc.		- Network for promoting geothermal	- Continuous study in unexplored fields	- Pilot project by public sector
State-owned Companies (Electroperu, etc.)		- Network for promoting geothermal - Organization in state-owned enterprise - Capacity building of public sector for project participation	- Development finance system (TSL) - Establishment of PPP scheme - Exploration by public sector	- Pilot project by public sector
Ministry of Environment	- Guideline for natural and social environmental considerations	- Network for promoting geothermal		
Ministry of Agriculture, Ministry of Exterior Commercial Trade and Tourism		- Network for promoting geothermal		- Management of hot water resources
Ministry of Economy and Finance		- Network for promoting geothermal	- Development finance system (TSL) - Establishment of PPP scheme - Exploration by public sector	- Establishment of subsidy system

- MEM-DGE should formulate the "National Plan for Renewable Energy" as early as possible, and concrete objectives and policies of the government should be clearly stated in the national plan.
- The present legal framework comprised of the geothermal resource law and the law for promoting power generation projects by renewable energy, does not appear to contain fundamental problems. However, when problems come out in the application of the framework, or when delays frequently occur in developments by private sector, the legal system relating to management of the development by private sector and the direct participation of state-owned companies to geothermal development should be revised or updated.
- It is desirable that MEM-DGAAE raise their knowledge about geothermal-related environmental impacts through collaborative works with the Ministry of Environments, and formulate the guidelines for natural and social environmental considerations for geothermal development. Especially for the development in protected areas, care must be taken in formulating the guidelines so that it can enable the geothermal development supplemented with proper mitigation measures for

environmental impacts, considering that geothermal power generation is a low environmental load power source.

- MEM-DGE and INGEMMET should design to deepen their knowledge concerning the exploration/exploitation of geothermal resources, and to build their capacity so that they could properly manage and direct private firm's development activities.
- It is desirable to improve a network among governmental organizations in order to watch and monitor private firm's geothermal developments, and to cope with issues in promoting geothermal developments. It is necessary to intensify the system and administration of the geothermal committee, which is a suitable organization to have a role of the center of the network.
- An updating system should be established in MEM-DGE and INGEMMET, for a continuous utilization of the "Geothermal Development Database" developed in this Master Plan study.
- From mid/long-term viewpoint, it is desirable to establish a system for governmental organizations (ex. state-owned enterprises) to participate in geothermal power generation projects, and to continuously intensify the firm's ability.
- As a part of support scheme for private sector, it is desirable to establish a development finance system including the two step loans so that a private firm to be able to procure low-interest finances. Also, some kind of preferential tax systems should be considered.
- Early undertaking of establishment of a PPP scheme as a governmental project of geothermal power generation is necessary in order to cope with a possible situation where development by private sector does not grow as expected. In addition, a scheme centered on exploration drilling by a governmental organization should be established from mid/long-term point of view.
- A continuous study/exploration work aiming at clarifying the geothermal potential in an unexplored area is necessary for extracting new candidate fields for geothermal development. INGEMMET should be in charge of the exploration work as it used to be until the present. Expansion of the organization of INGEMMET and intensification of its ability is required.
- For promoting the multi-purpose use of geothermal energy, MEM should cooperate with the Ministry of Agriculture and the Ministry of Exterior Commercial and Tourism, the present competent authorities of resources and its utilization, in order to establish a legal system and a subsidy system for geothermal heat utilization businesses including simultaneous heat utilization with power generation. Following to the establishment, it is desirable to carry out a pilot project by governmental organizations, so that the project could be a model case of the application of the established legal/subsidy system.

II-2 Geothermal Development Database

II-2.1 Objectives of Construction of Database

The collection and analysis of the data related to the promising geothermal field in Peru was carried out in this study. The information are contained in the geothermal resource database which was newly constructed I the study. The geothermal development database is constructed based on the geothermal resource database by adding the other information about electric supply and demand balance, power grid, natural and social environmental issues, and so on. Thus, the database does not focus to the specific geothermal field to provide detail information of the field, but rather is comprehensive to provide the general information of geothermal development in Peru and basic information for each geothermal field in the country. The geothermal development database can be utilized to search and update the necessary information regarding the geothermal development in Peru. The database is expected to assist the acceleration of geothermal development in Peru.

II-2.2 Specification of Database

The database of the Peru Geothermal Master Plan has been created using the MS-Access relational database system. In a relational database different categories of data and information are stored in different tables that are linked by one-to-one and one-to-many relationships which allow for efficient and flexible data storage, with minimal duplication and considerable flexibility of data retrieval.

The start-up menu of the database is shown in Fig. II-2.2.1.

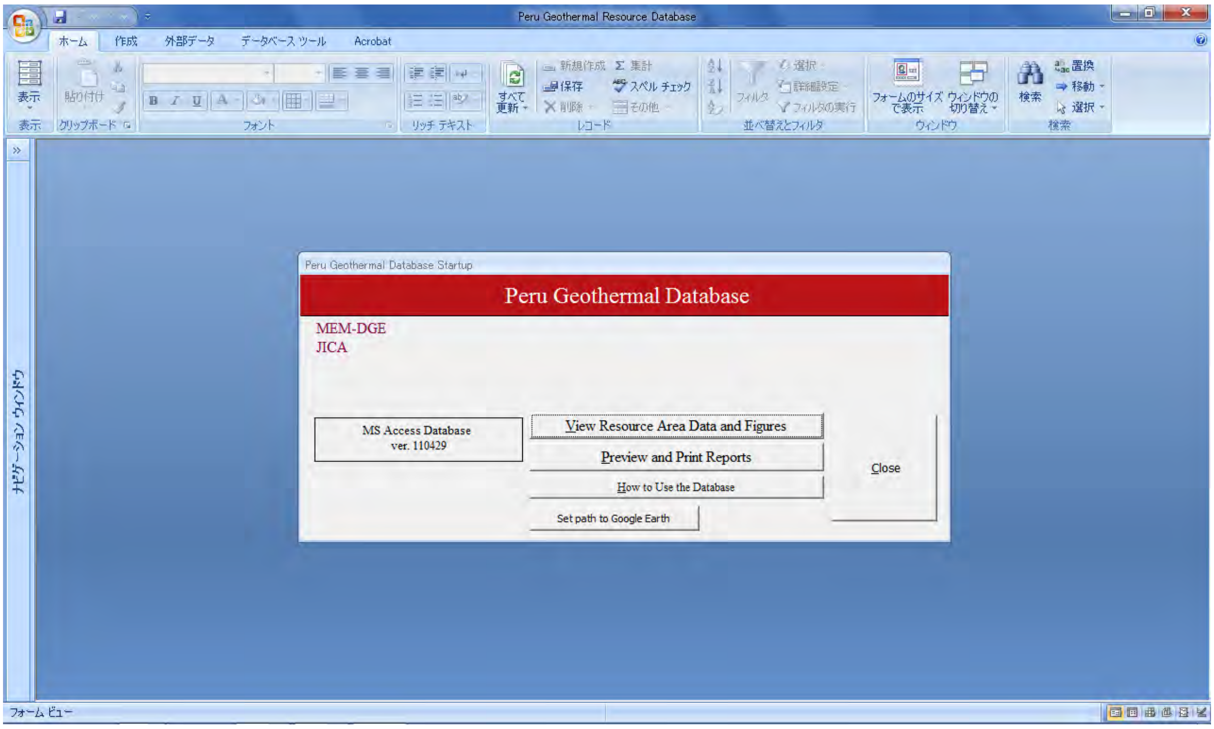


Fig. II-2.2.1 Start up menu of the geothermal resource database

There is a pull-down to choose resource area from home screen. The information of the selected field can be browsed and edited from this screen. A sample screen is shown in Fig. II-2.2.2.

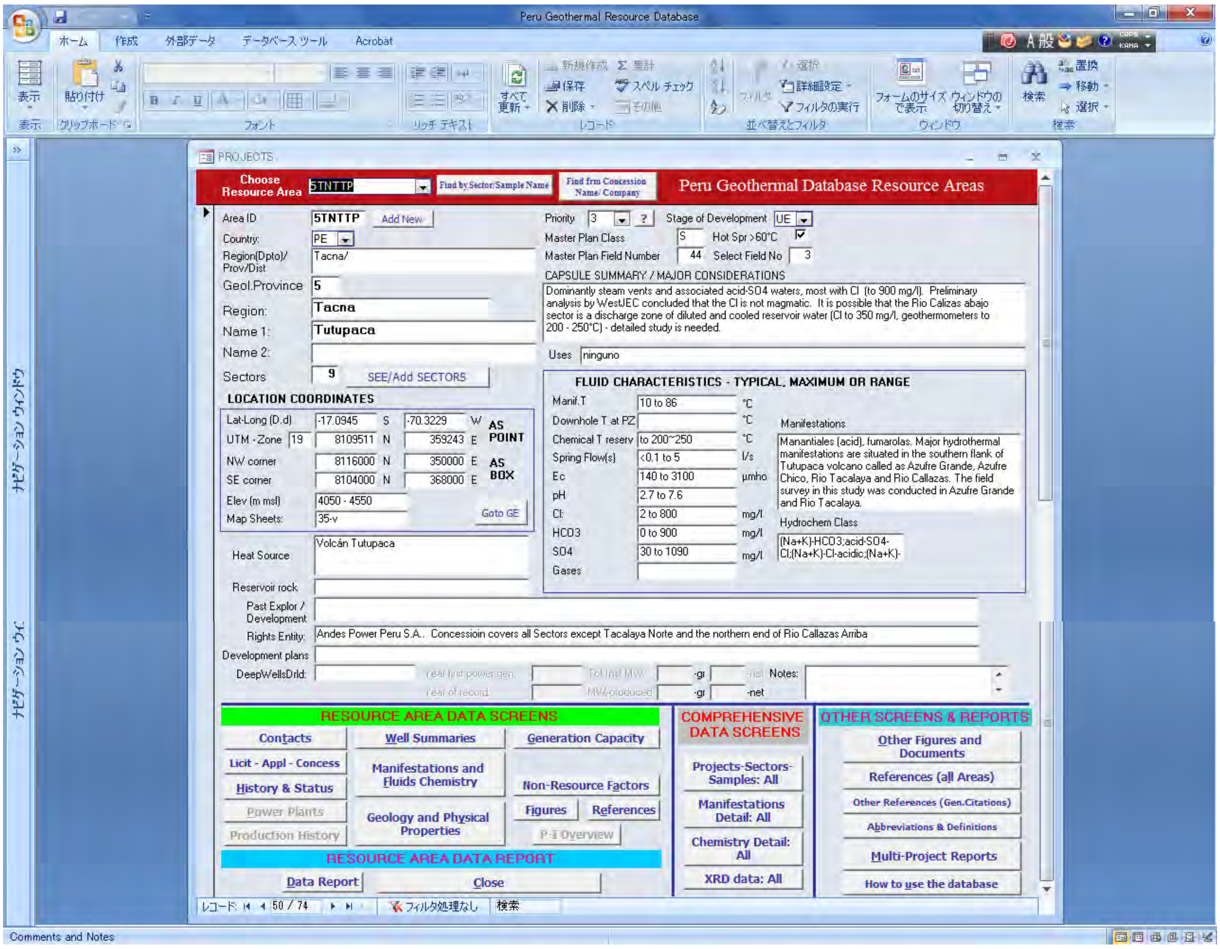


Fig. II-2.2.2 A sample of home screen for a selected field on the geothermal resource database

Data organization accommodates the field classifications shown in Table II-2.2.1. As mentioned above, the geothermal manifestations in Peru were classified to 61 fields. In order to include information for isolated, scattered hot springs around the country that do not fall into one of the already recognized "fields", additional 12 groups, which combine with the 61 fields to make 73 different resource areas, was prepared. There is also one record for Peru country-wide information.

Table II-2.2.1 List of "Geothermal Field" for the geothermal resource database

Geothermal Region	No.	Region	Field Name
(Northern Peru)	1	Tumbes	Tumbes
	2	Amazonas	El Almendral
	3	Amazonas	Corontochaca
	4	San Martin	San Mateo
	5	San Martin	Picurohuasi
	6	Loreto	Contamana
1. Cajamarca-La Libertad	7	Cajamarca	Quilcate
	8	Cajamarca	Cajamarca
	9	Cajamarca-La Libertad	Huaranchal
	10	La Libertad	Cachicadan
2. Callejon de Huaylas	11	Ancash-La Libertad	Tablachaca
	12	Ancash	Huancarhuas
	13	Ancash	Chancos
	14	Ancash	Olleros
	15	Huanuco-Ancash	Azulmina
3. Churin	16	Lima	Conoc
	17	Pasco	Huayllay
	18	Pasco	Tambochaca
	19	Lima	Oyon
	20	Lima	San Jose
4. Central	21	Junin	Yauli
	22	Huancavelica	Coris
	23	Huancavelica	Nonobamba
5. Eje Volcanico Sur	24	Cusco-Apurimac	Cconoc
	25	Apurimac	Pincahuacho
	26	Apurimac	Antabamba
	27	Ayacucho	Puquio
	28	Ayacucho	Paila del Diablo
	29	Ayacucho	Pararca
	30	Arequipa	Ocoruro
	31	Arequipa	Cotahuasi
	32	Arequipa	Orcopampa
	33	Arequipa	Cailloma
	34	Arequipa	Coropuna
	35	Arequipa	Chivay
	36	Arequipa	La Calera
	37	Arequipa	Yura
	38	Arequipa	Jesus
	39	Moquegua	Ubinas
	40	Moquegua	Ulucan
	41	Moquegua	Calacoa-Putina
	42	Moquegua	Ccollo/Titire
	43	Moquegua-Tacna	Crucero
	44	Tacna	Tutupaca
	45	Tacna	Calientes
	46	Tacna	Ancocollo
	47	Tacna	Borateras
	48	Tacna	Chungara-Kallapuma
6. Cuzco-Puno	49	Cusco	Machu-Picchu
	50	Cusco	Choquecancha
	51	Cusco	Pacchanta-Marcapata
	52	Cusco	La Raya
	53	Puno	Ollachea
	54	Puno	Pasanoccollo
	55	Puno	Hatun Phutina
	56	Puno	Putina
	57	Puno	Chaqueylla
	58	Puno	Pinaya
	59	Moquegua	Jesus Maria
	60	Moquegua	Exchage
	61	Puno	Collpa Apacheta

Each geothermal field is characterized by a 6 character ID code named PROJID.

- The first character is the number of the geothermal region (Eje Volcanico Sur, etc.).
- The second two characters indicate the region name (Puno, Arequipa, etc)
- The last three characters indicate the field.

Thus, for example, Tutupaca field has 6 character ID code of "5TNTTP". The first "5" identify geothermal region "Eje Volcanico Sur". The next two characters "TN" means region "Tacna". The last three characters "TTP" indicates field name "Tutupaca".

Most of the geothermal fields include numerous hot spring areas scattered over the countryside, so each field has been subdivided into a number of separate "Sectors". Some of the 73 resource areas have only one sector (that is, there is only one hot spring area, be it small or very large). Some have more than 10 different sectors (that is, there are more than 10 different hot spring areas that may or may not be related one to another).

II-2.3 Data and Information in Database

The data and information which are contained in the database is shown in Table II-2.3.1. Regarding the whole Peru, the geothermal resource map, national grid system map, etc. are contained. Regarding the each geothermal field, data and information on geothermal resource, electric supply and demand balance, natural and social environmental issues, and other information are stored. Description of the data and information for each geothermal field is given below.

Table II-2.3.1 Data and information in database

Area	category	➢ Data and information
Whole Peru	Geothermal resource	➢ Geothermal resource map ➢ Coordinate of each field
	Electric sector	➢ National grid system map
	Natural and social	➢ Map of environmental protected area
	Others	➢ Geothermal Law etc.
Each field	Geothermal resource	➢ Geological data ➢ Geochemical data ➢ Geothermal model ➢ Conditions and results of resource estimation
	Electric sector	➢ Development plan for power plant and transmission line ➢ Access to the main power grid
	Natural and social	➢ IEE results for promising fields, estimated GHG emission reduction, etc.
	Others	➢ Status of application

II-2.3.1 Geothermal Resource

Regarding the data related to geothermal resource, basic geological and geochemical data of all the fields are contained. The result of preliminary resource potential evaluation of each field is also included. For the selected promising fields, newly constructed geothermal conceptual models are contained. In addition, the input data such as reservoir area, rock properties, etc. used for Monte Carlo simulation and the results of calculation are stored.

II-2.3.2 Electric Power Demand and Supply

Regarding the data related to electric sector, the name of nearest substation and required length of transmission line for each geothermal filed is contained.

II-2.3.3 Natural and Social Environment

Regarding the data related to natural and social environment, the map showing environmental protected area is contained. The preliminary environmental study in selected 13 fields are summarized and positional relationship between promising field and protected/reserve area is stored. The expected emission reduction of CO_2 which will be derived from the substitution of thermal power plant to geothermal power plants to be constructed in the selected promising 13 geothermal field is estimated and the results are also contained to the database.

II-2.3.4 Authorization for Exploration and Concession for Power Generation Project

The information regarding the authorization for exploration and concession for power generation project as of November 2011 is stored.

II-2.4 Linkage to other Database

DGE and INGEMMET have their own databases. The feature of each database is as follows.

The database owned by DGE contains the information about concession of electric generation, distribution, and transmission line and substation as shown in Table II-2.4.1. The database is utilized by DGE as the jurisdictional organization to manage the information of all the electric industry in Peru. Thus, the characteristics is different from the database which is to be constructed in this study. Considering this situation, discussion with DGE was made and it was agreed to construct the geothermal development database independently from the database of DGE.

Table II-2.4.1 Contents of database of DGE

Category	Contents
Concession of Generation	Company, Company Code, Concession, Concession Code, Section, Source of generation, Situation (extinguished right, existing right, approval in process, inadmissible, administrative silence), Concession Type (authorized, definitive, temporary, informing)
Concession of Distribution	Company, Company Code, Concession, Concession Code, Area Name, Area Code, Electrical System, Peak demand, Service Hours, Number of users
Transmission lines or interconnected system	Company, Company Code, Concession, Concession Code, Line, Voltage, Capacity, Concession Type (authorized, definitive, temporal, informing)), Width of service
Substations	Company, Substation names, Voltage

INGEMMET has its own database called “GEOCATMIN”. It is made public on the Internet. The data is continually updated and the any user can download the necessary data through the Internet. The URL of GEOCATMIN is as follows.

http://geocatmin.ingemmet.gob.pe/geocatmin_en/

Regarding the construction of the geothermal database, the designing was discussed with INGEMMET. After the discussion, it was decided that the data and information in GEOCATMIN should not be included to the geothermal database because the data in GEOCATMIN is dynamic and continually updated. Thus, the database which was constructed in this study provides only the information to access to GEOCATMIN, and the user can refer to GEOCATMIN through Internet if necessary. The example window of GEOCATMIN is shown in Fig. II-2.4.1.

Fig. II-2.4.1 Example window of GEOCATMIN

II-2.5 Management and Update of Database

It is necessary to adequately manage and update the database when new information become available or there is some changes of the data in the database. DGE would be in charge of the management of the database. INGEMMET is also expected to assist DGE in terms of geothermal resource information. It is preferable that related organization will coordinate on the management and update of the database for the purpose of effective utilization of the database.

II-3 Geothermal Development Plan

II-3.1 Evaluation Criteria for Prioritization of Geothermal Development

In establishing the development plan of geothermal energy in all over the Republic of Peru, evaluation criteria for prioritization of development in geothermal fields (61 fields) were investigated. For determining weights of each criterion, the highest emphasis was placed on the geothermal resource potential in each geothermal field. Relations with the protected areas at each geothermal field were also emphasized. Economic efficiencies of geothermal energy development were also taken into considerations for those areas where its geothermal resources were evaluated to be promising and detailed investigation had been done in the Master Plan study. The second highest emphasis was given to the current situation in acquiring the authorization for exploration, since the grant of authorization would greatly affect the possibility of early development of geothermal energy.

Each geothermal field was classified into Rank A, Rank B, Rank C and Others, based on the evaluation results of each evaluation criterion. The evaluation criteria and the rank categories are shown in Table II-3.1.1.

Table II-3.1.1 Rank classification and evaluation criteria of prioritization in development

Rank	Description	Resource Potential	Authorization for Exploration	Topography and Access	Protected Areas
Rank A	Earliest development is expected. (The development would be done even without any support from the government)	High potential geothermal resource is expected.	Approved	No significant problem seems to exist.	There is no one nearby
Rank B	Following the Rank A (The authorization for exploration is to be waited for.)		Applied but not approved yet		There is no one nearby (to be confirmed)
Rank C	Relatively early development is expected, but the resource potential is to be confirmed.	High potential geothermal resource is possibly expected.	Approved		Not exist (to be confirmed for some fields)
Rank D-1	The resource potential is to be confirmed. (Based on the existing data, high potential resource can be expected.)		Not approved	Detailed survey is necessary.	
Rank D-2	The resource potential is to be confirmed. (Based on the existing data, the existence of high potential resource cannot be expected.)	Resource potential is not clear at present.			
Others	Environmental impact of possible geothermal project should be evaluated. If the impact can be avoided or mitigated sufficiently, the development should be permitted.	—	—	—	Exist a protected area highly regulated

- Geothermal Resource Potential: All geothermal fields were categorized in the following three levels according to the results of evaluations and surveys conducted so far.
  - Resource studies and explorations have been sufficiently conducted and the existence of high temperature resources is highly expected. (Rank-A, Rank-B)
  - Resource studies and exploration results are not sufficient, but the results show relatively high possibility of the existence of high temperature geothermal resources. (Rank C, Rank D-1)
  - Only few resource studies had been conducted and resource potential has not been clarified (Rank D-2)

For the classification of Rank D-1 and Rank D-2, resource data that are currently available (temperature and chemical composition of spring water) were investigated, and prospectiveness of geothermal resources were roughly evaluated for each field. The criteria in the evaluation were, 1) if temperature of hot spring exceed 80 ^{o}C, or, 2) if temperature of hot spring water exceed 50 ^{o}C and high geochemical temperatures were obtained (Na-K-Ca temperature exceeds 140 ^{o}C, K/Mg temperature exceeds 80 ^{o}C). The fields that met these two criteria were classified into Rank D-1, since relatively high prospectiveness of geothermal resource can be expected.

- Authorization for Resource Exploration: Among the fields where the grant of authorization for resource exploration have been published by MEM (as of November 2011), the fields where high temperature resources could be highly expected were classified into Rank A. Other fields were classified in Rank C.
- Topography and Accessibility: The following two criteria were adopted.
  - The result of field survey showed no problems for electric power generation project. (Rank A, Rank B, Rank C)
  - Field survey has not been conducted yet, and the current situation has not been clarified. (Rank D-1, Rank D-2)
- Protected Areas: The fields in or close to some protected area will require detailed EIA studies. Thus such fields were excluded from the priority evaluation. The areas where the "limitations in indirect use" are applied (such as National Parks) were the examples of such strongly regulated regions. Also, the protected area in Tacna Region (Vilacota-Maure Regional Conservation Area) was excluded from the priority evaluation for the time being, since in July 2011 SERNANP have already concluded that the geothermal development in the area is unfavorable.

The accessibility to the existing transmission systems, that is, the distances from each field to the nearest substations, is excluded from the evaluation criterion. The reason of the exclusion is because of the fact that the costs for transmission lines make up only a few percent of the total development cost in most of the fields. The costs for transmission lines could be reduced because of sparse vegetation due to the high altitude, especially in the southern region of Peru.

II-3.2 Prioritization of Geothermal Development

For the evaluation of priority for geothermal development, detailed evaluation based on the anticipated development plans have been applied to the promising fields that were selected in the Master Plan study. Simplified evaluations were applied to the other geothermal fields.

II-3.2.1 Development Plans for Promising Fields

In the Master Plan study, thirteen (13) geothermal fields were chosen as promising fields by investigating the existing resource data, considering the prospectiveness of geothermal resources and various conditions concerning energy developments. In the promising fields, resource studies including geological/geochemical surveys were conducted, and the possible development plans for the promising fields were devised based on the results of the resource studies.

The results of the resource studies and the details of the development plans are shown in Annex. The anticipated development scale and main specifications for the possible power development in the promising fields are summarized in Table II-3.2.1.

Table II-3.2.1 Main specifications for the possible power development in the promising fields

Field Name	Resource Potential P80 (MWe)	Possible Development Capacity (MWe)	Unit	Number of Production well	Number of Reinjection well
Chungara-Kallapuma	84.0	75	25MW x 3	19	9
Ancoccollo	98.2	90	30MW x 3	18	9
Tutupaca	113.8	105	35MW x 3	15	9
Crucero	79.4	70	35MW x 2	13	7
Pinaya	36.8	35	35MW x 1	13	6
Calacoa-Putina	108.2	100	25MW x 4	25	13
Ulucan	27.4	25	25MW x 1	5	4
Jesus Maria	17.3	10	10MW x 1	7	3
Ccollo/Titire	39.7	35	35MW x 1	10	5
Cailloma	9.1	5	5MW x 1	5	2
Chivay - Pinchollo	162.9	150	25MW x 6	22	13
Puquio	34.3	30	30MW x 1	12	5
Chancos	15.3	5	5MW x 1	5	2
Total	826.4	735	-	-	-

In addition, the project costs of geothermal energy development in the promising fields and the electricity selling price (US cent/kWh) for maintaining FIRRs to exceed 12% were examined. The results of the economic evaluations are shown in Annex.

II-3.2.2 Development Priority

The results of development priority evaluations for 61 geothermal fields including the promising fields are shown in Table II-3.2.2. In the table, various data/information including resource prospectiveness (hot water temperatures and its chemical compositions), estimated resource potentials, relations with protected area and grant of exploration rights are shown together with the results of the ranking.

Table II-3.2.2 Ranking of development priorities for 61 geothermal fields in Peru

Geothermal Region	No.	Region	Field Name	Elevation (m a.s.l.)	Hot Spring: Hot spring Tmax (°C)	Hot Spring: T NaKCa-max (°C)	Hot Spring: T K/Mg-max (°C)	Hot Spring: Cl max (ppm)	Resource Potential (MWe): Promising Fields*	Resource Potential (MWe): Other Fields	Resource Potential (MWe): Total	No. of Sector	Possible Develop. Capacity (MWe)	Grid Connection: Possible Substation	Grid Connection: Distanse (km)	Protected area	Authorization for Exploration (as of December 2011): Application	Authorization for Exploration (as of December 2011): Authorized	Authorization for Exploration (as of December 2011): Area Name in Application	Development Rank
(Perú Norte)	1	Tumbes	Tumbes	64	48	72	117	8,400		15	15	2		Tumbes S/S	11					D-2
	2	Amazonas	El Almendral	449	45	72	107	565		10	10	2		Nueva Jaen S/S	33					D-2
	3	Amazonas	Corontochaca	1583	28	39	56	183,000		7	7	5		Caclic S/S (2015)	36					D-2
	4	San Martin	San Mateo	1048	41	87	44	2,450		14	14	3		Moyobamba Nueva S/S (2015)	36					D-2
	5	San Martin	Picurohuasi	238	63	176	125	396,000		58	58	6		Tarapoto S/S	36	Area Conservation Regional / Parque Nacional b.z.				-
	6	Loreto	Contamana	98	84	140	52	15,200		48	48	3		Pucallpa S/S	143	Zona Reservada (direct use)				D-1
1. Cajamarca-La Libertad	7	Cajamarca	Quilcate	2087	63	218	161	1,240		70	70	7		Cerro Corona S/S	47					D-1
	8	Cajamarca	Cajamarca	2696	71	71	77	101		29	29	2		Cajamarca S/S	8	Coto de Caza (direct use)				D-2
	9	Cajamarca-La Libertad	Huaranchal	1941	74	221	123	220		54	54	5		Cajamarca S/S	43	Coto de Caza (direct use)				D-2
	10	La Libertad	Cachicadan	2855	70	204	83	841		40	40	3		Alto Chikama S/S	22					D-1
2. Callejón de Huaylas	11	Ancash-La Libertad	Tablachaca	2586	50	220	76	353		29	29	5		Sihuas S/S	29					D-2
	12	Ancash	Huancarhuas	2487	89	224	159	1,840		89	89	10		Kiman Ayllu S/S	36		V	V	Rupha / Yungay / Huancarhuaz	C
	13	Ancash	Chancos	2943	72	231	143	1,670	15.3	21	36.3	4	5	Huaraz S/S	30		V		Chancos	D-1
	14	Ancash	Olleros	3388	41	146	110	432		29	29	4		Conococha S/S	25	Parque Nacional (indirect use)	V		Olleros Sur / Olleros Norte	-
	15	Huanuco-Ancash	Azulmina	3437	70	69	45	170		53	53	5		Conococha S/S	22					D-2
3. Churin	16	Lima	Conoc	2538	49	93	55	290		21	21	3		Cahua S/S	11					D-2
	17	Pasco	Huayllay	4220	50	-	-	21		10	10	1		Huanuco S/S	22					D-2
	18	Pasco	Tambochaca	3408	60	226	118	673		24	24	2		Uchuchacua S/S	8					D-1
	19	Lima	Oyon	3003	61	190	53	354		45	45	5		Paragsha 2 S/S	47					D-2
	20	Lima	San Jose	3500	73	189	102	772		25	25	2		Carhuamayo S/S	47					D-1
4. Central	21	Junin	Yauli	4100	41	206	108	623		7	7	1		Pomacocha S/S	11					D-2
	22	Huancavelica	Coris	2000	50	221	128	1,880		10	10	1		Cobriza I S/S	18					D-1
	23	Huancavelica	Nonobamba	3754	44	235	128	1,880		15	15	3		Ingenio S/S	22		V		Ninobamba	D-2
5. Eje Volcánico Sur	24	Cusco-Apurimac	Cconoc	2538	41	80	58	45,800		43	43.3	3		Abancay S/S	18	Santuario Historico b.z. (indirect use)				-
	25	Apurimac	Pincahuacho	3098	62	192	103	638		25	25	2		Cotaruse S/S	29					D-1
	26	Apurimac	Antabamba	3628	43	223	136	498		15	15	2		Cotaruse S/S	36					D-2
	27	Ayacucho	Puquio	4053	80	369	210	2,110	34.3	10	44.3	1	30	Cotaruse S/S	113		V	V	Geronta	A
	28	Ayacucho	Paila del Diablo	3814	81	169	119	1,400		54	54	4		Cotaruse S/S via Pararca and Cotahuasi	36		V	V	Umacusiri	C
	29	Ayacucho	Pararca	2775	60	202	127	1,020		31	31	3		Cotaruse S/S via Cotahuasi	72		V	V	Sara Sara / Rio Pararca	C
	30	Arequipa	Ocoruro	4475	85	-	-	-		23	23	1		Cotaruse S/S via Antabamba	61	Reserva Paisajistica (direct use)				D-1
	31	Arequipa	Cotahuasi	2856	56	174	89	209		65	65	7		T-branch between Cotaruse S/S & Pararca	65	Reserva Paisajistica (direct use)				D-1
	32	Arequipa	Orcopampa	4029	55	54	32	66		29	29	4		Cotaruse S/S via Ocoruro and Antabamba	33	Reserva Paisajistica b.z. (direct use)				D-2
	33	Arequipa	Cailloma	4278	58	148	87	1,280	9.1	26	35.1	3	5	Cailloma S/S	11		V	V	Turu	C
	34	Arequipa	Coropuna	2986	51	235	70	237		15	15	3		Chuquibamba S/S	8					D-2
	35	Arequipa	Chivay-Pinchollo	3776	93	208	132	2,740	162.9	136	298.9	10	150	Callalli S/S	70		V		Pinchollo / Achumani / Hualca Hualca	B
	36	Arequipa	La Calera	3943	35	186	56	734		9	9	2		Santuario S/S	8	Reserva Nacional (direct use)				D-2
	37	Arequipa	Yura	2504	33	183	38	340		15	15	4		Yura S/S	8					D-2
	38	Arequipa	Jesus	2655	37	209	50	1,330		7	7	2		Cerro Verde S/S	8					D-2
	39	Moquegua	Ubinas	3077	62	91	56	704		24	24	3		Socabaya S/S	43		V		Ubinas	D-2
	40	Moquegua	Ulucan	2734	80	243	145	7,260	27.4	0	27.4	1	25	Socabaya S/S	127		V		Huaynaputina	B
	41	Moquegua	Calacoa-Putina	3300	91	186	118	1,340	108.2	45	153.2	5	100	Moquegua S/S			V	V	Quellaapacheta / Tiscani	A
	42	Moquegua	Ccollo/Titire	4330	83	217	167	11,400	39.7	27	66.7	4	35	Moquegua S/S via A S/S	117		V		Ccollo / Titiri	B
	43	Moquegua-Tacna	Crucero	4567	73	357	216	7,090	79.4	3	82.4	2	70				V	V	Crucero / Pasto	A
	44	Tacna	Tutupaca	4268	86	215	112	897	113.8	29	142.8	6	105		22		V	V	Tutupaca	A
	45	Tacna	Calientes	4341	90	219	195	3,340	100	0	100	1	100		30	Area Conservation Regional	V	rejected	Rio Carientes	-
	46	Tacna	Ancocollo	4216	87	219	206	2,380	98.2	55	153.2	5	90		22	Area Conservation Regional b.z.	V		Ancoccollo / Ocururane	B
	47	Tacna	Borateras	4397	87	223	198	2,390	40	31	71	4	50		75	Area Conservation Regional	V	rejected	Borateras / Rio Maure	-
	48	Tacna	Chungara-Kallapuma	4349	85	210	170	2,950	84	17	101	4	75			Area Conservation Regional	V		Casiri / Achuco / Rio Kallapuma	-
6. Cuzco-Puno	49	Cusco	Machu-Picchu	1924	52	211	129	2,260		49	49	6		Sururay S/S	22	Santuario Historico (indirect use)				-
	50	Cusco	Choquecancha	3010	88	220	124	1,340		43	43	3		Dolorespata S/S	36					D-1
	51	Cusco	Pacchanta-Marcapata	3529	64	192	105	565		40	40	3		Combapata S/S	54					D-1
	52	Cusco	La Raya	3754	52	189	109	4,090		26	26	5		Onocora S/S (2011)	29					D-1
	53	Puno	Ollachea	3313	70	191	113	576		45	45	3		San Rafael S/S	29					D-1
	54	Puno	Pasanoccollo	3906	75	172	106	982		65	65	6		Puno S/S	36					D-1
	55	Puno	Hatun Phutina	3724	71	179	109	139		39	39	4		Puno S/S via Putina	50					D-1
	56	Puno	Putina	3986	55	188	79	13,200		53	53	6		Puno S/S	43					D-2
	57	Puno	Chaqueylla	4100	57	119	70	11,300		26	26	3		Tintaya S/S	54		V		Condoroma	D-2
	58	Puno	Pinaya	4387	83	193	135	13,400	36.8	27	63.8	3	35	Callalli S/S	70		V	V	Pinaya / Chocopata	A
	59	Moquegua	Jesus Maria	3943	52	152	112	14,300	17.3	17	34.3	3	10	Puno S/S	67					D-1
	60	Moquegua	Exchage	3561	42	176	116	6,360		27	27	5		Socabaya S/S via Ubinas	22					D-2
	61	Puno	Collpa Apacheta	4013	54	153	61	48,600		13	13	2		Puno S/S	40					D-2

The priority evaluation results are summarized in Table II-3.2.3. It can be expected that total 640 MW power generation would be achieved in the fields categorized in relatively high priorities (Rank A and Rank B).

Table II-3.2.3 Result of development priority evaluations

Rank for Priority	Description	Geothermal Field	Possible Power Output (MW)	Total Possible Power Output (MW)
Rank A	Earliest development is expected. (The development would be done even without any support from the government)	Tutupaca	105	340
		Crucero	70	
		Calacoa-Putina	100	
		Pinaya	35	
		Puquio	30	
Rank B	Followin the Rank A (The authorization for exploration is to be waited for.)	Chivay-Pinchollo	150	300
		Ancocollo	90	
		Ccollo/Titire	35	
		Ulucan	25	
Rank C	Relatively early development is expected, but the resource potential is to be confirmed.	Cailloma	5	(60)
		Huancarhuas	(30)	
		Paila del Diablo	(15)	
		Pararca	(10)	
Rank D-1	The resource potential is to be confirmed. (Based on the existing data, high potential resource can be expected.)	17 fields (including Chancos and Jesus Maria)	—	Unknown
Rank D-2	The resource potential is to be confirmed. (Based on the existing data, the existence of high potential resource cannot be expected.)	24 fields	—	Unknown
Others	Environmental impact of possible geothermal project should be evaluated. If the impact can be avoided or mitigated sufficiently, the development should be permitted.	7 fields (including Borateras, Calientes and Chungara-Kallapuma)	—	>225

Note: Number of the evaluated geothermal fields is 61 in total.

- Rank A: Among the promising fields chosen, five (5) fields where the authorization of exploration right has been already granted are categorized in this class. Early power development can be expected in the fields since the granted private companies are obliged to accomplish their exploration activities within three years.
- Rank B: Four (4) fields where the authorization of exploration right has not been granted are categorized in this class. The fields are next to the Rank A fields, and relatively early developments of geothermal resources can be expected in these fields.
- Rank C: Four (4) fields where the project economy is relatively low, or the fields where relatively high resource potential is expected and the exploration right has been authorized, are categorized in this class. The development scale in the fields except the 13 promising fields is conservatively assumed as 30 % of the estimated resource potential. Although the authorization of exploration right has been granted in these fields, it is desirable to continue investigations for resource confirmation or project feasibility.

- Rank D-1: The fields where reconnaissance survey has been done are categorized in this class. Additional resource surveys are necessary. In these fields, geochemical data show relatively high prospectiveness. Higher emphasis in resource study should be placed on Rank D-1 fields.
- Rank D-2: The fields where only simple survey has been conducted are categorized in this class. Much more studies are necessary. The existing data obtained so far do not show high prospectiveness.
- Others: Four (4) fields are located in the vicinity of national parks or historical sanctuary. Also, there were three (3) fields that exist inside of regional protected area in Tacna Province (Vilacota-Maure Regional Conservation Area).

II-3.3 Road Map of Geothermal Power Development

An integrated plan for geothermal power development in Peru that aims to develop 1,000MW electricity by 2030 was devised in conformity with the objectives stated in the recommendations, considering the results of ranking of geothermal fields. The yearly progress of the integrated development plan (the Road Map) is shown in Table II-3.3.1 and Fig. II-3.3.1.

Table II-3.3.1 Intended commencement year of power generation in geothermal fields

Rank for Priority	Region	Field Name	Area Name for Application of Authorization	Authori-zation	Possible Power Output (MW)	Target Year
A	Tacna	Tutupaca	Tutupaca	V	105	2016
A	Moquegua-Tacna	Crucero	Crucero	V	70	2016
A	Moquegua	Calacoa-Putina	Quellaapacheta	V	100	2017
A	Puno	Pinaya	Pinaya	V	35	2018
A	Ayacucho	Puquio	Geronta	V	30	2018
B	Arequipa	Chivay-Pinchollo 1	Pinchollo / Achumani / Hualca Hualca		50	2018
B	Tacna	Ancocollo	Ancoccollo / Ocururane		90	2019
B	Moquegua	Ccollo/Titire	Ccollo		35	2020
B	Moquegua	Ulucan	Huaynaputina		25	2021
B	Arequipa	Chivay-Pinchollo 2	Pinchollo / Achumani / Hualca Hualca		100	2022
C	Ancash	Huancarhuas	Rupha	V	30	2018
C	Ayacucho	Paila del Diablo	Umacusiri	V	15	2019
C	Ayacucho	Pararca	Sara Sara	V	10	2020
C	Arequipa	Cailloma	Turu	V	5	2021
D	-	unknown	-		300	2024-2030

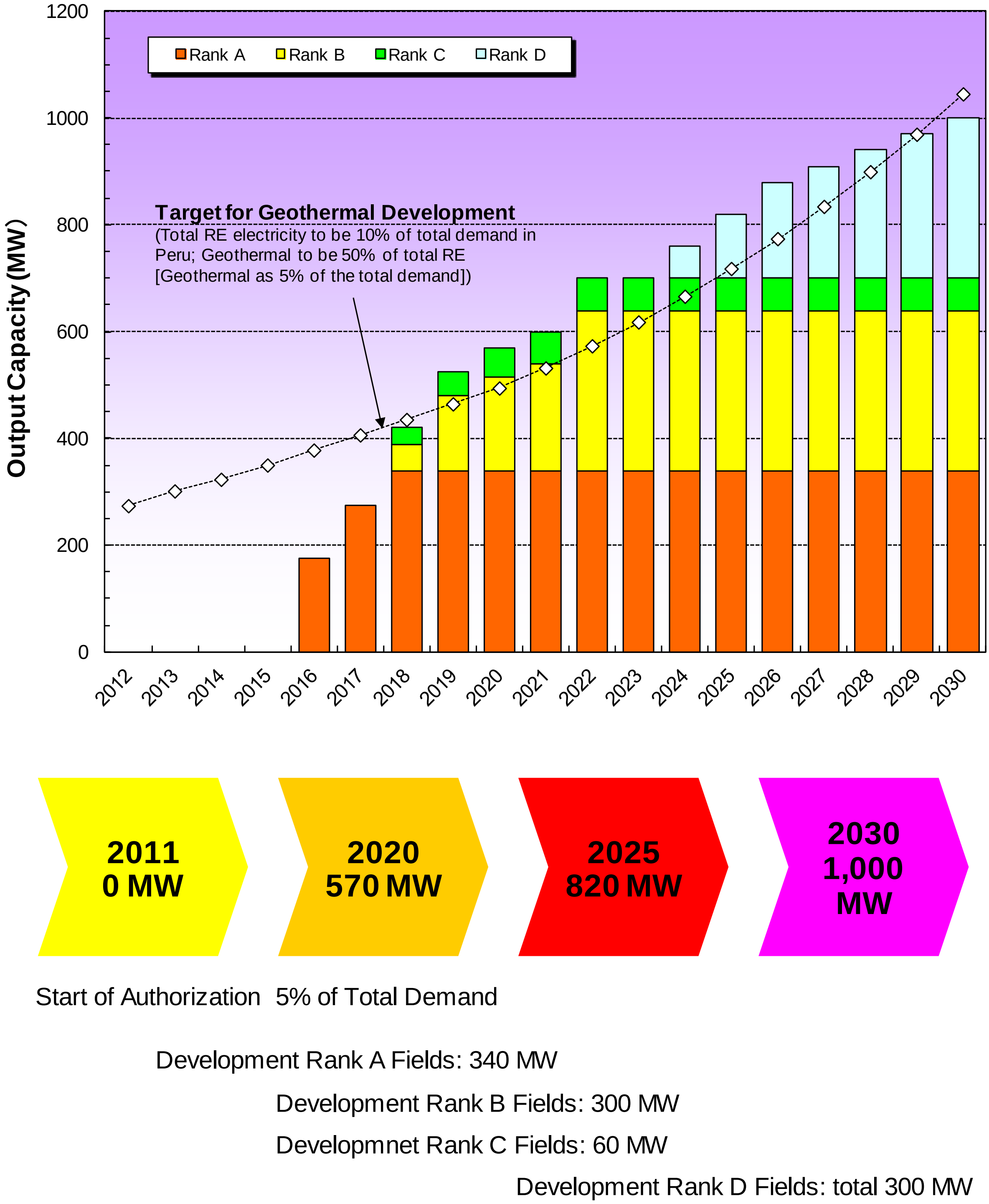


Fig. II-3.3.1 Road map of geothermal power development in Peru

The intended commencement years of power generation in geothermal fields were so determined that the total output could catch up the 5% of total electricity demand as early as possible. It was assumed that the load factor of future power plants is equally 85%. The earliest commencement of power generation will be 2016 even for the Rank A fields where the authorization of exploration right has been already granted in 2011, since three more years will be required for exploration activities, and three more years will be necessary for plant construction activities. It is assumed that two more years will be necessary for the commencements of Rank B fields, that is, the commencement of Rank B fields will be 2018. For Chivay-Pinchollo field where the development scale is bigger than others, the first period of development is assumed to be completed by 2018, and the second period of development is assumed to be finished 2022. For Rank C fields, the earliest period of commencement of power generation is assumed to be 2018, since more time will be required comparing with those of Rank A fields for investigation and confirmation of geothermal resources. The resource development in Rank D fields (Rank D-1 and D-2) largely depends on the progress of future studies and it is difficult to estimate the commencement period of power generation in Rank D fields. Thus the commencement period for Rank D fields is assumed to be not earlier than 2024.

The milestones in the intended development Road Map were set as follows: 570 MW in 2020, 820 MW in 2025, and 1,000 MW in 2030. For the realization of the objectives, proper managements and instructions must be given to the exploration activities practiced by private companies, and it is desirable for the government of Peru to support or to participate in the exploration activities when the exploration studies do not work effectively. In addition, the Road Map should be revised and updated if necessary according to the progress of the exploration/development activities.