EUROPEAN COMMISSION

Blue Book on GEOTHERMAL RESOURCES

Blue Book on GEOTHERMAL RESOURCES

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BLUE BOOK ON GEOTHERMAL RESOURCES

"A Strategic Plan for the Development
of European Geothermal Sector"

Executive Summary

Executive Summary

Geothermal energy is one of the indigenous and environmentally friendly energy resources in use which the European Union intends to expand in order to reach its established goals for RE contribution to gross energy consumption in Europe, from the present 6% to 12% by the year 2010.

A key aim of the Blue book is to identify a series of measures which could effectively promote the use of geothermal energy in the EU, EEA countries and Switzerland, as well as countries that are likely to become associated with the EU in the near future (Agenda 2000 countries).

This study describes the present world-wide status of geothermal development, and the availability of geothermal resources. The advantages and benefits that make geothermal energy competitive, environmentally beneficial, reliable and safe compared to most other energy sources are also presented.

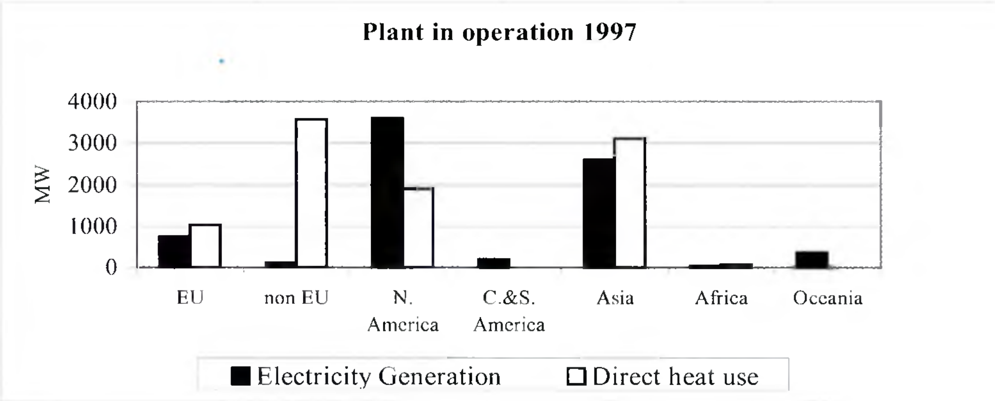
A detailed analysis of the global market conditions is also presented with short term opportunities and medium term development prospects by 2010. Furthermore, the Blue Book identifies a series of actions to develop the geothermal sector in the EU, particularly measures to increase the presence of European operators in the domestic and world geothermal markets.

GEOTHERMAL RESOURCES

Geothermal resources are suitable for many different types of uses but are commonly divided into two categories, high and low enthalpy and according to their energy content. High enthalpy resources (>150 °C) are suitable for electrical generation with conventional cycles, low enthalpy resources (<150 °C) are employed for direct heat uses and electricity generation using a binary fluids cycle.

In recent years, significant advances have been made in use of ground source (geothermal) heat pumps for extracting energy from very low temperature resources (<20°C) for both heating and cooling. Other applications also use the seasonal energy storage in shallow formations (>200 m) which make use of the energy storage capacities of the rocks. These relatively recent uses have multiplied the number of countries and regions that can harness geothermal energy.

The present installed capacity and energy production from geothermal resources for electricity generation and direct heat use in the world is summarised in the figures below.



Electricity is presently produced from geothermal produced steam in 21 countries all over the world. Geothermal electricity generation in Europe is about 4,300 GWh/y, concentrated almost exclusively in three countries: Italy, Iceland and Turkey. The generation of the same amount of electricity from an average coal-fired plant would displace the emission to the atmosphere of 5 million tons of carbon dioxide, 46 thousand tons of sulphur dioxide, 18 thousand tons of nitrogen oxides, and 25 thousand tons of particulate matter every year.

All European countries exploit about 18,000 GWh/y of geothermal energy for direct heat uses such as space heating, greenhouses, balneology and processing industries representing about 52% of world production. EU countries represent only 11% of this total, whereas Iceland alone uses 17% of the total. Almost all fifteen EU countries have direct heat uses (most commonly for spas and bathing) while large space heating is mainly used in France, Germany and Italy.

COMPETITIVENESS OF GEOTHERMAL ENERGY

Geothermal energy has been produced commercially on the scale of hundreds of MW for over three decades both for electricity generation and direct utilisation in many parts of the world. Geothermal energy has a number of positive features which make it competitive with conventional energy sources and some reneweables sources. These features include:

- it is a local energy source that can reduce demand for imported fossil fuels,
- it has a large positive impact on the environment by displacing combustion of fossil fuels,
- it is efficient and competitive with conventional sources of energy,
- geothermal plants can operate continuously, without constraints imposed by weather conditions, unlike other renewable sources,
- it has an inherent storage capability and is best suited to base-load demand,
- it is a reliable and safe energy source which does not require storage or transportation of fuels.

Moreover, pronouncements from the recent global conference held at Kyoto on climate change and EU strategies on environment control, recently declared in the White Paper from the Commission, include targets for the greater use of renewable sources of energy. A greater use of geothermal energy will have a large net positive impact on the reduction of carbon dioxide and other pollutants which clearly fits this strategy.

The more recent generation of geothermal power plants, emits on average only 136g/kWh of carbon dioxide per kilowatt-hour of electricity generated compared to the 453g/kWh of carbon dioxide for a power plant fuelled by natural gas or 1,042 g/kWh of carbon dioxide for a coal fired power plant.

At present the renewable energy sources with the greatest potential and the lowest emissions in Europe, in the short to medium term, are hydropower and geothermal energy. In this respect, it should be noted that the capacity factors for hydro and geothermal in Europe is now more than 70%, whereas 20-35% are typical values for solar and wind.

The availability factor of geothermal energy, expressed as the percentage of time the rated energy may be produced, depends mainly on the nature of the resource and secondarily on the availability of the equipment. Experience shows that this availability is often over 90% for geothermoelectric power plants and even higher for direct use plants. Under these circumstances the plant factor expressed (as the percentage of time the plant actually produces energy) is almost equal to the availability factor. For direct use, the plant factor is practically coincident with demand. Such factors are higher than those for fossil fuel plants and far higher than other renewables.

Taking the above factors into consideration only an increase in the use of biomass, hydro and geothermal energy can realistically influence the level of greenhouse gas emissions in Europe over the next 5-10 years for total energy use. These technologies can displace considerably more greenhouse gas emissions than any contribution from the foreseeable increase in utilisation levels from other renewables. Wind energy could make a significant contribution by 2005 and is growing rapidly.

Both high and low enthalpy geothermal power plants, can be implemented in modular units. This approach reduces the initial capital outlay and spreads investment, it also enables the availability of the resource to be evaluated before full-scale operation commences and allows revenue generation at the earliest possible opportunity, thereby improving the overall scheme financial performance and reducing exposure to geological or mining risk.

This study includes an example of a typical cost breakdown for a field and plant investment based on a reference 55 MW geothermal power plant and then proceeds to examine factors which can affect its economic performance. This reference or base case is used purely as an illustrative example.

Costs, and therefore the economic viability of geothermal energy schemes, are in reality strictly dependent on site-specific conditions and the type of application. It should be emphasised that the electricity generation cost is most sensitive to the specific cost of drilling wells and individual well productivity which varies considerably between different countries.

The great variability of technical and economic parameters involved in the implementation of geothermal projects (the specific field cost plus the plant cost) means that each geothermal project will invariably have a unique production cost and no broad generalisation is possible.

In the case of direct heat uses the investment cost and heat production cost vary considerably and reflect regional factors evident in different countries, and different types of application. The main factors which influence the production cost are the characteristics of the resources (depth, temperature, flowrate etc.), local climatic conditions, local heat demand and the pattern of heat consumption (large district heating systems, individual heating or cooling, geothermal heat pumps, others uses, etc.).

The overall competitiveness of geothermal energy is also determined by comparison with both conventional and other renewable energy sources. Usually the cost of energy is based upon standard economic and financial analyses. The funding of geothermal projects by the main international financing agencies are currently based on strict application of a least-cost analysis as part of their procedure for granting loans for energy projects.

It should be stressed that at present in Europe, the low cost of fossil fuels, especially natural gas, makes only the best geothermal resources competitive from a strict financial comparison.

Nevertheless, geothermal energy could become more competitive compared with conventional sources of energy if the comparison is not limited exclusively to strict financial criteria, but also takes account of other factors such as shadow costs and their economic consequences (the so-called "externalities").

The related *external costs* of conventional generation, (which in the case of geothermal resources is similar to other renewable sources) become **external benefits,** and are a parameter that substantially changes the level of the competitiveness in favour of geothermal energy. These external benefits can be quantified in monetary terms and should be an acknowledged factor for comparative purposes.

If externalities are included among the investment parameters, the full social and economic benefits can be realised, however, this may require public incentives to ensure successful investment in geothermal energy is possible. The acquaintance to the investor of this "added value" should not be regarded as a subsidy but looked on as a realignment of the economic benefits which arise from the project.

The external cost of traditional fuels has been estimated to be almost 10 times higher than the corresponding cost of renewables and almost 50% of the overall economic cost (against 1% for the renewable sources case).

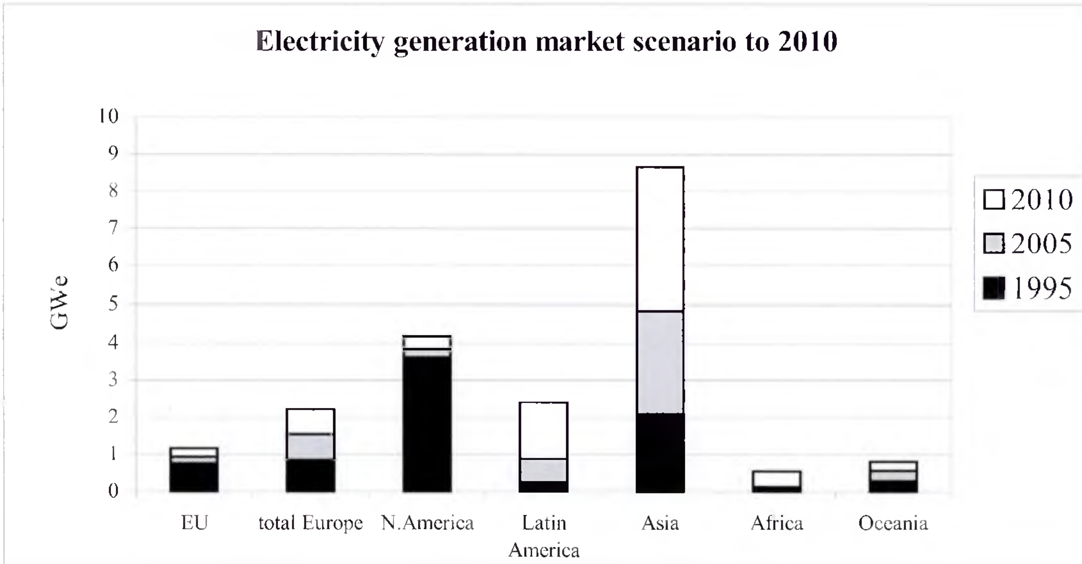
The quantification of externalities is a crucial aspect if geothermal energy is to be fairly evaluated, and also avoids penalising projects evaluated purely on the basis of a cash flow analysis.

MARKET SITUATION AND PERSPECTIVES

The Blue Book has identified a series of measures that could be used to expand the exploitation of geothermal resources in Member States and increase the presence of European operators in the world geothermal market. This market is rapidly expanding, and European operators risk loosing their traditional dominance in the sector. This is due at least in part to the aggressive policy of the non-European industry which now provides a wide range of geothermal products and services, and a weak industrial/political lobby in Europe which favours decentralised geothermal interests founded in national bodies.

An average scenario up to the year 2010 for the **world electricity generation market** is shown in the below figure.

The greatest expansion in electricity generation in Europe is predicted for Iceland, Russia, Italy and Turkey.



The largest expanding markets are currently in South East Asia and Central-South America where market conditions differ. In the first region two main producers (Indonesia and the Philippines) have the same type of free market conditions while in Latin America a transition from state run monopolies to a concession system is currently in progress.

Private operators (mainly from the USA) are gradually dominating the South East Asian markets for electricity production from geothermal energy and their presence appears to be overwhelming the European competitors.

The Latin American market still seems partially open to penetration from European operators, which is generally positively received by local authorities on the continent. Efforts should be made to steer the European industry in this direction because non-European operators are presently moving to consolidate their presence in the Central and South American markets.

American and Japanese operators represent serious competition for the European geothermal industry which has not been able to meet the strategic and financial risks that are now dominating free-market economies which have been progressively imposed on the world market for electricity production including geothermal energy.

As a consequence European operators risk being push progressively to the fringe of the geothermal world market for electricity production and related businesses, or only sustaining a presence as subcontractors of services and components. The dominance and management, as well as most of the profits from projects, will consequently remain outside the European industry.

In contrast, **the market for direct uses** of geothermal energy has extensive potential in European countries where there are large resources to be exploited and a long tradition of using geothermal heat use. Opportunities both to extend this usage and to develop related businesses exist, especially in Eastern European countries and CIS countries, where large centralised district heating systems already exist which mainly use conventional fuels.

The market for direct use applications only exists when both resource and demand are coincident. This is why geothermal resources are only used where there is a large local energy demand. It is conceivable that new direct heat markets could be opened up where geothermal resources exist for example, horticulture, tourism and industrial processing.

Carbon dioxide emission reduction and energy saving aspects are becoming increasingly important in developed countries, and direct utilisation of geothermal resources could make a large contribution to this objective.

A minimum case scenario of the market for direct heat uses to the year 2010 in the EU, and some others European countries, is shown in the figure below.

This scenario is expected to grow considerably if the development of geothermal heat pumps in many European countries will be implemented. Referring to the rest of the world, the market for the direct heat uses is quite unforeseeable and its development is generally subordinate to the implementation of national policies devoted to the reduction of pollutants emission.

ACTIONS IN FAVOUR OF THE GEOTHERMAL ENERGY

The EU action plan should have two goals:

- to increase the exploitation of geothermal energy in the EU and associated countries;
- to support European firms within the sector to increase their share of the world market

Support for the spread of exploitation and use of geothermal energy will be directed mainly within the EU and associated countries, while support to EU operators will be directed at all other countries.

The recent White Paper "Energy for the Future: Renewable Sources of Energy" describes the EU strategy and objectives, but suggests that each Member State should decide its own strategy according to its own potential and resources.

This implies that an effective action plan will be outlined and decided at Member State level. The EU would be responsible for the guidelines and pressing Member States and Local Authorities to drive the implementation of new geothermal initiatives and in some cases to implement direct actions in favour of them, aiming at following:

1. **To stimulate the creation of European consortia and joint ventures among different subjects (engineering firms equipment manufacturers, electric power companies, financing agencies) interested in investing in geothermal projects in Europe and abroad to cope with the competition from non European companies. This could be achieved by giving priority to programmes and projects including co-financing of European industrial partners for preliminary identification studies, prefeasibility studies (of the advance type, reimbursable during execution of the work) and plant implementation.**

   This action could be focused specifically at Latin American and Chinese markets which currently appear the most open and "free" to EU operators.

2. **To favour National Geothermal Associations, and the European Branch of IGA, in their non-profit making activities for the promotion, information, dissemination and transfer of experience and contacts within the world geothermal community. These organisations, together with the EGEC, should become the principal EU contact for geothermal energy matters such as the EU geothermal programmes and statistics reference, information for decision makers, awareness communication, promotion, contacts with other renewable sources association and other European industrial association, etc.**

3. **To support the newly created EGEC (European Geothermal Energy Council) among the European geothermal manufacturers and service companies which operate within Europe and abroad in a similar way to the Geothermal Energy Association in the USA. The EGEC would strengthen European consortia among energy operators wanting to invest in geothermal projects in Europe and**

abroad, and assist European companies in competition with existing Japanese and US consortia.

4. **The maintenance and improvement of the EU's existing research and financing programmes, from DGI, DGXII, DGXIII, DGXVI and DGXVII dedicated to energy projects including Alure, Phare, Tacis, Joule, Inco-Copernicus, Structural Funds, Altener, Synergy and Thermie. These programmes have in the past positively influenced research, testing and promotion of new geothermal applications in recent years as the knowledge of geothermal problems and opportunities has grown.**

5. **To promote the environmental benefits of geothermal energy through favourable financing condition such as:**

   - **tax exemptions or reductions for RE products;**
   - **tax incentives to be addressed to geothermal projects financing**
   - **financial incentives for end-users to buy equipment and services**
   - **loans and special interest rates devoted to investments in RE resources in general.**

6. **Geothermal energy should be included in specific "target projects" and demonstration projects such as the European Green Cities, which is supported by the EU Thermie programme, both as an environmental friendly resource and as an indigenous energy supply for saving imported fossil fuels. Examples of special target projects could be:**

   - **partial or total replacement of fossil fuels by geothermal energy for the generation of electricity in the Azores, the Greek islands, as well as Italy's small islands and the Canaries which would provide environmental and economic benefits to these communities. Both technical assistance and public relations activities are needed to promote geothermal electricity production in these areas (see "Campaign for take-off, paragraph 3.2.4 of integration of RE in 100 Communities [1]);**

   - **technical and financial support for demonstration projects in the use of medium temperature geothermal water for electricity production using binary fluids.**

7. **To establish an insurance system for EU countries in order to cover the geological risk which is an effective measure to stimulate and re-launch the geothermal European market and improve the exploitation of this renewable resource. This system could also be demonstrated within the EU and used as an example for analogous initiatives in other areas/countries of the world.**

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[1] "Energy for the future: Renewable Sources of Energy - White Paper for a Community Strategy and Action Plan - 1997".

8. Implement proper actions devoted to the systematic integration of geothermal energy into existing and new EU and national RE development programmes. This action should move in two directions:

- **integration of geothermal energy in national and regional New and Renewable Energy development programmes since in some EU countries geothermal energy is not included and in some cases is not even considered as a renewable form of energy.**

- **integration of geothermal energy use in the development of new district heating systems and the rehabilitation of existing networks within EU countries and especially in countries which could become associated in the near future. This integration could start for rehabilitation and modernisation projects of large diffused district heating systems in different European countries (Agenda 2000, Russia and other European countries) financed by EU programmes (TACIS, PHARE etc.) or international financing institutions (WB, EBRD etc.). The integration of geothermal energy could become a compulsory condition, when applications are made for investment funds**

Special attention should be paid to the possibilities offered by the rapid expansion of direct use applications for geothermal energy in Central and Eastern European countries and CIS countries, where unexploited but plentiful geothermal resources have been identified. There is a long tradition of using geothermal energy for direct applications (mostly for balneology and greenhouses) in many of these countries, and most of the towns have district heating systems using water heated by hydrocarbons.

With education as well as financial and technical support, a significant reduction could be made in carbon dioxide emissions through replacement of coal and other hydrocarbons partly or totally with geothermal and other non-polluting energy resources. There is wide scope for the integration of indigenous energy sources in the space heating market in these countries.

9. Promote directives in order to acknowledge RE investments (including geothermal) with an extra price or a contribution for the KWh_e/KWh_t produced which corresponds to the external benefit derived from the substitution of conventional energy sources. The relative funds could be achieved by a tax (green tax) charged on the KWh_e/KWh_t produced through conventional sources. (Considering the present prevailing contribution from the latter the extra charge at the same should be negligeable in absolute terms).

10. **Increase the use of information brochures and actions of the "Multi-energy" type, with the objective of increasing the level of information and confidence of using geothermal energy by decision-makers, private and public operators, town planners, designers, even within EU programmes. The establishment of a proper methodology for a cost evaluation of low enthalpy geothermal projects, possibly supported by software, would be a useful tool. Moreover, there is a great need for demonstration projects in individual countries to convince the public and decision makers of the viability of geothermal energy, both alone, and in integrated solutions with other locally available energy sources such as waste burning and biomass.**

11. **Promote a detailed study for the evaluation, in quantitative terms of the external benefits from substitution by geothermal applications. This evaluation should be based on statistical data from specific applications (electricity generation and direct uses) in EU countries and contrasted with comparable conventional options.**

12. **Considering the good development perspectives of this application, special attention could be devoted to the promotion and support for the GHP market via the followings steps:**

    - **decrease the cost for ground loop installation (standardised technologies with drilling companies, better access for the public to the drilling company information, etc.);**

    - **provide low interest loans for GHP installation;**

    - **provide better information for the public (full and easy access to information related to GHP technologies) and better co-ordination between active operators (drillings, companies, main features, engineering, etc.). A specific programme should be implemented, or the EGEC (European Geothermal Energy Council) could establish and manage a publicity campaign (similar to what has already been achieved in Switzerland and the USA), which is aimed at domestic users communities and even individual countries.**

The general public and decision makers should be informed of the fact that geothermal resources exist in every country and that these can be used to substitute environmentally degrading fossil fuels for every day activities such as the heating and cooling of buildings.

European Commission
DIRECTORATE GENERAL for ENERGY

BLUE BOOK ON GEOTHERMAL RESOURCES

"A Strategic Plan for the Development of European Geothermal Sector"

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" The Blue Book on Geothermal Resources " by:

as Contractor.
CESEN S.P.A. Piazza della Vittoria 11A/8, I - 1612 Genova - Italy,
as Co-Contractors:
BRGM - Tour Mirabeau, 39-43 Quai André Citroen, F - 75739 Paris Cedex 15 - France,
ETSU - Harwell, Didcot, Oxfordshire OX11 ORA, United Kingdom,
GTN - Geothermie Neubrandenburg GmbH, D – 17008 Neubrandenburg, Germany,
ORKUSTOFNUN - Grensasvegur 9, IS - 108 Reykjavik, Iceland,

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Genoa, May 1998

Introduction

Geothermal energy has been produced commercially on the scale of hundreds of MW for over three decades both for electricity generation and direct utilisation in many parts of the world. Large scale development of geothermal energy began with electricity generation in Italy and district heating in Iceland during 1930's. There is some direct utilisation of geothermal energy in 35 countries in Europe, and electricity is produced commercially in six European countries (France (Guadeloupe), Iceland, Italy, Portugal (Azores), Russia and Turkey.

Geothermal energy is more firmly established as a commercial energy source in Europe than most other new and renewable energy sources, such as solar, wind and wave energy. In this sense, it is more comparable to hydropower. Unlike hydropower, however, only a small fraction of the geothermal resources of Europe are harnessed at present.

Following the United Nations conferences on the environment in Rio (1991) and Kyoto (1997), the European Union has committed itself to reducing the overall emission of greenhouse gases by at least 8% below 1990 levels in the commitment period 2008-2012. Prior to year 2012, biomass, hydro and geothermal, and to a less extent wind energy, are economically ready to make a significant contribution towards an overall reduction in the CO2 emissions in Europe.

In recent years the European Commission has sponsored various initiatives to increase the contribution from renewable energy sources to reach a target of total energy consumption from renewables of 12% by the year 2010. This aim means that the present renewables energy contribution for the EU of less than 6% would need to double during the next decade.

The two-fold increase in the current market penetration of renewable energies by 2010 will also have additional positive benefits including a 17% reduction of imported fossil fuels and a drop of 402 million tonnes/year in CO2 emissions. This ambitious target will only be achieved with the adoption of a Community strategy to tackle the numerous non-technical barriers which presently hinder the penetration of renewable energy technologies in energy markets.

For some time various Community RTD and demonstration programmes have helped in creating European technological progress in the renewable energy sources sector. Recently the Commission's ALTENER I programme has been used to develop specific financial instruments for renewables promotion among its energy objectives. Moreover, the European Commission in its White Paper "Energy for the Future: Renewable Sources of Energy" has outlined its views with regards to Community strategy and includes an action plan for renewables.

Geothermal energy is one of a number of indigenous and environmentally friendly energy resources which the Commission of the European Communities intends to promote for use in Europe and to improve its competitiveness, enhance security of supply and improve environmental protection.

The development of geothermal energy can also widen the business and employment opportunities within the European geothermal sector (manufacturing industry, engineering and consulting companies, drilling and equipment companies,etc.), not only in local and regional markets but also world-wide.

The present study describes the status of geothermal development and the availability of geothermal resources as well as the advantages and benefits that make geothermal energy competitive, environmentally beneficial, reliable and safe compared to most other energy sources.

The Blue Book aims to identify a series of measures which could be effective in the promotion of the technology. The main emphasis is placed on the EU and associated countries as well as countries that are likely to become associated with the EU in the near future (Agenda 2000 countries).

This Blue Book, in common with comparable reports on other renewable energy technologies, takes a global view of current trends in the market and the resource. The study encompasses a review of the size of the resource in 104 countries, the status of the technology, economic conditions which govern investment, the prospects for the market within the EU and world-wide. This report includes recommendations for the development and use of geothermal energy in Europe up to 2005 and 2010.

The study has been organised in two sections:

1. A Main Report which summarises the key issues on geothermal energy. These include the present nature and size of the resource, technical and economic aspects of the technology, the environmental benefits, a market analysis and the relevant actions and goals for the successful promotion of the technology.

2. The Annexes include surveys of geothermal resources in European countries and in selected non European countries, technical data, an economic analysis and a market assessment of the global geothermal industry. This assessment could, in future, serve as a database for further analyses and periodic revision.

BLUE BOOK ON GEOTHERMAL RESOURCES

"A Strategic Plan for the Development of European Geothermal Sector"

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BLUE BOOK ON
GEOTHERMAL RESOURCES

Chapter 1

Chapter 1

GEOTHERMAL RESOURCES AND THEIR USES

1.1 Introduction

Geothermal energy is the natural heat of the earth. Immense amounts of thermal energy are generated and stored in the earth's core, mantle, and crust. The heat is transferred from the interior towards the surface mostly by conduction. This heat flow makes temperatures rise with increasing depth in the crust on average by between 25-30 °C/km.

An average thermal gradient of 30 °C/km means that at a depth of 2 km the temperature in the rocks is around 70°C in areas where there is no volcanic activity and where ground water is not affecting the thermal gradient.

The exploitable geothermal resources are generally related not to conductive systems but to convective ones. This means that the heath is brought near the surface by fluids (mainly waters) flowing vertically from depth toward the surface, so that sufficiently high temperature may be reached by drilling at economical depth.

Geothermal resources are suitable for many different types of uses and according to their temperature are commonly divided into two categories, high and low enthalpy. High enthalpy are suitable for electrical generation with conventional cycles, low enthalpy resources are employed for direct uses.

Exploitable geothermal systems occur in a number of geological environments.

- **High temperature resources**, used for power generation (with temperatures above 150 °C) are confined to areas geologically active, that is where movements of the earth crust bring the magma near the surface.

  The most important and widespread of these areas is the so called "Pacific ring" or "fire belt" that encompasses the American and Asian continental borders around the Pacific Ocean where a compressional tectonic regime often associated with subducting crustal plates is active. This area includes all the Latin American geothermal fields from Chile to Mexico as well as the Californian ones, and those of Kamchatka, Japan and the Philippines. The same kind of conditions exist in Indonesia and in the central Mediterranean area from Turkey to Greece and Italy.

Another kind of geological environment which favours the existence of geothermal resources is where continental spreading is active, the so called mid-oceanic rifts (extensional tectonic regimes). These include Iceland and the Azores in the Atlantic Ocean and Hawaii in the Pacific. Mid continental rifting such as the African rift system also yields geothermal potential.

- Conventional electric power production is limited to fluid temperatures above 150°C, but considerably lower temperatures are also used with the application of binary fluids.

  The use of cascade systems whereby high enthalpy fluid is used for electricity generation and the lower temperature fluid is passed through a series of different uses is practised in many countries, e.g. Iceland, Italy and Japan. This increases the overall energy efficiency significantly. In some cases a number of valuable minerals can also be extracted from the thermal fluids.

- **Low temperature resources** which are mainly used for heat production (with temperatures below 150°C) can, on the other hand, be found in most countries. These are formed by the deep circulation of meteoric water along faults and fractures, and by water residing in high porosity rocks, such as sandstone and limestone, at sufficient depths for the water to be heated by the Earth's geothermal gradient.

- Direct heat use is one of the oldest, most versatile and also the most common form of utilization of geothermal energy. Space and district heating, agricultural applications and aquaculture are the best known and most widespread forms of utilization. Industrial applications are also wide spread and become typical for specific aims where the geothermal resources meet local needs.

  In recent years, significant advances have been made in application of heat pumps for extracting energy from very low temperature resources (<20 °C) for heating and cooling. Seasonal storage in shallow formations (< 200 m) makes use of the energy storage capacities of the rocks. This adaptation has multiplied the number of countries and regions that can harness geothermal energy.

The major uses of geothermal resources are summarized in the diagram of Figure 1.1.

The major advantages of geothermal energy use over conventional energy sources and some of the other renewables sources that will be discussed and presented in this report are :

- it is a local energy source that can lead to a reduction in imported fossil fuels
- it has a large positive impact on the environment
- it is efficient and competitive with conventional sources of energy
- it is a reliable and safe energy source which does not require storage or the transportation of inflammable fuels.

World-wide geothermal utilisation for electricity generation and direct use is shown in Figure 1.2.

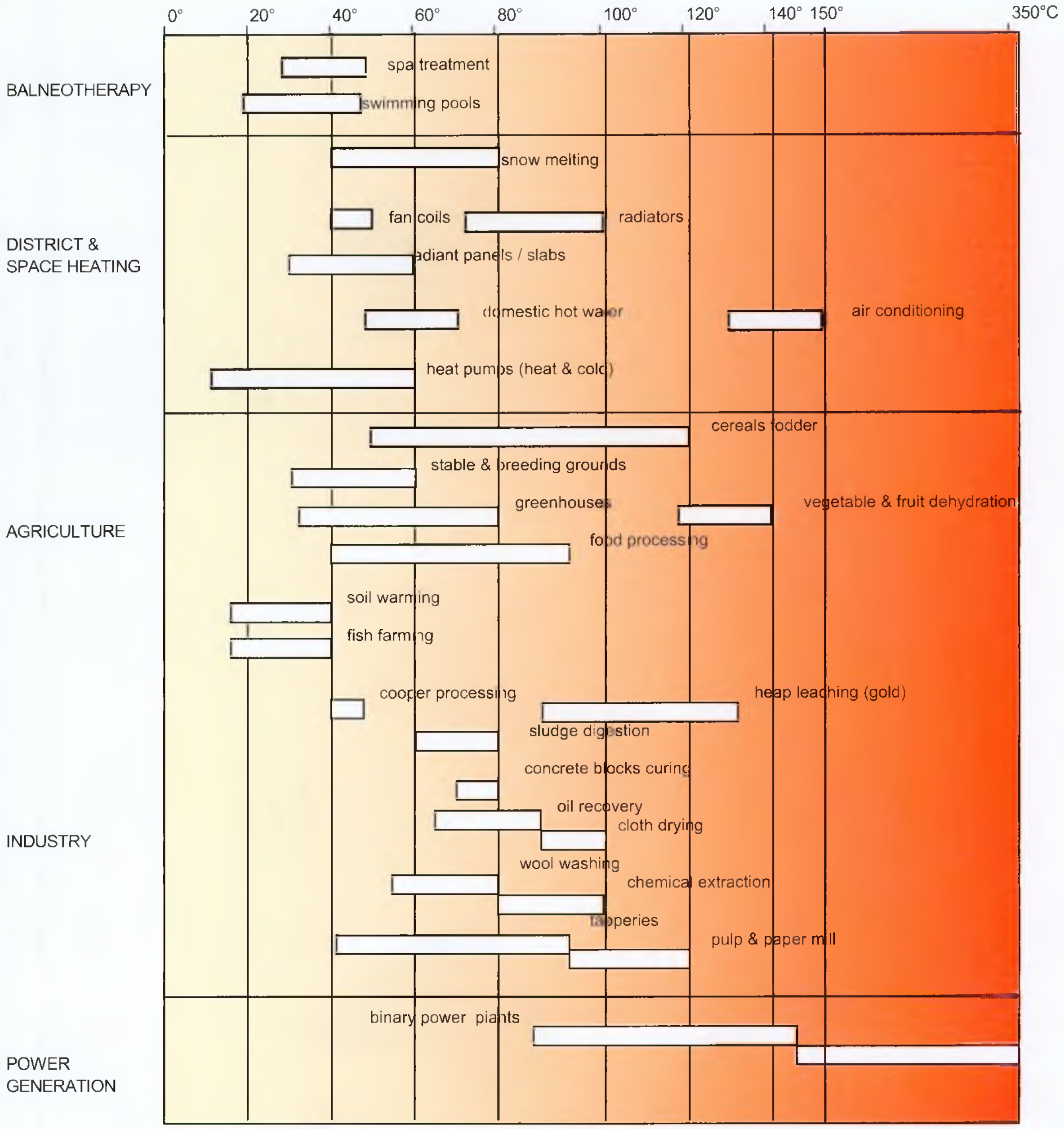

Figure 1.1 The major uses of geothermal resources at low - medium - high temperatures

Global electricity generation from geothermal resources is about 45 TWh/y and the installed capacity is about 7,700 MWe. The total world thermal energy production is about 35 TWh/y and the installed capacity is about 9,700 MWt. The data presented in the following tables for the geothermal utilisation reflect the worldwide situation updated in 1977 of the installed capacity (MWe or MWt) and energy produced per year (GWh_e/y or GWh_t/y) of the plants in operation. The estimated geothermal potential assessed from the probable and possible resources, for both electricity generation and direct heat uses, is shown in Figure 1.3 and Figure 1.4 respectively.
Detailed data on the nature and size of the geothermal resource, plus details of existing geothermal plants and activities for each of the 104 countries evaluated in this study, are summarised in the “Country Papers” presented in Annex 1.1.

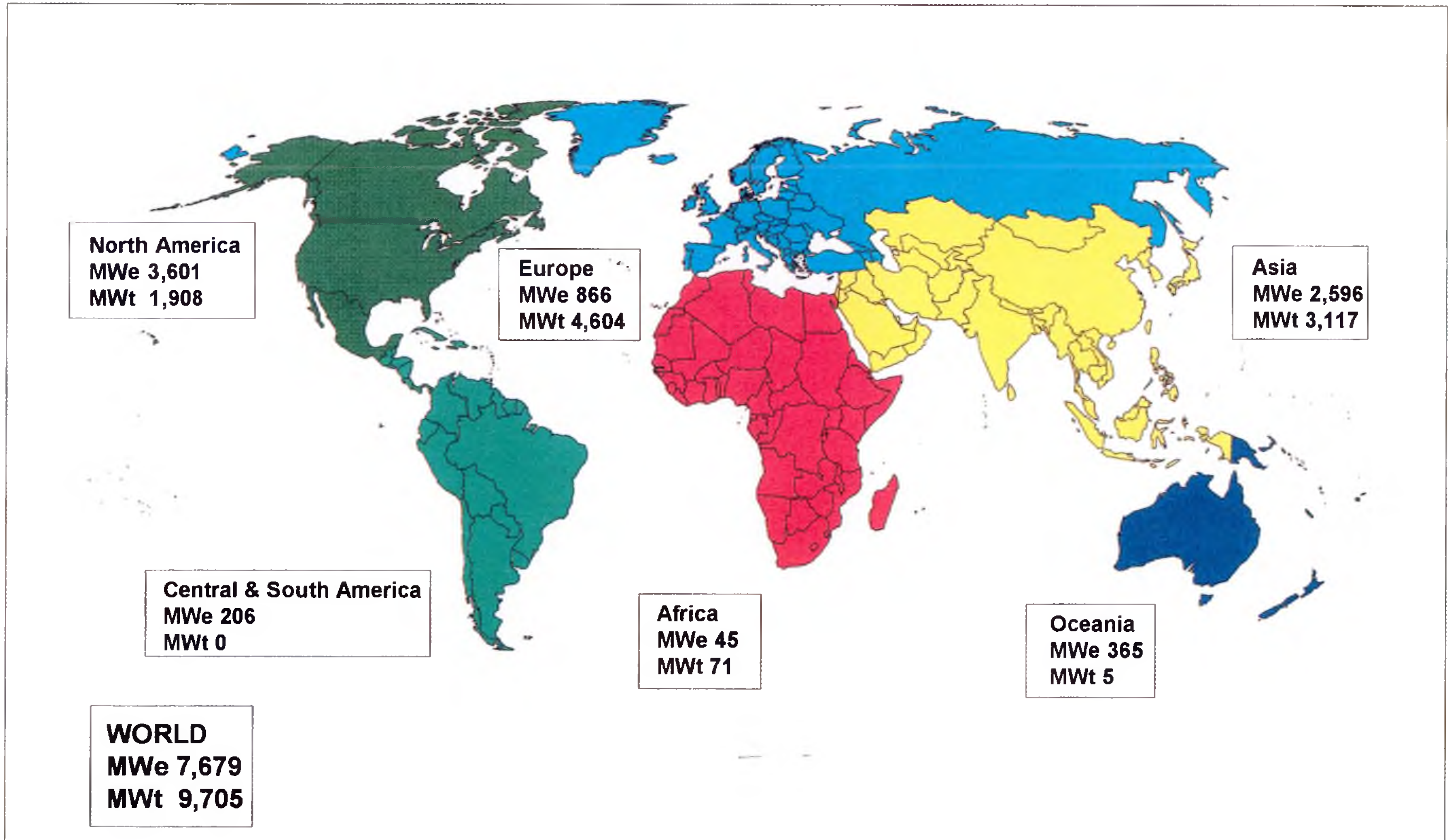

Figure 1.2 Geothermal utilisation in the world for electricity generation (MWe) and direct heat uses (MWt)

1.2 Resources and present uses in Europe

Most European countries have some exploitable low-enthalpy geothermal energy resources whereas high enthalpy resources, suitable for electricity production in continental Europe, are only found at economic drilling depths in Italy, Greece and Russia. High enthalpy resources are often present in European islands or those affiliated with EU member states. These localities include Iceland, the Azores (Portugal), Guadeloupe (French TOM) and the Canary Islands (Spain). Some of these resources are already exploited.

The geothermal utilisation of 42 European countries has been evaluated in this study (15 EU countries, 3 EEA countries, 11 Agenda 2000 countries, Russia, Switzerland, Turkey, as well as 11 other European countries). A summary of the installed capacity and generation from geothermal energy for both electricity and direct heat use (including the geothermal heat pumps) is shown in Table 1.1.

Electricity is produced from geothermal resources in six European countries but only two (Italy and Russia) in the continental Europe. The total installed capacity is 866 MWe and the total electricity produced is 4.3 TWh/y (equivalent to about 0.4 Mtoe). Direct heat use of geothermal energy is practised in 28 European countries. The installed capacity is about 4600 MWt and the thermal energy production amounts to 18 TWh/y (equivalent to about 1.6 Mtoe).

The direct use of geothermal energy can involve a wide variety of applications including the geothermal heat pumps. In most industrialised countries, a significant percentage of the energy consumption is devoted to heat production at temperatures of 50-100 °C, which are common in low-enthalpy geothermal areas. Most of this energy is supplied by the burning of oil, coal or gas at much higher temperatures. The scope for using geothermal water alone as well as in combination with other local sources of energy is therefore very large.

The direct use of geothermal energy is at a relatively advanced stage in European countries compared with other parts of the world. It supplies a wide range of applications and uses due to the versatility and demand for base-load heat demand plus the availability of the resource. European countries have been pioneers in the exploitation of geothermal resources. European experience and expertise in this sector has been duplicated by other countries world-wide. However, European operators should still be in a position to maintain their leading role in the development and utilisation of geothermal energy for both direct use and for electricity production.

	Electricity generation			Direct utilisation		
	Plant in operation 1997			Plant in operation 1997		
	(MWe)	(GWh/y)	(ktoe)	(MWt)	(GWh/y)	(ktoe)
Austria	-	-	-	21	84	5
Belgium	-	-	-	4	19	1.6
Denmark	-	-	-	3.5	15	1.3
Finland	-	-	-	0.1	0.5	0
France*	4.2	24	2	309	1,359	117
Germany	-	-	-	307	806	69
Greece	-	-	-	23	37	3.2
Ireland	-	-	-	0.7	1	0.1
Italy	742	3,762	324	314	1,026	88
Netherlands		-	-	n.a.	-	-
Portugal **	8	46	4	0.8	5	0.5
Spain	-	-	-	n.a.	-	-
Sweden	-	-	-	47	351	30
UK	-	-	-	2	15	1.3
EU countries	**754**	**3,832**	**330**	**1,032**	**3,719**	**317**
Iceland	**80**	**375**	**32**	**1,443**	**5,878**	**506**
Russia	**11**	**25**	**2**	**210**	**673**	**58**
Switzerland	**-**	**-**	**-**	**190**	**265**	**36**
Turkey	**21**	**71**	**6**	**160**	**800**	**69**
Bulgaria	-	-	-	95	346	30
Czech Rep.	-	-	-	2	15	1.3
Hungary	-	-	-	750	3,286	283
Poland	-	-	-	44	144	12
Romania	-	-	-	137	528	45
Slovakia	-	-	-	75	375	32
Slovenia	-	-	-	37	217	17
Agenda 2000 countries	**-**	**-**	**-**	**1,140**	**4,911**	**432**
Croatia	-	-	-	11	50	4.3
Georgia	-	-	-	245	1,000	86
Macedonia	-	-	-	75	151	13
Ukraine	-	-	-	12	60	5.2
Yugoslavia, FR	-	-	-	86	670	58
Other European countries	**-**	**-**	**-**	**429**	**1,931**	**213**
Non EU countries	**112**	**471**	**40**	**3,572**	**14,458**	**1,314**
Grand total Europe	**866**	**4,303**	**370**	**4,604**	**18,177**	**1,631**

* Guadeloupe (for electricity generation), ** Azores n.a.: data not available

Table 1.1 Geothermal utilisation for electricity generation and direct heat uses in European countries[1]

[1] * Plant in operation: installed capacity (MWe or MWt) and energy produced per year (GWhe/y or GWht/y)
* 1 GWh = 860×10^6 kcal 1 toe = 10^7 kcal

1.3 Resources and present uses in non-European countries

The utilisation of geothermal energy for electricity production and direct use in some non-European countries is presented in Tables 1.2 and 1.3.

Electricity is produced from geothermal resources in fifteen non-European countries: four industrialised (about 3,700 MWe) whereas the remaining eleven developing countries (about 3,100 MWe). The annual electricity production in these countries is some 41 TWh. Out of the total installed capacity in the non-European countries, about 53% is installed in USA and Mexico, about 38% in Asia (Japan, Philippines and Indonesia), about 5% in New Zealand with a further 4% from three countries from Central America.

Direct use of geothermal resources is now established in nine non-European countries. The total installed capacity is 5,100 MWt which produces about 17 TWh per year (equivalent to about 1.5 Mtoe). In the USA the largest use is for geothermal heat pumps (about 60% of the total), while in China direct heat use is distributed mainly among space heating, bathing, greenhouses heating and fish farming and in Japan mainly among bathing.

Geothermal electricity production is equally common in industrialised and developing countries. However, it is noticeable from the share of geothermally generated electricity in individual countries that geothermal energy plays a much more significant role in electricity production within individual developing countries than in industrialised ones. Good examples of this trend are El Salvador, Kenya and the Philippines. In all of these countries, 10-20% of each country's centrally generated electricity originates from geothermal steam. Costa Rica is likely to join this group of countries shortly. It is expected that some 15% of the country's electricity will be generated from geothermal energy by the year 2000. In Mexico about 5% of the electricity generated in 1994 was from geothermal sources. Geothermal electricity in Indonesia provides 4% of the primary energy consumed.

Geothermal energy is very important to several developing countries whose economies and energy demands are expanding rapidly. Electricity generated from geothermal sources is unlikely to be of comparable significance within the energy sector of individual industrialised countries due to the high electricity consumption per capita in these countries and the lack of sufficient geothermal resources. The principal exception to this statement is Iceland where 5% of the electricity is being produced from geothermal energy. By the year 2000, more than 15% of the electricity in Iceland will be generated from geothermal energy.

The pattern of direct heat utilisation from geothermal sources across the world is illustrated in Figure 1.5. Space heating and cooling is the dominant type of direct use (33%), but other common types are swimming pools, bathing facilities and therapeutic uses (19%), greenhouse heating (14%), heat pumps for both heating and cooling (13%), aquaculture (11%) and industrial process (9%).

	Electricity generation		
	Plant in operation 1997		
	(MWe)	(GWh/y)	(ktoe)
China	32	175	15
India	-	-	-
Indonesia	589	4,385	377
Japan	300	3,530	304
Philippines	1,445	8,000	688
Thailand	0.3	2	0.2
Asia	**2,596**	**16,090**	**1,384**
Ethiopia	-	-	-
Kenya	45	390	34
Zambia	-	-	-
Africa	**45**	**390**	**34**
Canada	-	-	-
Mexico	753	5,682	489
USA	2,848	14,660	1,261
North America	**3,601**	**20,342**	**1,750**
Argentina	0.7	3.5	0.3
Bolivia	-	-	-
Chile	-	-	-
Costa Rica	60	447	38
Ecuador	-	-	-
El Salvador	105	486	42
Guatemala	-	-	-
Honduras	-	-	-
Nicaragua	40	250	22
Central-South America	**206**	**1,187**	**102**
Australia	0.2	0.8	0.1
New Zealand	365	2,900	249
Papua New Guinea	-	-	-
Oceania	**365**	**2,900**	**249**
Grand total non-Europe	**6,813**	**40,909**	**3,519**
Grand total World	**7,679**	**45,212**	**3,889**

Table 1.2 Geothermal utilisation for electricity generation in non-European countries[1]

[1] * 1 GWh = $860x10^6$ kcal 1 toe = 10^7 kcal

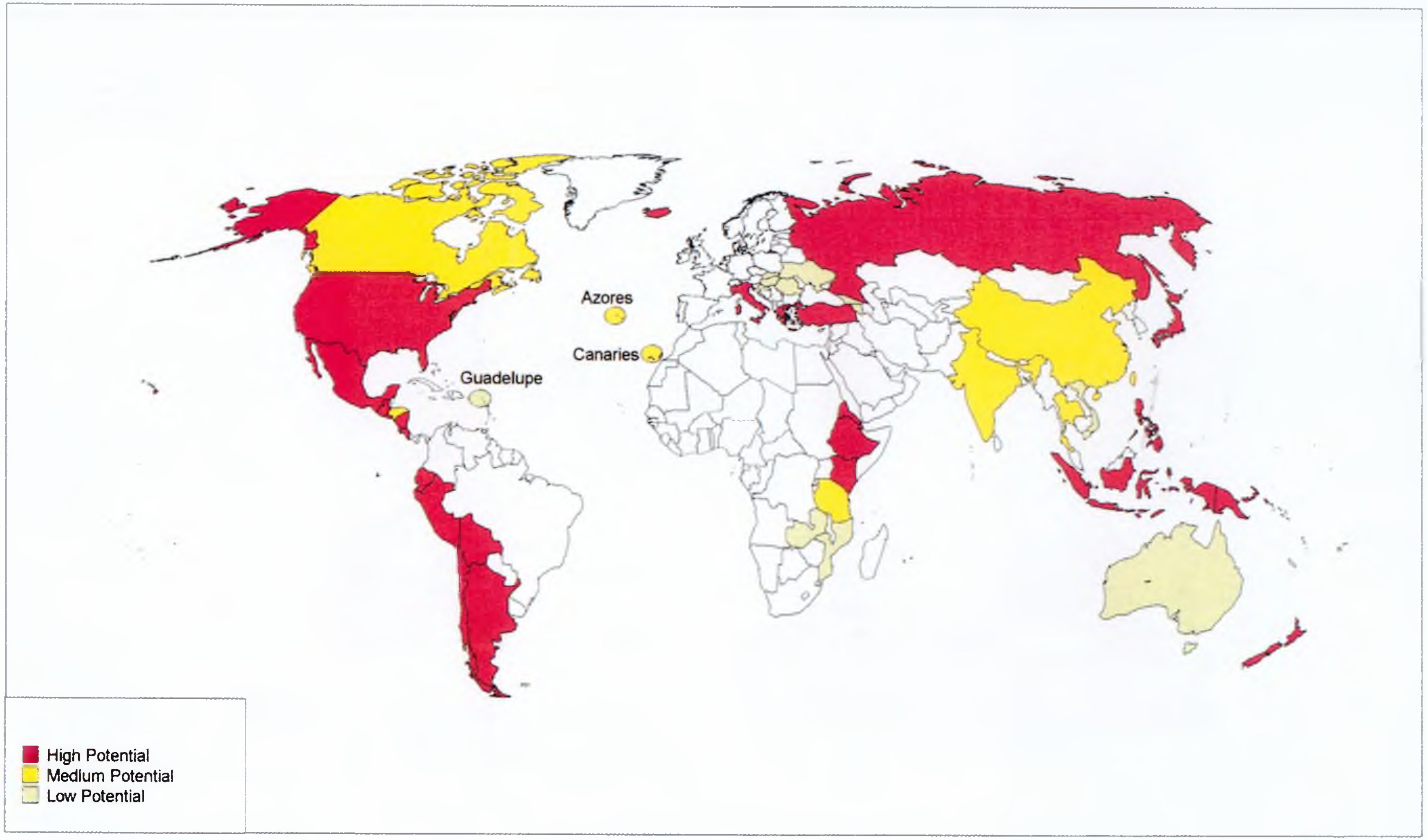

Figure 1.3 Electricity generation: geothermal potential (probable and possible resources).

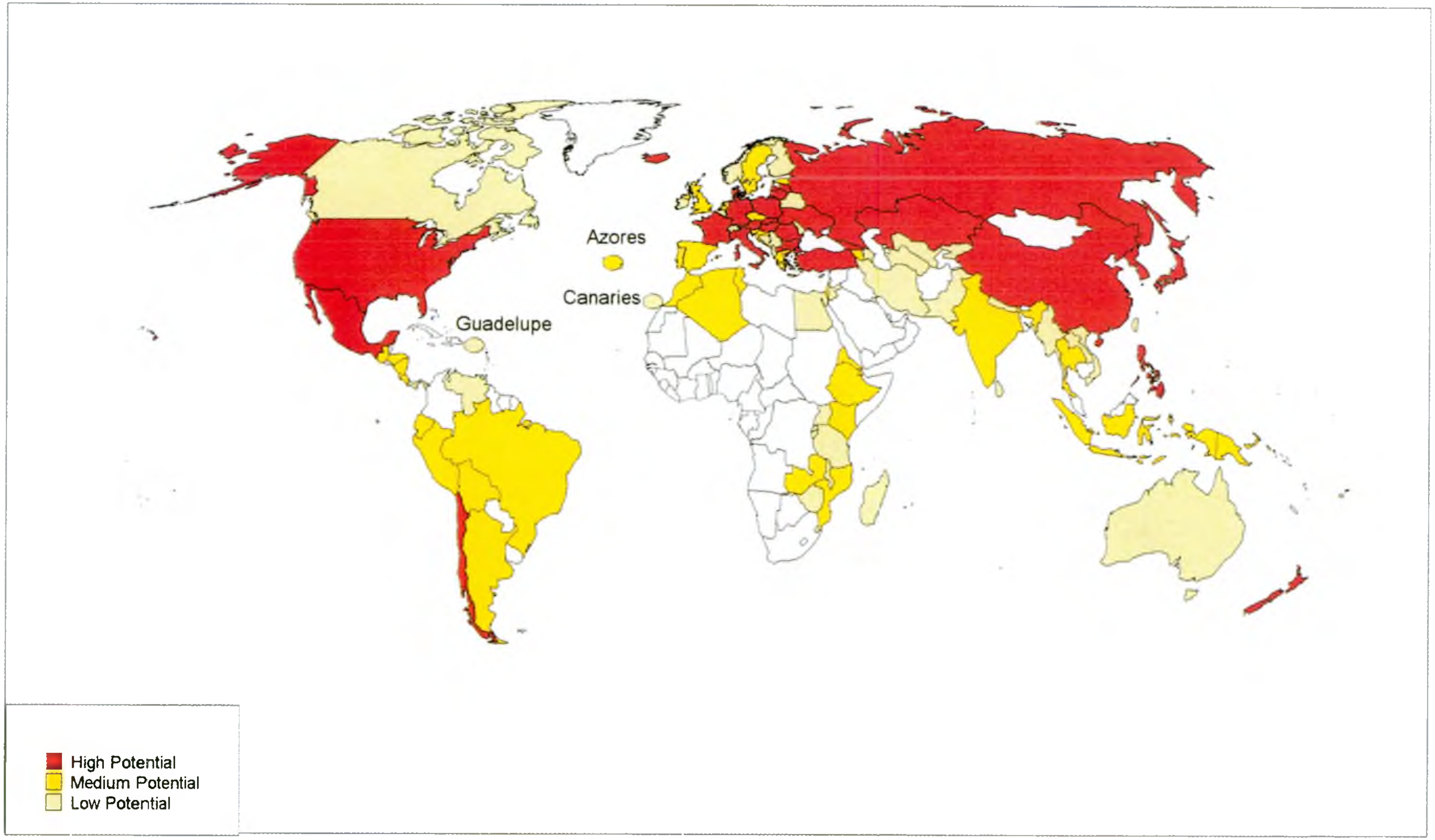

Figure 1.4 Electricity generation: geothermal potential (probable and possible resources).

	Direct utilisation Plant in operation 1997		
	(MWt)	(GWh/y)	(ktoe)
China	1,914	4,717	406
Israel	42	332	29
Japan	1,159	7,500	645
Thailand	2	8	0.7
Asia	**3,117**	**12,557**	**1,080**
Algeria	1	5	0.4
Tunisia	70	350	30
Africa	**71**	**355**	**30**
Canada	3	13	0.2
USA	1,905	3,971	342
North America	**1,908**	**3,984**	**342**
New Zealand	5	25	2.2
Oceania	**5**	**25**	**2.2**
Grand total non-Europe	**5,101**	**16,921**	**1,455**
Grand total World	**9,705**	**35,098**	**3,086**

Table 1.3 Geothermal utilisation for heat production in non-European countries(1)

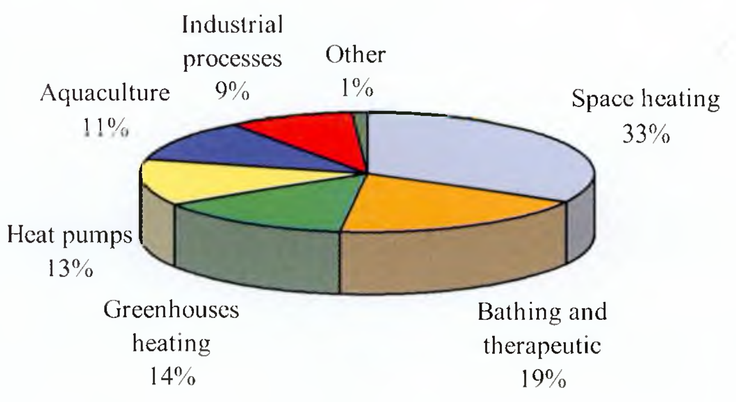

Fig.1.5 World distribution of direct heat utilisation (1995)

(1) * 1 GWh = 860×10^6 kcal 1 toe = 10^7 kcal

BLUE BOOK ON GEOTHERMAL RESOURCES

Chapter 2

Chapter 2
TECHNICAL ISSUES

The development of geothermal energy can be divided into four distinct phases:

- surface exploration
- deep exploration (drilling)
- construction of surface equipment (plant)
- monitoring and reservoir management (operation)

In the initial surface exploration phase multidisciplinary studies are performed including geological and vulcanological surveys, geophysical prospecting (electrical, gravimetric, magnetic and sometimes seismic), as well as analyses to determine the geochemistry of waters and gases. Data from each of these assessments are collated and used to locate potential target reservoirs which can only be identified from drilling exploratory wells.

The main activity of deep exploration is the drilling of wells, but geoscientific activity goes on in this phase too. It is necessary to define the geological stratigraphy of the wells by tying the geological profile from the borehole to data from earlier surveys. The composition of deep formation fluids is also analysed to determine the thermodynamic characteristics of the wells and to measure the productivity of the well in terms of mass flow and enthalpy. The final activity of this phase is the assessment of the size of the resource from a specific reservoir and its ability to sustain production over a specified technical life time.

The results from deep exploration and the characteristics of the natural fluids present determine the type of plant which needs to be chosen:

- for electrical generation when high enthalpy fluids are produced,
- for heat exploitation with both high and low enthalpy resources.

The size of the resource present will then determine the scale of the appropriate development drilling programme which is performed in parallel with the construction of the plant and the piping system. At the same time reinjection wells for the disposal of waste waters are also drilled.

Geothermal reservoirs are more dynamic than hydrocarbon reservoirs. Therefore, continuous monitoring and evaluation of a specific reservoir's responses is required throughout the whole exploration and development programme to ensure that the resource is sufficiently adequate for the intended energy demand.

An outline of the three main sections of a geothermal operation are depicted in Figure 2.1 and can be separated into the following sections:

A. Geothermal wells and fluid production equipment (extraction and reinjection)
B. The geothermal plant, where the fluid is hardenessed (transformation of the raw fluid into a utilisable product). This part can be reduced to its simplest expression (i.e hot water directly through the heating installation of a greenhouse) or can be highly sophisticated (i.e condensing steam turbine plant) , depending on the type of utilisation and the characteristics of the resource.
C. The distribution network towards the end-user. This indispensable network is not specific to geothermal energy, although it does require some modifications.

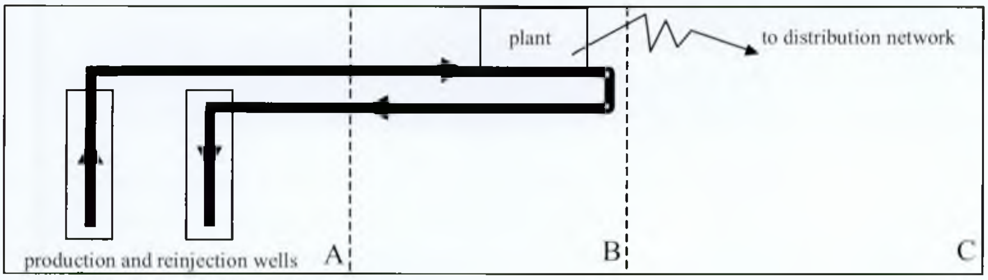

Figure 2.1 – A scheme of a geothermal operation

2.1 Equipment for electricity generation

According to the production characteristics of the geothermal field, i.e. mass flow and enthalpy, size and thermal cycle of the power plant can be selected.

The size of the plant, that is the power generation system which may be installed, is determined on the basis of the available market, the actual productivity generally based on mathematical simulation model of the reservoir. The thermal cycle is chosen depending on the characteristics of the fluids but also on economics of the project.

Three cycles are normally available:

2.1.1 Back-pressure units

High enthalpy fluids may be dry steam or a mixture of steam and water. In this case steam and water are divided in cyclone separators, the steam sent to the turbine, the water to reinjection.

These turbines are low-cost and low-efficiency. Their size is small, generally between 1 and 5 MW and are generally installed near the well-heads. The steam consumption is in the order of 15 kg/kWh, which is about double the quantity required by efficient condensing turbines.
This cycle, in which steam is discharged to atmosphere after its expansion in the

turbine, is used in fields with high gas content (over 10% of the weight of the steam) as gas extraction for condensing plants becomes relatively expensive for gas concentration in this range. The use of binary plants might also be feasible for high gas fields.

Back pressure units may be installed and implemented in a few months and may be moved from one site to another. They are, therefore, suitable for timely and provisional installation in an early phase of the field's development. This practice is recommended because it is anticipated that the income from exploitation of the field allows an efficient monitoring of the field behaviour before the installation of larger power plants.

2.1.2. Condensing units

In this cycle the steam is condensed at the output of the turbine, lowering the exhaust pressure to around 0.10 ÷ 0.12 bar, which increases the enthalpy differential and therefore the efficiency of the cycle. The steam consumption is in the order of 7-8 kg/kWh when the gas content is lower than 1% and in mild climate conditions.

Production from water dominated fields requires the use of steam/water separators with either single or double flash cycles. In the single [should this be double?] flash systems the separation pressure is chosen so that the inlet pressure in the turbine can be optimised (generally between 5 and 7 bar). In these conditions the separated water still has a high enough temperature (in the order of 150-170°C. This water can therefore be flashed again at a lower pressure of 2-2.5 bar and fed to the turbine at a proper stage.

A double cycle is not always recommended for two reasons. Firstly, the final temperature of the separated water (~120°C) often increases scaling in the reinjection wells. Secondly, the cost of the equipment for the second flash does not necessarily result in a commensurate increase in energy production relative to the additional investment required, especially when the water content in geothermal fluid decreases with time, as often happens in high enthalpy reservoirs.

2.1.3 Binary cycle

In this cycle the geothermal fluid flows through a heath exchanger, evaporates a secondary fluid with a low boiling point (chloro-fluoro carbons, ammonia, isobutane) which drives a turbine is condensed and recycled within a closed system. These units are used to generate electricity from low-to-medium temperature resources. By selecting the appropriate secondary fluid, binary systems can be designed to operate with inlet temperature as low as 90°C.

These units have higher costs per unit of installed capacity by comparison with conventional condensing units, but are in many cases, the most suitable alternative for geothermal development. High conversion efficiency can be obtained, especially when the gas content of the fluid is high. In such cases, binary plants can be more economical than conventional condensing plants with gas extraction equipment. For medium enthalpy fluid (100-200°C) binary plants are usually the most economical alternative regardless of gas content.

Binary cycle units provide a high degree of flexibility for optimising the use of geothermal resources which can be further enhanced when used in combination with cascade systems.

2.1.4. Other cycles

There is another system, the total flow cycle, or biphase rotary separator. This cycle was developed to extract power from a two-phase steam/water mixture which is transformed into a two-phase jet with high kinetic energy. A rotary separator separates the liquid phase which is then used to drive a turbine separately from the steam. The biphase unit is generally used in conjunction with a conventional turbine driven by steam that is discharged from the biphase rotary separator. This type of plant has little potential for further technical developments

PRODUCTION	GEOTHERMAL PLANT
Field surface equipment(s) • well-head and valves • silencer • separators (in wet fields) • steam and water pipes • reinjection pumps (if necessary) • chemical treatment systems	Back pressure units • turbine and generator Condensing units • steam scrubbers • turbine and generator • condenser • gas extraction system • cooling towers Binary plants • heath exchanger • turbine and generator • condenser • cooling towers • circulation pumps Biphase rotary plants • chemical treatment • two-phase nozzles • rotary separator • liquid turbine • liquid recovery rotor

Table 2.1 Equipment and main components for electricity generation.

2.2 Equipment for direct heat uses

Geothermal energy has a wide range of applications which require direct heat use. The broad range of temperature of geothermally derived fluids, whether steam or water, can be utilised in various processes.

The main direct uses of thermal energy are space and district heating, industrial process heating , agricultural applications (greenhouses and fishfarming), balneological purposes, recreational activities and spas where there is a prerequisite for large base-load demand.

Most direct use applications require equipment to transfer heat from the often highly saline and therefore corrosive geothermal fluid to fresh water that can be used to distribute heat towards the end-users and equipment for treating the fluid.

Every use obviously requires equipment which is specifically designed for the composition and temperature of the formation fluid and its eventual application, but in principle the following table summarises the main components.

A more detailed description of equipment used is described in the Annex 2.1.

PRODUCTION	GEOTHERMAL PLANT
Production and reinjection well(s)	Direct uses
• wellhead and valves	• heat exchangers (if necessary)
• cleaning devices	• filters
• piping system	• degassing systems
• pump(s)	• reinjection pumps (surface pumps)
	• chemical treatment
	• heat pumps
Ground coil: horizontal and vertical (ground probe)	

Table 2.2 Equipment and components for thermal utilisation.

2.3 Geothermal heat pumps

In recent years the exploitation of shallow geothermal resources (within a maximum depth of 100m) has been developed in many countries.

Two circulation systems are used: the open loop system which exploits ground water through shallow ground water wells (<100m), while the closed loop system only exploits the heat within the ground. The heat exchange devices are usually pipes laid horizontally or vertically in the ground (horizontal/vertical ground coil), borehole heat extraction systems (BHE).

Heat Pumps are the essential components of such systems commonly called Geothermal

Heat Pumps (GHP). There is a wide range of applications of GHP like combined heat extraction/storage, space heating/cooling.

The typical GHP systems include three major components: a ground loop, the heat pump itself and the heating and/or cooling distribution system (including also the domestic hot water).

Another application of GHP in direct use systems refers to the deeper cooling-down of the thermal water after the direct heat exchange, or the permanent integration of the GHP when the temperature of the thermal water is around 40°. Both compression and absorption heat pumps are used

All these schemes need further optimisation to develop the awareness of developers, the geothermal industry and governments to the potential offered by this new technology. It is also necessary to compare and optimise this technological solution under widely different site-specific and climatic conditions.

2.4 Technology development

Geothermal energy has been produced commercially on the scale of hundreds of MW for over three decades both for electricity generation and for direct utilisation. Most of the technology is conventional and adopted from other fields of energy use and mining.

Technical improvements, research and development activities are however needed just as in the case of other energy sources to improve and enhance energy output and reduce technical and financial risk.

Geothermal development started with geothermal water with very low mineralisation. Gradually, the technology has been developed to extract heat out of highly mineralised brines that are common in the sedimentary basins of Europe.

Important fields of technological development in Europe include:

- *Inhibitors to prevent or delay scaling and corrosion*

  Scaling inhibitors to limit calcium carbonate scaling are successfully used in different geothermal fields, but improvements in research for other scaling factors should be beneficial.

  The evolution of new coating material to protect conventional pipes/equipment that come in contact with the corrosive fluids and new materials (metal alloys, plastic, etc.) that can withstand the effect of corrosive fluids, may allow the development of geothermal fields not yet exploited.

  Patch-flex tubing is the most recently developed material to create a tough impermeable lining on casing walls that is self-sealing and pressure resistant along its entire lenght. Thermo-setting resins, fibres and elastomers can be used as efficient and economical tool to repair perforated or badly corroded casing and to reduce scaling.

- *Down-hole pumps that can operate at high temperatures and in highly mineralised water*

- *Reinjection and long term reservoir management to sustain formation fluid pressure and flow into sandstone.*

- *Horizontal drilling along productive aquifers. This can greatly increase production from a well and reduce total drilling cost at a project.*

  For heating purposes, thermal energy is better suited to higher temperatures. Consequently, storage systems require temperature levels in excess of 50°C, but require further research and development support.

- *Heat pumps both for heating and air conditioning (cooling).*

- *Deep down-hole heat exchangers.*

  The present BHE technology has been developed for use at shallow depths but could be extended to deeper BHE systems (>1000m).

- *Parts and components of geothermal power plants.*

  Research in design and engineering is continuing to improve the cost-effectiveness of parts and components for geothermal power plants, minimising the use of expensive materials, for example, by reducing the use of external plating where possible. Improvements in turbine efficiency and output could reduce attrition which modifies the cross-sectional profile of turbine blades.

2.5 Seasonal storage of hot water

Underground heat storage has been under consideration since the early 1970s and has subsequently been practically demonstrated at low temperature levels for space cooling or for combined heating and cooling (mainly associated with heat pumps). It is still not widely used but might have further applications, for example, in district heating, in waste heat recovery or with solar heating.

Storage periods may be only for short term duration (diurnal) to long term (seasonal). The latter option requires energy recovery at least three months after the end of the loading period.

2.6 Advanced geothermal technologies for the future

Research programmes presently carried on several new technologies that in the future could increase geothermal potential.

- *Hot Dry Rock systems (HDR)*

  Geothermal industry today uses hot aquifers for production of energy.

  The principle of HDR is the extraction of energy from hot artificially-fractured rocks. A pair of wells is drilled into the rock, terminating several hundred meters apart. Water is circulated down the injection well and trough the HDR reservoir, which acts as a heat exchanger. The fluid then returns to the surface through the production well, and thus transfers the heat to the surface as steam or hot water. Various HDR experiments had been carried out in USA, United Kingdom, Japan, Germany. An European scientific project, initiated by the European Union in Soultz-sous-Forêts in 1987 is under progress; if it successes, industrial development could start in the future (2020). Other major programs are running in Japan, or under preparation such as in Australia and Switzerland.

  It is, in principle, a simple concept. In practise experimental results have revealed that artificially induced circulation is often hard to sustain without major loss of water. Nevertheless more promising results have recently been observed from the European programme.

- *Geopressured reservoirs*

  Geopressured reservoirs are deep reservoirs (4-6 km) in large sedimentary basins which contain pressurised hot water that has remained trapped at very high pressures due to specific geological conditions. Geopressured fields could produce: 1) the thermal energy of the pressurised hot water, 2) hydraulic energy by virtue of the very high pressure, 3) methane gas.

  Geopressured resources have been investigated extensively in the US but major uncertainties remain in the ability to exploit this resource and the technology that would be required to manage and control it.

  Some geopressured resources could exist in Europe (Panonian basin in Hungary), but no investigation or research programmes currently exist.

- *Magma energy*

  The thermal energy stored in magma bodies represents a huge potential resource. The goal of the US Magma Energy Extraction Programme is to determine the feasibility of locating and utilising magma as a viable resource. This programme is in progress but many technical problems remain.

BLUE BOOK ON GEOTHERMAL RESOURCES

Chapter 3

Chapter 3
THE CASE FOR GEOTHERMAL ENERGY AND ACCEPTABILITY

3.1 Facts about geothermal energy

Geothermal springs have been used for bathing, washing and cooking for thousands of years in many countries. There are ruins of baths dating from the Roman empire at numerous localities in Europe from as far a field as England and Syria. Similarly, there are over two thousand year old records of geothermal usage in China. Health spas have been operated for most of this century at numerous hot spring localities in Europe, in particular in Central and Eastern Europe.

Large scale utilization of geothermal water for heating houses and greenhouses started in several European countries between the two world wars. The largest district heating systems were built in Iceland and the most extensive geothermal greenhouses were constructed in Hungary. The oil crises in the early 1970's caused a new wave of interest in Europe for heating of houses with geothermal water pumped from large sedimentary basins such as the Paris basin. The significant fall in oil and gas prices in 1986 has made district heating schemes less economical than before and the incremental use in space heating from geothermal energy has consequently been slow over the last decade.

At present, all European countries utilise about 18,000 GWh/y (1,6 Mtoe) of geothermal energy for direct heat uses such as space heating, greenhouses, balneology and industry representing about 60% of the world production. The EU countries represent only 11%, and Iceland alone 17% of this total. Practically all fifteen EU countries have direct heat uses (most commonly spas and balneology) while large space heating is mainly used in France, Germany and Italy.

Recent developments in the application of geothermal heat pumps, using the earth as a heat source for heating or as a heat sink for cooling, have made it possible for all countries in Europe to use the heat of the earth for heating and/or cooling, as appropriate.

In the US more than 250,000 units have been installed in recent years and in 1994 they extracted about 8 PJ/y from the ground.

Sweden and Switzerland have pioneered the use of this technology in Europe where more than 4,000 small size units are presently operating. The latter country is currently producing some 420 GWh/y of thermal energy from warm groundwater using geothermal heat pumps even though it is a country not renown for geothermal energy.

In 1994 this country, with only 7 Million inhabitants, used heat pumps to extract 0.82 PJ/y for heating (or 228 GWh/y). If a similar growth in utilisation were achieved in all countries in the northern part of Europe where climatic conditions demand longer periods of utilisation (north of the Alps and west of the Urals, about 350 Million of inhabitants), the thermal energy produced through geothermal heat pumps alone would amount to some 11.4 TWh/y. This figure is in addition to the conventional direct use of geothermal energy at 1995 levels.

Geothermal heat pumps have been officially rated among the most energy efficient space conditioning equipment available. They reduce the need for new generating capacity and are found to perform at greater efficiencies than conventional air conditioning systems.
Some units are now present in almost all EU countries and their use could rapidly increase.

Electricity was first generated from geothermal steam in 1904 at Larderello in Italy. A 250 kW power station was put into service in 1913; thereafter a steady expansion in the sizes and the numbers of generating units took place until, by the early 1940's some 130 MW of geothermal power generated in Tuscany were feeding the electrified Italian railway system. The second country in the world to produce electricity on a large scale from geothermal sources was New Zealand in 1958.

Electricity is presently produced with geothermal steam in 21 countries all over the world. The geothermal electricity production in Europe is about 4,300 GWh/y. This displaces the emission to the atmosphere of 5 million tons of carbon dioxide, 46 thousand tons of sulphur dioxide, 18 thousand tons of nitrogen oxides, and 25 thousand tons of particulate matter every year, compared with the production of the same amount of electricity from an average coal-fired plant.

Electricity has been generated by geothermal steam in the USA since 1960 and is the second largest renewable energy source connected to the electricity distribution system after hydropower. Electricity produced from geothermal resources in the USA displaces the emission to the atmosphere of 22 million tons of carbon dioxide, 200 thousand tons of sulphur dioxide, 80 thousand tons of nitrogen oxides, and 110 thousand tons of particulate matter every year, compared with the production of the same amount of electricity from an average coal-fired plant.

The utilization of geothermal energy requires mostly established technology and reliable engineering that can be adapted to specific conditions imposed by geothermal fluids. The technology, reliability, economics, and environmental acceptability of geothermal steam and water has been demonstrated throughout the world.

3.2 Environmental benefits

It is not possible to maintain an increase in the present standard of living in Europe and the rest of the world without an adequate supply of energy at reasonable cost. The environmental impacts associated with present energy production rates are, however, becoming increasingly unacceptable. The negative consequences are also becoming more widely evident. Above all the combustion of fossil energy sources such as coal, oil and gas release large amounts of carbon dioxide and other air pollutants leading to detrimental effects such as acid rain, respiratory diseases as well as contributing to the global greenhouse effect.

Until recently decision makers in Europe have largely neglected the important role that geothermal energy can play in reducing the emission of carbon dioxide and other greenhouse gases in Europe. Geothermal energy is available for direct use in all European countries and the resources are enormous. Gas emissions are minute in the case of direct use of geothermal, and only a fraction of that from fossil fuels in the case of electricity production from geothermal sources.

In order to reduce these emissions different strategies at a global level have to be adopted and pursued in parallel. These measures include:

- energy conservation
- improvements in combustion efficiency of conventional boilers and power stations
- combustion of fuels with lower carbon contents for example natural gas
- integration of renewable sources of energy in energy supply systems

According to the EU's "Green Book" on energy, the electricity generated from renewable energy sources in Europe was 180 TWh in the year 1991. The break-down was the following:

Hydro	94.3%
Geothermal	1.6%
Biomass	3.5%
Wind and solar	0.6%

Both geothermal energy and hydropower are reliable and widely applicable sources of energy with known environmental impacts. The emission of greenhouse gases are negligible from both geothermal and hydro. The use of biomass for electricity generation is associated with considerable emission of carbon dioxide although this is mostly compensated for by increased vegetation.

The reduction of carbon dioxide and other greenhouse gases is of major importance for the selection of suitable renewable energy sources. At present the energy types with the greatest potential in this respect in Europe in the short and medium term are hydropower and geothermal energy.

The increase in deployment of geothermal energy will have a large net positive effect on the environment in comparison with the development of fossil fuels, which is in accordance with recent pronouncements at the Kyoto conference on global climate change and EU strategies on environmental protection.

As an example, according to present situation in USA, the present electrical generation from a fossil fuel mix creates about the 70% of SOx emissions (the main cause of acid precipitation), 33% of NOx emissions, the 20% of carbon dioxide emissions (linked to the atmospheric greenhouse effect) and 50 % of nuclear waste.

In comparison geothermal power plants have sulfur-emissions rates that average only a few percent of those from fossil-fuel alternatives. The newest generation of geothermal power plants, emits as average of only 0.136 Kg of carbon dioxide per kilowatt-hour of electricity generated compared to the 128 Kg/kWh of carbon dioxide for a power plant fuelled by natural gas or 225 Kg/kWh of carbon dioxide for a coal fired power plant, as shown in Figure 3.1.

Geothermal fluids contain a variable quantity of chemicals and dissolved gas, largely nitrogen and carbon dioxide with some hydrogen sulphide and smaller proportions of ammonia, and boron. These components however are partially used and partially condensed and so the remaining gas quantities released in the atmosphere represent only a fraction of that emitted from fossil fuel fired thermal plants.

The amount of components depend on the geological conditions of different geothermal fields and, in case of reinjection of the fluids in the subsurface, pollution is almost absent. The removal of hydrogen sulphide from geothermal steam is a routine matter in geothermal power stations where the gas content is high.

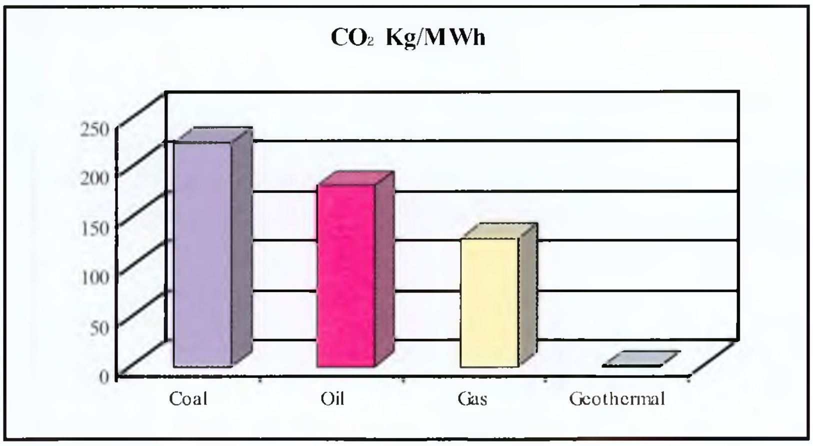

Figure 3.1 Comparison of carbon dioxide emissions as grams/kWh of electricity produced from geothermal and fossil fuel-fired electric power stations

Table 3.1 compares the carbon dioxide emissions in g/kWh from district heating systems using low-temperature geothermal resources and fossil fuels. The gas content of low-temperature water is in many cases insignificant, like in Reykjavik (Iceland), where the carbon dioxide content is lower than that of the cold groundwater.

In sedimentary basins, such as the Paris basin, the gas content may be too high to be released, and in such cases the geothermal fluid is kept at pressure within a closed circuit (the geothermal loop) and reinjected into the reservoir without any degassing taking place. Conventional geothermal schemes in sedimentary basins commonly produce brines which are generally reinjected into the reservoir and thus never released into the environment.

ENERGY SOURCE	kg of CO_2/MWh
Coal	310
Oil	250
Natural gas	176
Geothermal	ca. 0

Table 3.1 Carbon dioxide emission in g/kWh from low-temperature geothermal heating systems as compared to fossil fuels.

Geothermal Heat Pump (GHP) Systems have very low impact on the environment. Because GHP systems move heat that already exists rather than burning a fuel to create heat, they reduce the amount of toxic emissions in the atmosphere.

GHP systems use around 35% less total energy, and generate no combustion or indoor air pollutants. These systems produce no air pollution (or reduce total emissions if the fuel used to generate electricity needed for operating the GHP is included).

GHPs systems are generally 2.5 to 4 or more times more efficient than resistance heating and water heating alone.

In addition to energy saving, GHPs have additional benefits such as reduced maintenance costs, the opportunity to eliminate boilers and cooling towers and lower noise as there is no outdoor condenser unit unlike conventional cooling systems. Moreover, new buildings can be designed without any of these features if GHP is used as part of the temperature control system.

3.3 Visual impact

Some direct use installations have no visual impact. Thermal heating plants can be integrated within the urban landscape since all equipment including the pipes of large district heating systems can be concealed underground. Other uses of geothermal energy such as horticulture and fish farming tend to have relatively minor visual appearance, depending on the scale of development and the nature of the terrain in which these activities occur.

No visual impact is produced by geothermal heat pumps.

Electrical generation plant can have relatively minor visual impact and certainly no greater than the conventional fossil fuel burning plants; moreover these plants are located outside urban areas and require little land, taking up only a fraction of that needed by other energy sources.

The maximum efficiency in using the steam/water, however, implies not releasing any waste steam to the environment but to use the energy. Separated and condensed thermal water from the plants is furthermore routinely reinjected to the ground minimizing the release of steam and thermal water to the environment.

Environmental and visual impacts and land use will be most prevalent during drilling, testing and construction of geothermal schemes, mostly in the form of noise, traffic movement and dust. These effects are obviously temporary but national environmental legislation may demand implementation of ameliorative measures to comply with regulations.

The operation of geothermal plant is largely governed by local and national environmental legislation and regulation.

3.4 Health benefits for the public

Geothermal energy offers indirect benefits to the public, such the reduction of global emissions from the combustion of fossil fuels and the reduction of local atmospheric pollution.

Another great indirect advantage of geothermal power plants is the fact that they do not need storage or transportation facilities for fuel which would be necessary for conventional power plants, nor is there a necessity for waste disposal.

Direct benefits are numerous particularly for recreational purposes. The widespread occurrence of natural hot springs have for centuries been associated with health and recreation often leading to the development of resorts with spas. This historic association has not only led to the establishment of long term tourism, but also therapeutic uses, notably balneology.

Although other energy sources could be used for this type of treatment, geothermal energy is extremely well suited to large baseload heating applications such as swimming pools. Moreover, the relative abundance of energy often allows spas to be heated to higher temperatures than other conventionally heated facilities, which enhances their attraction for swimming and their suitability for clinic treatment of diseases.

3.5 Job creation

The number of individuals directly employed in geothermal energy is difficult to quantify with any degree of accuracy. Firstly, many service and specialist development companies as well as consultancies which work in this field also work in related industries notably oil and gas exploration and ground water management. The demand for specific services also tends to be cyclical. Equipment suppliers, such as turbine and pump manufacturers, pipe fabricators and control hardware companies will also supply items for geothermal schemes but only as part of their product range. However, a crude estimate of the global turnover related to geothermal energy, assuming an annual installation rate of 600 MWe, is between 1,360 and 1,600 MECU.

Assuming current deployment rates for geothermal energy used for direct heating schemes of 600 MWth per year, global turnover could reach between 180 and 510 MECU per year in this sector. These figures exclude routine operation, maintenance and refurbishment activities.

For power generation plant annual turnover for these activities is estimated to be between 1,800-2,300 MECU per year assuming ~6,800 MW of operational plant world-wide.

Direct uses, estimated to be ~10,000 MW, require operation and maintenance work valued at between 120-1,100 MECU.

Extrapolation to numbers of individuals employed can only be broadly estimated as these figures included the cost of capital equipment, materials and energy to operate schemes.
Collectively annual global turnover directly related to the installation and operation of geothermal plant for both electricity generation and direct uses ranges from 3,400 to 5,100 MECU.

Assuming that 30% of these costs is attributed to salaries, approximately 28,000 to 40,000 people could be employed in the geothermal industry world-wide. These estimates exclude people employed in activities such as recreating facilities, tourism, spas, greenhouses horticulture, processing industries and fish farming which use geothermal energy. These activities tend to be "labour-intensive" and therefore it can be said that geothermal development could be highly beneficial to the local economies and a tool for job creation.

3.6 Co-generation

Geothermal plants are characterised by a low operating cost but a relatively high investment cost. The price of the heat/energy therefore implies a high fixed cost which has to be taken into consideration when integrating geothermal into an energy supply system using two or more energy sources. The development of geothermal energy requires 1 to 3 km deep wells, the drilling of which is relatively expensive. Once a geothermal plant is installed the operating cost is very low as water is used as the energy carrier. Most of the cost is required as initial capital investment for drilling and generation plant. Geothermal production wells have in several countries been operated for several decades with only minor servicing. A significant part of the operation cost is for the use of electricity to drive pumps in wells and distribution systems.

Geothermal energy is best suited to base-load operation and can therefore be in direct competition with other base-load plants. The decision to invest in a geothermal option will always depend on the actual location, resource, the importance that local people place on a clean environment and investment criteria.

Geothermal plants can be operated as co-generation plants when they produce both electricity and heat as happens in Iceland and Italy (Larderello area).

Geothermal heating plant could be associated with a gas-fired co-generation plant to produce both heat and power as for example in France where one plant is already operating and another is under construction.

Another key advantage of geothermal plants is their capacity factor which is amongst the highest for all types of power plant. It is notably higher than capacity factors for other forms of renewable energy (that is the actual number of kilowatt-hours produced compared with the amount that could be produced if the plant operated continuously at full capacity).

With due consideration of the above economic constraints, geothermal heating plants can be integrated favourably with conventional peak-load plants. The latter have a low investment cost, high operation cost and high pollution. Therefore, they are kept in operation for as short periods as possible. It has become common practice in Europe that such peak load plants are able to cover at least 50% of the peak load, but produce only 10-20% of the amount of heat required annually. Thus, the above economic constraints have only little influence on the environmental advantages of geothermal energy.

In cases where the temperature of the geothermal reservoir is not sufficient for district heating systems, heat pumps or auxiliary boilers can be used. Compared to conventional plants, even these systems produce significantly less emissions than conventional thermal plants using fossil fuels.

BLUE BOOK ON GEOTHERMAL RESOURCES

Chapter 4

Chapter 4
COMPETITIVENESS OF GEOTHERMAL ENERGY

The sharp fall in fossil fuel prices during the mid eighties made geothermal energy, in certain cases, less competitive from a purely financial standpoint. However, from a wider economic perspective, geothermal energy remains competitive in comparison with conventional sources. The need to strengthen and diversify energy supply, whilst minimising gaseous emissions which contribute to the greenhouse effect, make the adoption of renewable forms of energy an urgent priority. Future European energy supplies will also need to become more dependent on indigenous sources to provide a sustainable future. The progressive substitution of fossil fuels will also reduce emissions which contribute to acid rain.

The future competitiveness of different energy sources can not be limited to strict financial comparisons. Other parameters such as detrimental or positive environmental effects, and their economic consequences must also be considered. The minimisation of other emissions, including dust, reduction of fuel and related transportation activity and space requirements as well as the reduction in expenditure on the disposal of by-products such ash from coal combustion, need to be accounted for.

Any comparison of different energy sources should, therefore, adopt a methodological approach which uses financial-based evaluations that can be properly integrated and balanced with economic-oriented ones so that a comprehensive “Full social costs” model can be developed. This approach can provide a broader perspective for decision makers.

The actual competitiveness of geothermal energy, and hence its short-term prospects in energy markets, can not be properly appreciated if some of the relevant variables still remain either substantially excluded or underestimated within a reference scenario.

The adverse environmental impacts of different energy technologies vary widely depending on the type of exploited resource, however, these effects could be regarded as key parameters if broader economic models are applied.

Conventional economic comparisons between different technologies exclude the cost of externalities such as damage caused by pollution. If this approach were adopted the external costs associated with alternative methods of energy production could compensate if not counterbalance the existing gap in terms of financial value and completely reverse the order of different technologies measured from a purely economic comparison.

4.1 Investment costs

The competitiveness of different power generation technologies should, initially, be based on a simple economic analysis based on a discounted cash flow of a reference project. Essentially this approach is a measure of the amount of energy produced by a system over its technical life relative to the initial capital costs and any operation, maintenance or refurbishment costs which are required to sustain energy production.

Most forms of power generation plant have a technical life of up to 20 years and in some cases longer. In order to determine the unit cost of generation in present day money future costs and revenue from energy sales must be discounted back to present day values. A reference discount rate needs to be used to reflect the rates of return which might be expected for a project. The rate used will reflect investment conditions in the country in question.

For a geothermal project all the initial feasibility and development costs as well as the capital investment required should be used. Some assumptions about the amount of energy that is anticipated from a scheme also need to be made. It is then possible to calculate the unit cost of generation that would be required for the scheme to break even.

The following section outlines a typical cost break down for a reference 55 MW power plant and then proceeds to examine factors which can effect the economic performance of geothermal power generation plant.

A geothermal project is developed in a sequence of well established phases as described in Chapter 2. The investment costs of a geothermal project can be separated into two main categories:

- field costs, including surface exploration, drilling, field development and reservoir management;
- plant costs, including machinery, equipment, design, engineering and civil works.

The specific break down of field and plant investment costs is strictly dependent on site-specific conditions and the type of application particularly for direct use applications. Figures 4.1 and 4.2 show the typical breakdown of a 55 MW electrical generation plant.

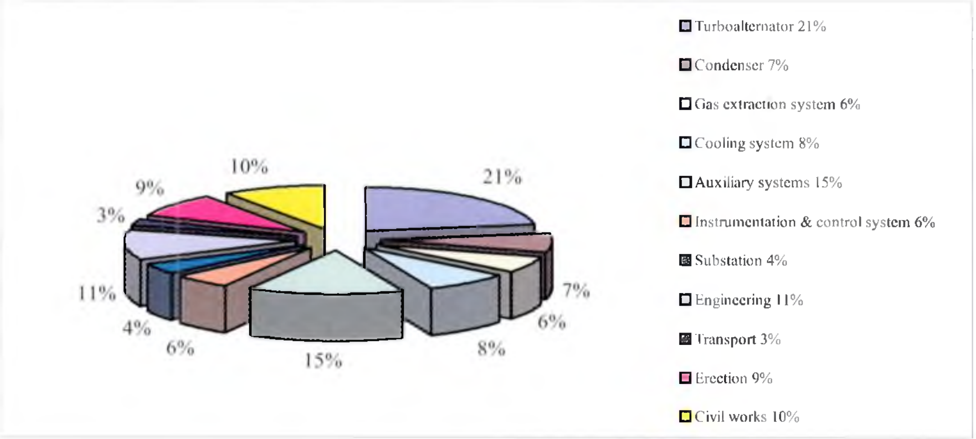

Figure 4.1 Plant Cost Typical Break down (55MW)

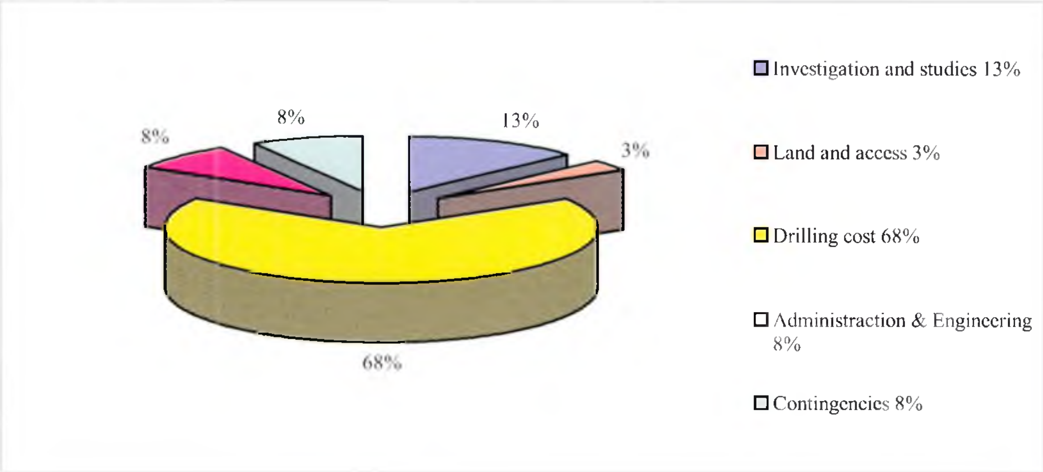

Figure 4.2 Field Cost Typical Break down

4.2 Costs for Electricity Generation

In the case of investment in an electricity generation plant, the proportion of investment in each phase can be strongly influenced by site-specific conditions. A critical break-even point can be reached where initial investment has to be weighed against the magnitude of the risk that the project will not reach its anticipated production targets. (Figure 4.3 and Figure 4.4)

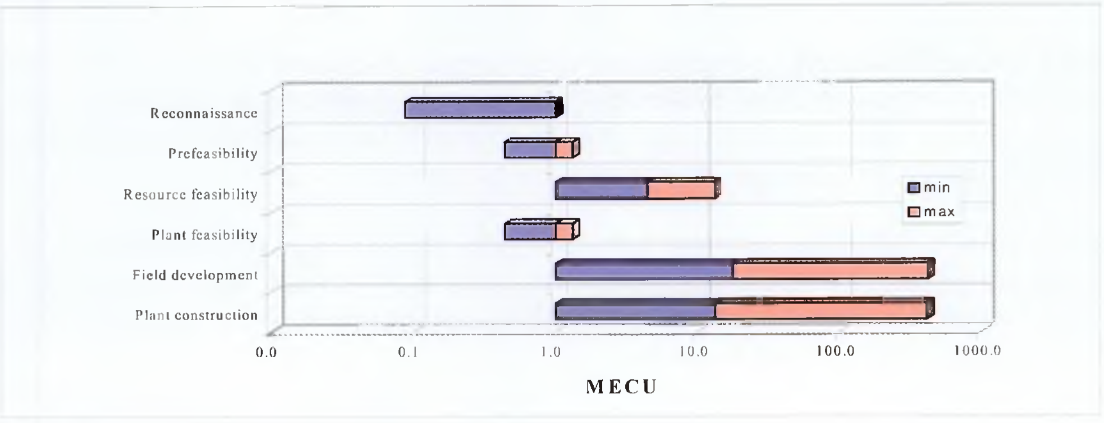

Figure 4.3 Investment Cost of Typical Phases

Figure 4.4 Project Phases and Risk Management

Preliminary surveys, exploration activities and associated feasibility studies drastically reduce the mining or geological risk as well as the financial risk; however, a residual risk will always exist because of natural geological variability. Substantially increasing invest costs will not necessarily diminish this risk.

Delays in production can lead to reduced rates of return because less energy is produced over the investment loan repayment period. Additional costs at the exploration stage have a negligible effect in comparison. The cost of geothermal energy, and therefore its economic viability, is most sensitive to drilling costs and well productivity.

The depth of geothermal wells in producing fields is between 500 and 3,000m with an average depth of around 1,500m. The cost of drilling wells (the drilling specific cost - ECU/m-) increases disproportionately with depth.

Well productivity is certainly the parameter that most affects the final cost of geothermal energy and varies from less than 2 to more than 30 MWe. The world average for productive wells is about 5-6 MW. Under these conditions and considering also the possible variation in well cost, the specific drilling cost may change from 1 to 15 or even more.

Such a potential variation, in comparison with the uncertainties of some tens of percent of the other component costs, make this parameter the most critical one. In a general assessment of geothermal generation costs, the well productivity has to be considered as a variable and the final cost as a function of this parameter.

Finally, market conditions may also have a considerable affect on the typical costs of a geothermal project. For example, drilling contracts may increase when there is high demand induced by the oil market. The cost is notably lower in countries or areas where drilling activity for oil also exists.

Market conditions may also partially affect the price of geothermal equipment. Although this influence may be great as an absolute value, it is low in terms of the overall cost of a scheme, possibly less than 10%. The economies of scale of the generation units have a much stronger influence on cost. The thermal cycle includes three kinds of geothermal turbines (as shown in paragraph 2.1):

- back pressure
- condensing
- organic cycle

The low cost, but low efficiency, back pressure turbines are economically justified only in an initial stage of a geothermal development or when the incondensable gas content of the steam is higher than 10%.

Binary plants are the most economical option for formation fluid temperatures between 100 to 200 °C and for all fluids with a high gas content.

The cycle used for the reference project's cost calculation, is based on single flash condensing turbines. Even if an intermediate size of condensing unit were theorectically available, the units normally used can be grouped, for sake of simplicity, into three categories according to their size, with the following estimated costs per unit:

• 10÷15 MW	1200÷1300 ECU/kW
• 25÷30 MW	875÷1050 "
• 55 MW	600÷ 850 "

The 55 MW size is generally regarded as the market standard of the upper size available although turbines around 65 MW or more can now be built.

These prices are relevant to single unit plants. In a modular strategy, further units of the same size may have a cost reduction of up to 20% of these average values.

With such a wide range of variability between the different parameters of geothermal projects (the specific field cost plus the plant cost) it is practically impossible to define a generic cost for geothermal energy.

It is possible, however, to use the parameters of an average, or reference project, and analyse the influence of the variation of each parameter on the final cost. The characteristics of such a reference projects are described in Annex 4.1.

It should be reiterated that, as explained in greater detail in Annex 4.1, the cost data shown in this chapter are pertinent to the same reference projects. Actual projects will obviously have different cost figures, due to the high degree of variability caused by local conditions, especially those related to the drilling of production wells and their productivity. For instance, in Iceland, the electrical generation cost, in a 20 MW co-generation plant, is as low as 21 ECU/MWh. In contrast, in Italy, some remote controlled highly sophisticated plants of the same size may have a production cost higher than those of the reference project, but even this cost is lower than alternatives in the local energy market.

Table 4.1 and Table 4.2 show the geothermal capital and field development costs as well as the main assumptions applied to analyse the reference schemes, namely 15MW, 30MW and 55MW single unit plants. The 55MW plant can be assumed to be a "typical geothermal project" and has been used to calculate the unit cost of generation and price and as a base case for a sensitivity analysis (as provided in Annex 4.1).

The production cost[1] calculated using the assumed reference parameters, produces results equal to the weighted average of the known generation cost of the major world producers, within the expected range of error of 3%.

The typical operating and maintenance costs and other assumptions for a 55MW geothermal power plant are given in Table 4.3. However, an acceptable estimate for the operating and maintenance costs for all equipment (field and plant) for power plants at lower sizes (10-15 MW and 25-30 MW) is a yearly expenditure of between 2 and 3% of the investment costs.

The drilling cost of replacement wells also has to be added. This cost can not be assessed generically because it is subject to the same uncertainties that occur with field development. The cost also depends on the rate of fluid flow decline from the production wells.

As a rough evaluation the cost for drilling a replacement well is at least double the operating and maintenance expenditure for the surface equipment.

[1] Calculations are based on the Discounted Cash Flow Method

Based on the assumptions for a typical case using a single unit 55MW, a generation cost[2] of 37ECU/MWh has been calculated. A comparison between the generation costs of the three different plant sizes, is presented in Figure 4.5.

The economy of scale correlated to turbine size produces significant differences in project performances. The cost per MWh relative to 15MW and 30MW plants is respectively 44% and 25% higher than for the 55 MW example.

	15 MW		**30 MW**		**55 MW**	
Investments	MECU	%	MECU	%	MECU	%
Surface Prospection	0.5	1	0.5	1	0.5	1
Deep Exploration	5	15	5	9	8	10
Field Development	7	20	11	19	18	22
Gathering System	3	8	5	9	10	12
Plant	20	56	33,5	62	45	55
Total	**35.5**		**55**		**81.5**	
Specific Costs	ECU/KW		ECU/KW		ECU/KW	
on Total investment	2300-2400		1800-1900		1400-1500	
on Plant investment	1200-1300		875-1050		600-850	
Terms	Years		Years		Years	
Surface prospecting[1]	1		1		1	
Deep exploration	2		2		3	
Construction[2]	2		2		3	

[1] Including the time for contracting a drilling company
[2] The term for development is assumed to be the same as plant construction. Plant time includes 6 months for bidding and contracting.

Table 4.1 Geothermal investment costs (estimated for the reference projects)

Description	Unit	Quantity
Economic life time of plant	Years	25
Contingencies (on project investment cost)	%	10
Discount rate	%	10
Yearly disbursements	-	Homogeneously distributed on each phase
Delivery point	-	At the high tension side of the plant substation[1]

[1] Transmission line cost and its operation are not included.

Table 4.2 Main assumptions for the assessment of 55MW geothermal plant

[2] No taxes or royalties are included.

Description	Unit	Value	Size
Total Operation & Maintenance cost[1]	% (yearly)	**3.5**	55 MW
(as percentage of investment cost)	% (yearly)	**3**	25/30 MW
	% (yearly)	**2**	10-15 MW

- Production / injection wells decline	% (yearly)	3
- Number of make-up wells[2]		15
- Piping and separation for make up production. wells	MECU	0.35
- Piping and separation for make up reinjection. wells	MECU	0.26

[1] Including Administration and Engineering
[2] To keep the steam production and reinjection capacity constant per 25 years

Table 4.3 Operation & Maintenance costs (55MW geothermal power plant)

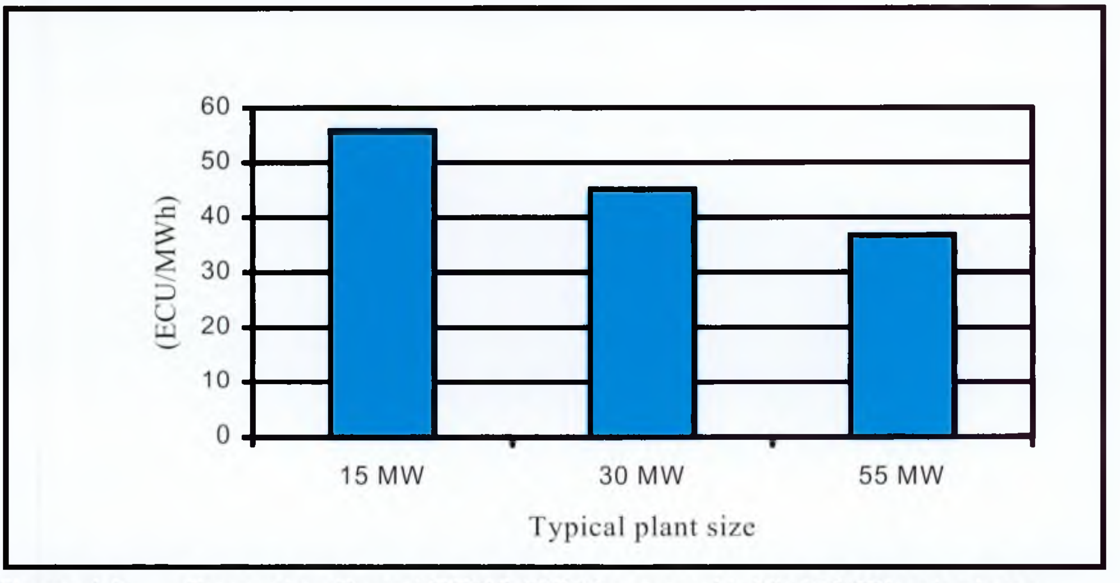

Figure 4.5 Generation Costs (ECU/MWh) between 15-30-55 MW unit plants.

A more detailed analysis of generation costs, as a function of technical and economic characteristics is presented in Annex 4.1.

This analysis shows that fluctuations in plant load factor and well productivity have a more critical impact on production costs compared with variations in drilling. Moreover, the specific cost of a power plant is a function of the size of the single units and of the plant as a whole. Figure 4.6 illustrates how variations in well productivity change relative to the installed capacity of the plant. The lowest cost analysed (740 ECU/kW) is that of a single 55 MW plant, the largest cost approximately corresponds to a 10 MW unit.

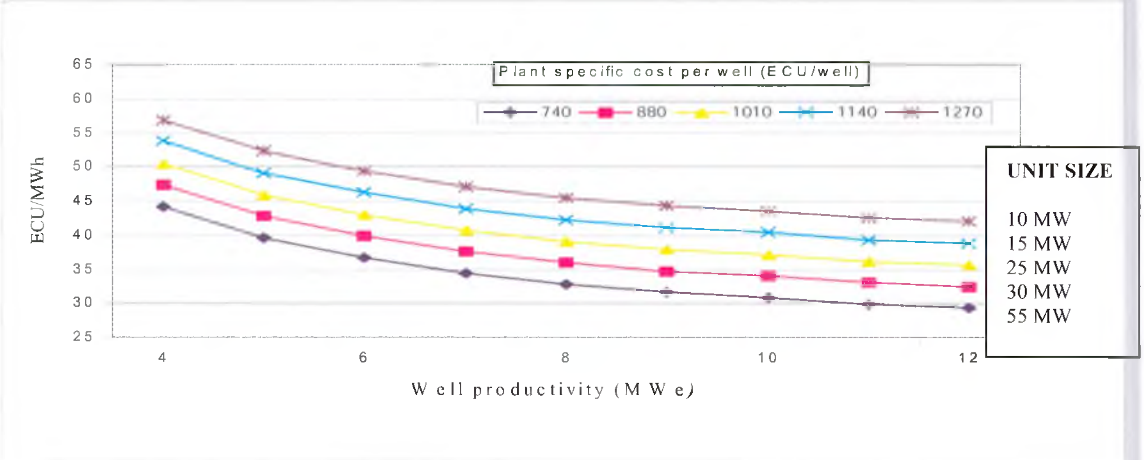

Figure 4.6 Generation cost calculated versus well productivity variation and power plant specific cost for each considered unit size.

The Pay-back[3] period is contingent not only on the generation cost but also on the selling price of energy and therefore on the local market conditions. It is therefore impossible to define a generic pay-back for geothermoelectric generation. Nevertheless, a rough evaluation of this parameter, based on the 55 MW reference project examined in the previous chapter, offers a useful guide. If the selling price, for example, guaranteed an expected IRR of 15% to the developer on his investment in the plant, and 20% for the investment in field development, as is usually requested by private investors, the pay back period would be in the range of 5-6 years from the beginning of production (Figure 4.7).

Further economic analysis, including the effects of pay back time, sensitivity and financial analysis including pricing criteria, are set out in Annex 4.1.

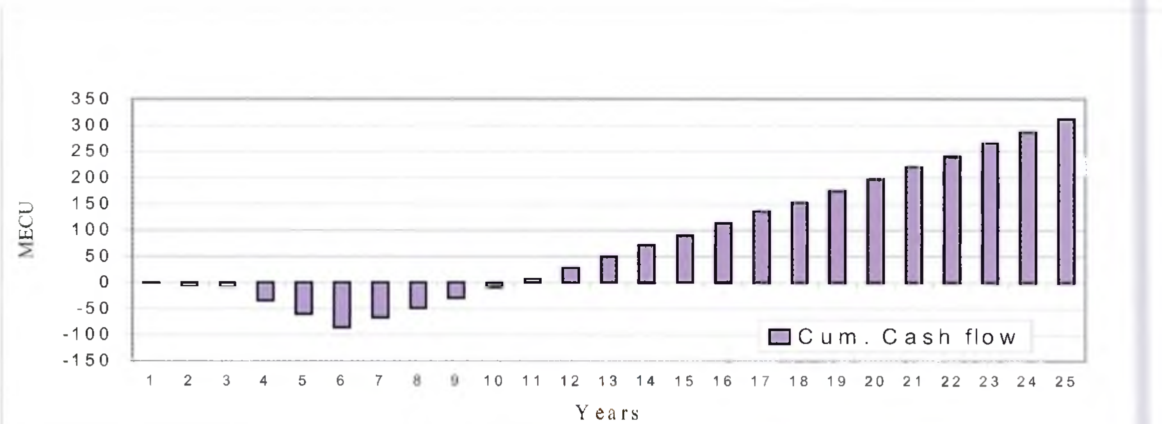

Figure 4.7 Pay-back analysis

[3] Pay-back period is the time between the beginning of the production and the moment when the cumulated cash flow become positive

4.3 Costs for Heat Production

Investment cost and operating costs vary considerably between countries and the type of use, which depends on the characteristics of the resource (local geological conditions), the local heat demand and heat consumption pattern (district heating systems, individual or building geothermal heat pumps systems, etc.)

Data have been collected and analysed in two main cases:

- district heating system (several hundred or thousand of end users)
- Geothermal heat pumps (individual houses and building)

District Heating systems

Investment costs can be broken down into:

- well costs (drilling and well equipment costs)
- geothermal plant costs, i.e. investments related to exploiting the geothermal fluid (including the building)
- heat-distribution network costs

Well costs vary considerably between countries depending on the characteristics of the resource and the market for drilling. In Figure 4.8 drilling cost (kECU/m) variability is illustrated versus well depth. The drilling cost together with other capital costs for infrastructure items influences the cost of production and distribution of geothermal energy for direct uses in the different countries.

Due to these variabilities it would be valuable to make a comparative study in selected countries of how drilling costs and other infrastructure conditions affect the cost of geothermal energy in different countries.

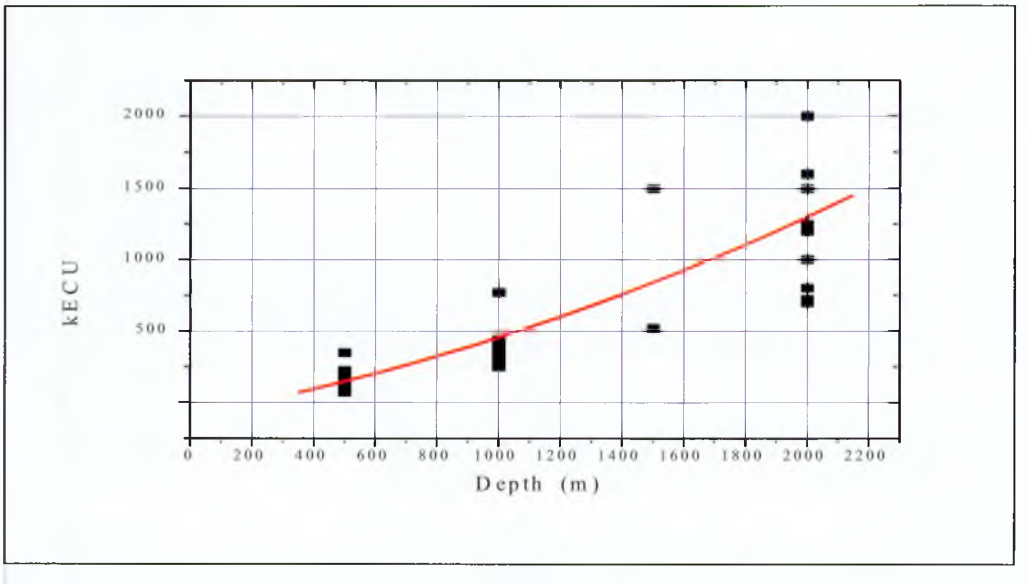

Figure 4.8 Drilling cost in Europe versus well depth (kECU/m).

Geothermal plant costs are determined by the site-specific characteristics of the resource and the local heat demand as well as the pattern of heat consumption. The installed capacity should have a high load factor related to the climatic conditions of the region. Moreover, the plant needs to be located in close proximity to the final end users to minimise heat loss and should have a technical life of 20 years to warrant the size of investment and heat productivity.

Heat-distribution network costs strongly depend on whether a former network exists or not. The total investment is several times higher where a new network needs to be installed.

Investment and production costs which correspond to the major use of low enthalpy geothermal energy, i.e. district heating systems, have been collected and analysed. The following cost variation for the capital investment and production of the geothermal energy for heating purposes is representative of European countries:

- the investment cost vary from 0.200 to 1.2 million ECU/MW.
- the production cost vary from 5 to 45 ECU/MWh.

The general characteristics for geothermal district heating systems is a high investment cost and low operating cost (which is independent of the market price for oil and gas). With an average plant life of approximately 20-25 years and a long repayment period the investments are profitable. Profitability is also important from an environmental point of view, by saving of imported fuel, and stimulating local business and employment.

The variability of costs depends on site-specific conditions (resource, climatic conditions, users etc.). The cost varies according to the resource (depth, temperature and flow rate) and the presence and condition or the existence of distribution infrastructure (mainly the pipeline distribution network). The pay-back time therefore varies according to these different criteria, and on the type of investor. In most countries (i.e. France, Italy etc.) district heating operators are local authorities which can accept repayment periods of 15-20 years.

Some comments are given below:

- *Germany*
  In Germany, the specific investment cost for a geothermal heating plant without a distribution network ranges from 0.7 to 1.2 million ECU/MW.

- *France*
  The type of operation developed in the Paris basin (Dogger aquifer), includes more than 35 geothermal district heating systems operating with one or several doublets.

  The investment for geothermal energy production from this system (including the drilling of 2 wells of 2,000m depth, geothermal plant and equipment) is about 0.2 million ECU/MW geothermal capacity. This value has to be compared with the investment for an oil-fired boiler system of 0.108 million ECU/MW for the same power capacity.

Where a former heating network exists the investment for heat thermal production is more profitable (shorter repayment period). The production cost is around 12 ECU/MWh. This cost includes refunding the investment required to drill the wells, and the geothermal plant operating and maintenance costs, excluding heating network costs. This value can be compared with the cost of fossil-fuel alternatives: gas 26.3 ECU/MWh, fuel oil 34 ECU/MWh.

In France the cost for the heating network varies considerably depending on whether there is a former network. It is important to note that the maximum installed geothermal capacity is never more than 50% of the total capacity needed for the district heating system; but geothermal energy produces more than 80% (from 80 to 100%) of the total heat needed for the district heating network. For this reason the total investment cost for a geothermal district heating system (including geothermal energy production system + heating network with back up system) is from 0.2 million ECU/MW to 0.6 million ECU/MW. That represents a total investment of 1,300 to 3,100 ECU per dwelling in Paris area (for heating and domestic hot water).

The final production cost per unit of heat in a new geothermal district heating system is 20 to 30 ECU/MWh including the loan repayment, operation and maintenance costs for both the geothermal and heating network, and fuel costs for the back up systems.

- *Italy*
  The two main large geothermal district heating systems operating in Italy (Ferrara and Vicenza) run with doublet systems at around 2,000 m depth. The average investment cost in Italy is about 1,500 ECU per dwelling. Due to the climate conditions, the average hours/year , in the Po Valley region are about 2,200. The average investment cost is about 0.600 million ECU/MW including drilling, geothermal plant and heating network costs. The production cost is 15 to 20 ECU/MWh.

- *Iceland*
  In Iceland the heating network is always built at the same time the geothermal system is developed. All the heat needed is produced with geothermal energy (i.e. the district heating capacity equals the geothermal resource capacity). Due to the climatic conditions in Iceland the heating period is longer (6000 hours/year), comparing to an average of 4500 hours/year in France and average of 2500 h/y in Italy.

  The average investment is about 0.915 million ECU/MW for a geothermal district heating system.
  The production cost is 5 to 10 ECU/MWh.

<u>Geothermal Heat Pumps (GHP)</u>

The GHP systems include three major components: a ground loop (or borehole heat exchanger), the heat pump itself and the heating and / or cooling distribution system (they can also provide domestic hot water). GHP systems are of two major types: earth coupled (close-loop) and ground water source (open-loop).

In 1993, a study by the US Environmental Protection Agency of all residential heating and cooling systems, concluded that GHPs could reduce energy consumption and related emissions by 23-44% compared to air-source heat pumps, GHPs generally have lower emissions compared with other equipment, and GHPs have the lowest annual operating cost of all technologies, as well as competitive life-cycle costs.

GHPs system investment cost is, however 20-40% higher than for a conventional heating system. A residential GHP system is also more expensive to install than a conventional heating (due to the requirement for an underground connection) and is most effective when operated year round for both heating and cooling. In such cases the incremental payback period can be as short as 3 to 5 years.

GHPs system installation-costs should be competitive (and can be lowest option) with a central combustion furnace/central air conditioner combination.

The specific investment cost for a ground loop (for a GHP system) is estimated to be from 3,000 to 6,000 ECU in Europe for a $100 m^2$ individual home and a <100 m deep well (depending on the geological situation, the ground system, and the drilling cost in different countries).

In most situations, GHP systems have lower life-cycle costs when considering energy and maintenance cost (from US studies).

GHP systems operate by moving or transferring heat rather than converting it from another energy source. Much less electricity is used to move heat rather than convert it.

4.4 Availability of geothermal energy

The availability factor of geothermal energy is the percentage of time (generally referred to a reference year) and the rated energy which can be produced. This factor depends on the availability of the equipment and the resource.

To assess the availability of the equipment, the time for programmed maintenance and accidental break down have to be considered. Experience shows that availability is often over 90% for geothermoelectric power plants and even higher for direct use plants.

To evaluate the availability of the resource, low and high enthalpy resources have to be examined separately. While low enthalpy resources may be generally regarded as totally renewable and constant in time (if properly managed), high enthalpy resources are in most cases only partially renewable within a technical time-scale.[4]
Moreover, most of the exploited high enthalpy geothermal fields show a decline in well yields. Therefore the availability of the field-plant system as a whole may be lower as a result.

[4] They are fully renewable from a geological standpoint.

The majority of the fields may, however, reach availabilities which are comparable to those of the equipment. Nevertheless, over-exploitation in some cases (not minor ones) has resulted in drastic decreases in availability. Good field management is therefore necessary to keep the availability constant throughout the technical life of the plant.

Apart from these cases an availability of around 90% may be regarded as normal.

Availability of the plant includes combined aspects of safety, maintainability (promptness maintenance actions) and maintenance. Availability indicators are time availability (capacity to respond to a solicitation), power availability (capacity to ensure, by request, a certain level of power), energy availability (capacity to satisfy the energy demand for a time period).

The strongest competitive points for geothermal energy are that geothermal plants can operate continuously, without constraint imposed by weather conditions, as is the case with some other renewable sources. They are not dependent on fossil fuel supply, transportation or storage which has a concomitant risk of explosion and pollution. Geothermal energy has an inherent storage capability and is best suited to the supply of base-load demand.

The plant factor (that is the percentage of time the plant actually produces energy) is therefore almost equal to the availability factor. For direct use, the plant factor is practically a direct function of the demand. Such factors are higher than those of fossil-fuel plants and far higher than most other renewables.

Geothermal power plants, both high and low enthalpy ones, can be installed in modular units. This approach reduces the initial capital investment, anticipates the availability of the resource, allows revenue generation at the earliest possible opportunity thereby improving the overall financial performance of schemes and reducing exposure to risk.

GHPs operate in all climates. They are most cost effective in colder regions (because ground temperature is constant over the entire year even when the external temperature is cold). Typical loop installations for GHP (ground loop) are expected to work for than 30 years.
In US, nearly all GHP system manufacturers offer a warranty for major components that is equivalent to the warranties for conventional heating and cooling systems. Manufactures of plastic pipe used for ground loop warrant their products for 25-50 years.

4.5 Comparison with other energy sources

Direct comparison between geothermal energy and other energy sources needs to be given careful consideration, partly because both capital and operation and maintenance costs vary widely for geothermal schemes and some other technologies; and partly because some new and renewable energy technologies are still undergoing technical development which will lead to further cost reductions.

Other technologies such as wave energy are still at an early research and development stage. Cost projections are therefore best estimates which assume that performance of designs conceived at the present time will achieve their rated energy outputs for the estimated capital costs. Comparisons between electricity generating technologies and those used for direct heat are treated separately.

A discounted unit cost has been estimated to compare different technologies. Annual operating and maintenance costs also include any fuel required to operate the plant, but not major refurbishment. The comparison presented in Table 4.4 is based in ECU at 1995 cost; but for geothermal plants the figures are those presented in paragraph 4.1 according to the assessment of Annex 4.1. Clearly, due to the complexities of each renewable source the figures presented must therefore be regarded as a broad generalisation.

Current figures for the unit cost of electricity from geothermal sources indicate that it is competitive with some forms of renewable and conventional energy sources, notably waste combustion. Other technologies including small hydropower, landfill gas and onshore wind are more competitive, despite having lower load factors with the exception of land fill gas. The figures also reveal that geothermal energy is more competitive than photovoltaics or near-shore wave.

Operating and maintenance cost for photovoltaics could be generally considered negligible if batteries are not included in the plant.

A key feature of all forms of renewable energy is the nature and availability of the resource which ultimately governs the unit cost of generation. However, it is useful to recall here that other renewables, such wind and solar energy have a limited resource availability (i.e. avg. maximum solar radiation are only about 4-5 equiv. hours) and are therefore not reliable as base load sources for consumers.

Development and operational costs for power generation from geothermal sources are highly sensitive to site-specific conditions. The unit cost of generation for onshore wind will depend on the annual mean wind speed as energy capture increases in proportion to the cube of the wind speed. Similarly the unit cost of electricity produced from hydropower schemes will vary depending on the permitted amount of mean annual flow which can be abstracted. Often this is restricted by environmental legislation and seasonal fluctuations in flow.

Variations in unit costs of generation from waste combustion are mainly due to the variation in disposal charges or "gate fee" paid to the incinerator operator for incinerating the refuse. Since this form of power generation is primarily regarded as a form of waste disposal, with energy recovery as a benefit, high power generation costs may reflect other priorities which out weigh direct competitiveness with other forms of electricity generation.

GHP systems are of importance for the production of heat for space heating and warm water preparation at any time of the year and day. For example, the share of primary energy consumption for heat production is more than 50% in Germany. The increasing use of geothermal low-enthalpy resources for heat production can significantly contribute to the saving of fossil fuels, thus reducing pollutant emissions.

	Geothermal	Small Hydro	Wind (onshore)	Urban Solid Waste Combustion	Land Fill Gas	Anaerobic Digestion (agricultural waste)	Photo Voltaics	Tidal Barrage	Wave (near-shore)
Typical unit size (MWe)	10-55	0.001-10	0.41	10-27	1	1	1-100 kW	240	2
Availability factor %	95	>95	98	90	90	90	70-99	90	94
Load Factor (%) (Time plant generates at rated power)	65-85	15-95	18%-35% (24%)	90	80	27	3-15	26	25
Construction time (years)	1-3	1-2	0.25	2-3	1	1	10-180 days	7	< 1
Economic lifetime (years)	25	40	15	20	15	20	15-25	>40	30
Investment cost (ECU/kW)	2,300-1,400	970-3,600	850-1,100	5,000-6,400	1,200	7,260-8,470	24,200-5,500	2,100-2,800	-
Fixed operating and maintenance cost (ECU/kW)	49-46	18-30	24-36	379-429	67-202	600-726	Negligible	109-145	-
Generation cost for energy (ECU/MWh)	55 – 30	22 - 140	36 – 84	24 – 160	42	120 – 160	1,250-620	120 – 160	110
EU installed capacity (MWe)	834*	9,000	3,500	1,437	298	150	60	240	0
World installed capacity (MWe)	7,679	27,900	4,821	3,069	1,385	5,300-6,300	376	261	0

Table 4.4 Electricity generation: comparison between geothermal and other RE resources.
For geothermal data:* include Iceland, generation cost derived using 10% discount rate
For other RE resources data: published information; EU figures exclude Iceland; generation cost derived using 8% discount rate
Cost values at 1995.

Table 4.5 shows the installed capacity (MWe) and the electricity production (GWh/y) in EU (including Iceland) for geothermal, wind, small hydro, solar and tidal energy. Data are updated to 1997 from different published information.

1997	**Installed capacity**		**Production per year**	
Energy Source	(MWe)	(%)	(GWh/y)	(%)
Geothermal	834	6.1	4,207	9.1
Wind	3,500	25.7	3,833	8.3
Small hydro (< 10 MW)	9,000	66.0	37,800	81.4
Solar PV	60	0.4	65	0.1
Tidal	240	1.8	540	1.1
Total	13,634	100	46,445	100

Table 4.5 Electricity generated in EU from five RE resources.

In Table 4.6 geothermal energy is compared with other conventional energy sources for electricity generation. All costs have been updated to 1997, data of geothermal EU installed capacity include Iceland. Generation cost data derived using 10% discount rate. For further data see Annex 4.2.

The low unit cost of electricity produced from new CHP plant is cheaper than almost all other forms of power generation if the availability and load factors are higher than 80%. As far as the conventional power plants are concerned, the economic lifetime, the operating and maintenance cost and therefore the unit generation costs have been based on relevant average values. For further data see Annex 4.2.

Moreover, the fuel source allows minimal pollution abatement. The use of natural gas is generally more competitive where a comprehensive pipeline distribution networks exist. However, a comparison based solely on the unit cost of energy can not take account of local demands for energy which might be well suited to geothermal sources.

	Geothermal	**Coal**	**Natural gas**	**Fuel oil**	**Nuclear**
Average unit size (MWe)	10-55	600	225	600	2,000
Availability factor (%)	95	90	80	95	95
Load Factor (%) (Time plant generates at rated power)	65-85	85	80	85	75
Construction time (years)	1 - 3	4	2.5	3	3
Economic lifetime (years)	25	35	30	40	30
Investment cost average (ECU / kW)	2,300–1,400	950	550	900	3,080
Fixed operating and maintenance cost (ECU / KW / yr)	46 - 49	48	33	27	92
Fuel cost (ECU cents / kWh)	0	1.53	1.65	2.02	0.05
Unit generation cost (ECU/MWh)	55 - 30	37	30	39	74
EU installed capacity (MWe)	834*		315,000		120,000

Table 4.6 Electricity generation: comparison between geothermal and conventional energy sources. (* 1997, including Iceland).

In contrast, new coal fired plant now requires flue gas treatment to meet emission abatement requirements in some countries which is partly responsible for higher capital investment than gas, increasing the unit costs of electricity, as well as the fuel costs includes transport costs.

The relatively higher unit costs of generation from nuclear power reflect higher capital investment, despite cheaper fuel costs, making the technology less competitive than gas and comparable to new coal and geothermal.

Finally two other key factors should be stressed when the competitiveness of geothermal energy is considered. This energy source offers the lowest effective cost for final users and, with the use of cascade systems, enables the use of heat to be rationalised.

A simple comparison between geothermal energy and other energy sources for district heating indicates that it is broadly competitive with biomass and solar heating (see Table 4.7), while the use of natural gas can be competitive where a comprehensive pipeline distribution network exist.

However, broad comparisons can not take account of local factors which often tend to favour a particular energy source because of local circumstances. For example, solar heating is likely to be more appropriate in southern Europe where insolation levels are high. Gas-fired heating systems are highly competitive where comprehensive distribution networks exist and where deregulated, competitive energy markets have been introduced such as in the UK.

In central and eastern Europe, Italy and Iceland, where there are good geothermal resources and a strong acquaintance with the resource, geothermal energy is not only competitive but is widely developed, particularly for base-load applications where alternatives would be less competitive. Moreover, by developing a more sophisticated approach, such as the cascade concept, geothermal resources can be developed for new commercial ventures.

Energy source	**Generation cost ECU/MWh**
Geothermal	5-20
Biomass	48-60
Solar	48-360
Fuel oil	14
Natural gas	9

Table 4.7 Heat generation: comparison between geothermal and other energy sources.

Indeed geothermal energy is suited to large base load heat demands which are coincident with the resource. The most suitable markets are therefore district heating applications, horticulture, fish farming or recreational pursuits such as spas and swimming pools in regions of the world, such as continental Europe which have both abundant supplies of natural gas and geothermal resources, heating schemes have been developed since the early 1980's. There has been a change in emphasis towards extending or improving existing district heating networks .

The use of cascade systems which optimise heat from geothermal sources, and the use of gas or oil fired boilers to supply peak demand can improved the prospects for geothermal energy, without additional major capital investment or risk. In areas where natural gas supplies are absent, geothermal resources can offer a viable alternative particularly if there are opportunities for new industries or activities such as horticulture which could be designed to optimise the geothermal resource available.

All the conditions which relate to the competitiveness of geothermal resources outlined above exclude the external costs associated with power generation from conventional fossil fuel and nuclear sources. These "shadow costs" can be almost exclusively avoided by using geothermal plants where external costs are very low. A comparison of different energy sources which incorporates external sources is presented in Table 4.8.

Energy source	**External cost**	**Generation cost**	**Total cost**
		ECU cents / KWh	
Conventional			
Oil	2 - 6	4 - 6	6 - 12
Coal	2 - 13	3 - 7	5 - 20
Clean coal	1 - 3	3 - 7	4 - 10
Natural gas	0,5 - 1	3 - 5	3,5 - 6
Nuclear	2	3 - 8	5 - 10
Renewable			
Solar PV	0 - 0,3	43 - 59	43 - 60
Wind	0 - 0,1	4 - 11	4 - 11
Biomass/Energy crops/ /Forest residues	0 - 0,6	5 - 8	5 - 9
Waste to energy (MSW/IW)	2	1 - 10	3 – 12
Geothermal	...	3-5.5	...

Table 4.8 Comparison of mean values of external costs for conventional and renewable energy sources.[1]

The *external costs* of conventional generation, which in the case of geothermal resources (similar to other renewable sources) became **external benefits,** are a parameter that substantially changes the level of the competitiveness in favour of geothermal energy. These external benefits can actually be considered in monetary terms and acknowledged as an investment in the geothermal plant.

Generally speaking because financial accounting systems include only the direct costs of the geothermal project as well as their monetary benefits, their true social costs and

[1] i.e. Environmental costs of Electricity, PACE University Centre for Environmental Legal Studies, Oceana Publications, N.Y. , 1990 - and CESEN estimates.

benefits are not reflected in the full valuation system. Some benefits and costs are "external" to the valuation system (i.e. environmental impact) which creates a discrepancy that excludes externalities between private sector (short term financial investments) and social (longer term) costs and benefits.

The main externalities directly linked to a geothermal project are:
- an increase in the indigenous energy resource production and a concomitant decrease in the share of imported energy supply.
- can help to upgrade the efficiency of the overall final energy system
- environmentally positive impact which avoids pollution

It should be emphasised that if the financial evaluation excludes the above externalities, the projected financial performance for individual schemes could, in many cases, appear to offer a poor return on investment when compared with traditional energy sources, even if public and institutional bodies try to push for initiatives to increase the proportion of renewable energy. Consequently, private investors could be reticent and might be dissuaded from investment in geothermal schemes.

If externalities are included, the full social and economic benefits can be realised but this may require public sector incentives or insurance to mitigate against risk to ensure successful investment.

An investor's acquaintance of this "added value" should not be regarded as a subsidy but a realignment of the economic benefits that arise from the project.

The quantification of externalities is a crucial aspect if geothermal energy is to be evaluated fairly. The approach also avoids the risk of penalising this technology purely on the basis of a specific project's cash flow.

Some studies[1] have attempted to quantify the external cost of conventional fossil fuels suggesting costs are almost ten times greater than costs related to energy production from renewable sources and almost 50% of the overall economic cost compared with 1% for most renewable sources. Nevertheless, the external costs of geothermal sources are inevitably excluded from most comparisons, however, the value of these extenalities are comparable to other renewable energy sources.

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[1] i.e. Environmental costs of Electricity, PACE University Centre for Environmental Legal Studies, Oceana Publications, N.Y. , 1990 - and CESEN estimates.

BLUE BOOK ON GEOTHERMAL RESOURCES

Chapter 5

Chapter 5

MARKET PERSPECTIVES

5.1 Role of geothermal energy

The geothermal energy market is determined by the availability of the resources for electricity generation and direct heat use, and the competitiveness and profitability of them.

Chapter 1 indicates the extensive development possibilities within and outside the EU; generally heat use in Europe, heat and electricity world-wide (depending on the country). In addition the development of Geothermal Heat Pumps (GHP) enables optimisation of the use of electricity for heating/air conditioning; here again both the internal and export markets show large opportunities.

Geothermal energy is competitive, reliable and is based upon sound experience acquired in Europe in different fields (electricity generation, direct use, geothermal heat pumps and consultancy).

The growth rate of geothermal development has in the past been significantly affected by the prices of the competing fuels on the world market, especially oil and natural gas. The growth rate is, however, quite high due to the fact that geothermal energy is the lowest cost option for many countries. It is, furthermore, generally acknowledged that geothermal energy is one of the cleanest energy sources available on the market.

During 1975-1995, the world average growth rate in geothermal utilisation for electricity generation was 9% per year, which is one of the highest growth rates that has been experienced for a single energy source. The average growth rate in the direct heat use of geothermal energy is about 6% per year over the last decade.

For the direct heat applications, the growth rate conditions are less clear at present, but again are highly affected by competition from oil and gas on the world market. The large potential and the growing interest for the development of direct applications in various countries gives rise to optimism for the growth of direct applications. The growth rate should perhaps be expected to be higher than that for electric generation, both because low temperature geothermal resources are available in a much greater number of countries and because direct application projects tend to be less capital intensive than the electric ones.

The most important developments are in industrialised countries, no doubt because a well-organised economy and fiscal system - and a firm development policy - are essential. Nevertheless, considering that this energy represents a development factor, it could be more widely exploited in developing countries.

Recent scenarios for a number of leading geothermal countries indicate a prospective growth rate in the use of geothermal energy for electricity production in the range of 6% to 30% per year in the period 1994-2000 and up to 20% per year for the period 1994-2020.
It is, therefore, not unreasonable to assume an average growth rate of aggregate geothermal energy will be some 10-15% per year over the next three decades, if favourable conditions of the energy market prevail or improve (prices, regulations, environmental incentives).

The participation of private operators in steam field developments for electricity production through project financing tools such as BOT, BOO and BOOT[1] have significantly increased the speed of geothermal development in countries like the Philippines and Indonesia which presently are amongst the countries with the highest growth rates. This recent approach to the market economy expansion will be extensively applied also in other countries.

One reason for a continued high growth rate in the direct use of geothermal energy is that in recent years significant development and interest have been made in the use of geothermal heat pumps for optimizing energy use for heating and cooling. This type of application multiplies the number of countries and regions that can harness geothermal energy.

The wide application of the geothermal heat pumps for space heating in countries such as Switzerland, Germany and Sweden, none of which has active volcanoes or evident geothermal manifestations on the surface, demonstrates that good opportunities for geothermal resources exploitation exist even in countries not formerly associated with geothermal energy.

If the environmental aspects were given a higher priority geothermal energy would become more competitive and there would be a commensurate increase in potential growth rates.

If world policy moves towards an integrated-resource planning with all environmental and other hidden costs explicity accounted for, it would be possible to use more renewable energy resources economically; total energy costs would decrease and a much cleaner environment could be realised.

Another advantage of geothermal energy is that it is a local resource which provides both economic and strategic benefits allowing many countries to reduce dependence on imported fuels.

[1] BOT (Build, Operate, Transfer); BOO (Build, Own and Operate); BOOT (Build, Own, Operate, and Transfer).

The present status and market prospectives for geothermal energy for electricity generation, direct heat uses and geothermal heat pumps are presented with forecast to 2005 and 2010.

5.2 Electricity generation market

The market for geothermally generated electricity is strictly governed by economic considerations which are largely determined by the competitiveness of other energy sources.

At present day oil prices only the best geothermal reservoirs are profitable to develop, especially where private sector investors are involved. Private sector investment is generally averse to high risk schemes unless there are commensurate high rates of return as in the oil industry. Investors will therefore seek lower risk investment options offered by conventional fossil fuel. However, this approach to investment excludes the value of externalities.

The market conditions for investment are different in each country and are dependent on legislation, the availability of an indigenous industry and the availability of investment capital. Electricity markets can be broadly summarised into three categories.

1. countries where electrical generation is restricted to state owned agencies.
2. countries where electrical generation is under state control but private investors may operate under concessions or special contracts.
3. countries where legislation allows the private investors to operate in the energy market.

In the first case the market is limited to supply of engineering consulting services, drilling, equipment supply and power plant construction to the state owned public utility.

In the third case, where private operators have been working for several years and there is a strictly exclusive private sector market, private sector investment criteria will prevail. The market therefore grows or declines depending on the cost of alternative energy sources. In this kind of market only a few private operators are present in the geothermal sector.

In the second case the trend is now growing so that the countries within the first group are now changing their laws to allow private sector investment in energy supply. This evolution is typical in Latin America. Constraints, opportunities and goals for this type of market are examined later on.

Present status of market

The development of geothermal energy for electrical generation purposes has been pursued at different paces and paths according to the specific institutional and market conditions of each country.

In the countries where there was indigenous technical expertise and financial institutions with comparable investment which existed before the beginning of the geothermal development (United States, Italy, Japan, Iceland and New Zealand): geothermal exploration and plant implementation have been mainly regulated by free market conditions or where there was a state monopoly an exclusive market developed. In this case the decision to implement a geothermal project is determined mainly by financial considerations and operations may be carried out by two different ways:

-) With two operators: One is a mining company which is exclusively involved with geothermal field exploitation and steam production, and a public utility which is solely responsible for the implementation and operation of the geothermoelectric plant;

In this case the mining company gets the lease or concession from land owner, produces and sells the steam to the «public utility» which produces and sells the electric energy into the market.

-) with a single operator, a single company develops the field, owns and operatores the power plant and sells the power.

In all countries, with the exception of the USA, electricity generation used to be in the hands of public utilities. It is only recently that the trend to open up the electricity market to private enterprises has developed.

Under these new conditions the development policies for geothermal energy will be regulated mostly by private sector investment criteria. However, in the interests of its national energy policy a government, may be prepared to pay a private investor a price higher than the least cost alternative, taking into account shadow prices, or strategic convenience to develop indigenous resources, or weighting the opportunity to diversify the energy resources.

At present the market in South East Asia is ripe and self regulating, and can be difficult a company to enter in the market if it is not yet established in the area. In contrast, the changes now occurring in the Latin American market may offer challenging opportunities to European operators particularly equipment manufacturers.

An analysis of the geothermal turbines and generators market in Annex 5.2 shows that it is dominated by five main companies (three Japanese, one Italian and one Israeli) which during period 1971-1995 installed about 6,771 MW in the world, about the 88% of the total (7,668 MW). The European presence represents only the 16% of the market, the Japanese manufactures dominate the 73% of the market, and Israeli manufactures represents about 3% of the market.

The survey results for geothermal electricity generation equipment that will be installed or replaced by the year 2000 are presented in Table 5.1. The capacity which is likely to be installed by that date is split between five main manufacturers. The figures represent plant that is either under construction or will be completed by the year 2000.

Manufacturer / Area	MWe	
	1991-1995	2000
Ansaldo(1)	150	396
Fuji		30
Mitsubishi		60
Ormat	10	6.6
Toshiba		
Europe	160	492.6
Ansaldo	35	
Fuji		
Mitsubishi		
Ormat	73	
Toshiba		
N.America	108	--
Ansaldo	55	60
Fuji		50
Mitsubishi	5	
Ormat		25
Toshiba	55	
C.America	115	135
Ansaldo	220	115
Fuji	80	406.5
Mitsubishi	255	
Ormat	--	32
Toshiba	123	232
Asia	678	785.5
Total	1,060	1,413.1

(1) Including Plants Substitutions

Table 5.1 Installed capacity for period 1991-1995
and forecast to 2000 for the main power plant manufacturers

The European manufacturers in particular, even with a long presence in the sector, have little expertise in resource exploration and exploitation and only limited experience in the operation of geothermal systems. This sector of the industry is almost exclusively devoted to the supply of components and power plant assembly

Engineering firms with experience in exploration, exploitation and management of geothermal fields, including design and project management, have no financial resources to invest in capital intensive projects like geothermal ones.

The few public utilities existing in Europe with both the capability and financial power to enter this market successfully show little interest in these opportunities as they consider the geothermal market a minor one or perhaps lack incentive to invest in new projects outside national boundaries.

EU is quite limited and is dominated by Italy, (Tuscany/Latium area, volcanic islands). Greece could present a new market, and the volcanic archipelagos as the Azores, the Canaries and DOM French territories offer promising opportunities.
The Market outside EU is mainly in Iceland, Russia and Turkey.

The market outside Europe remains the most important and has the attraction of high growth rates. In the last few years the fastest growing markets have been located in SE Asia (Philippines and Indonesia) where there are further possibilities for new local markets in Thailand and China. Central and South America have good geothermal resources which could offer better prospects for European operators rather than in SE Asia where the competition is dominated by established Japanese and American companies.

AREA / Country	1997 (MWe)	% of world capacity	1997 (GWh/yr)	% of world generation
European Union	754	9.8	3,832	8.5
Iceland	80	1.0	375	0.8
Russia	11	0.1	25	0.1
Turkey	21	0.3	71	0.2
North America	3,601	46.9	20,342	44.9
Central America	205	2.7	1,184	2.6
South America	0.7	0.0	3.5	0.0
Asia	2,596	33.8	16,090	35.6
Oceania	365	4.8	2,900	6.4
Africa	45	0.6	390	0.9
Total	**7,679**		**45,212**	

Table 5.2 Total installed capacity and total electricity generated in the world from geothermal energy at 1997.

Market Perspectives

It is advisable to look at the possible development of geothermal market from different standpoints. There are three kinds of actors are present in the market:

1. The consulting engineering firms for exploration, field development, plant design, project analysis and management.

2. The power plant suppliers (mainly turbogenerators manufacturers) which usually act as general contractors concerned with civil works, field equipment, installation of plant, substation, fluid collection and disposal systems.

3. The investors and operators of the field and/or the power plant

As already mentioned, the geothermal market has particular characteristics in distinct parts of the world. Different countries in different parts of the world can have similar market conditions. This especially true for USA and South East Asia where two main geothermal producers (Indonesia and the Philippines) have the same type of free market situation and Latin America where a transition from state property to a concession system is currently in progress.

The South East Asia market has changed in the last decade. In the seventies and the eighties the concessions were related to field development and the private investor sold the steam to a power plant owned by the state public utility.
In the last ten years there has been a tendency to lease a concession to operate field and power plant together, so that the investor sells electricity rather than steam.

In the past governments and state owned public utilities were clients for each one of the actors listed above. In the new privatised markets the only sector dealing with the primary client (the Government's Agencies) are the investors who now deal directly with engineering contractors and equipment suppliers.

The operators now involved in this market are a few companies, generally connected with oil or mining firms, with sound experience in geothermal exploitation and accustomed to dealing with mining risk or geological risk during the early phases of the development.

No European company which operates in this market has followed this tendency. Within the EU the combination of development expertise, operational experience and investment capability may exist, but no single company has adopted this approach or shown a willingness to enter new markets in this manner. For EU operators to be successful a consortium which includes a project financing package would need to be implemented (see Annex 4.1, paragraph 4).

The potential perspectives and the possible future opportunities for the Central and South America market are more detailed in Annex 5.5.

An analysis of the expected future share of the geothermal electricity generation market in a selected number of countries under five future market scenarios have been created with various forecasts ranging from high development to low development of the geothermal market. Projections are presented in Annex 5.1.

One of these, the so called «Medium Profile Scenario», has been taken to build up a reliable market forecast in terms of power capacity increase (MWe) at 2005 and at 2010. This scenario foresees that all planned resources, as indicated by the official national authorities, will be implemented by the year 2005, and is based on the following assumptions:

- by the year 2005 all under construction and planned plants will be installed together with a capacity corresponding to the 35% of the proven resources not yet exploited;
- by the year 2010 the additional 65% of the proven resources will be completely exploited. Proven resources, in this study, are those evaluated and defined through surface and deep exploration up to the plant feasibility.

However due to the lack of flexibility of this scenario's model analysis some adjustments on the megawatts installed for certain countries have been made based to the below considerations.

-) for the countries having no data available for proven resources, a certain share of probable and possible geothermal resources (estimated through reconnaissance and prefeasibility studies, as reported by the questionnaires and official published data).), have been regarded as potentially proven resources and partially exploited in 2010;

-) for countries were high enthalpy resources are fully exploited and proven resources well identified, low growth rates are foreseen only in connection with power plant substitution or exploitation of marginal geothermal areas.

Estimated increases (MWe) of the geothermal electricity generation by 2005 and 2010 for the EU market and world-wide markets, as defined by the Medium Profile Scenario, are presented in Table 5.3.

AREA / Country	Installed capacity (MWe)				
	1995	1996-2005	2006-2010	1996-2010	Total at 2010
Italy	742	80	90	170	912
Greece	0	80	130	210	210
Portugal (Azores)	9	5	10	15	24
France (Guadeloupe)	4	0	5	5	9
total EU	**755**	**165**	**235**	**400**	**1,155**
Iceland	50	**150**	**150**	**300**	**350**
Russia	11	**130**	**80**	**210**	**221**
Turkey	21	**260**	**200**	**460**	**481**
total Europe	***837***	***705***	***665***	***1,370***	***2,207***
USA	**2,848**	**130**	**0**	**130**	**2,978**
Mexico	**753**	**100**	**335**	**435**	**1,188**
Costa Rica	60	140	640	780	840
El Salvador	118	80	70	150	268
Guatemala	0	35	50	85	85
Nicaragua	70	105	360	465	505
Central America	**248**	**360**	**1,120**	**1,480**	**1,728**
Argentina	1	10	20	30	31
Bolivia	0	50	50	100	100
Chile	0	50	50	100	100
Ecuador	0	150	295	445	445
South America	**1**	**260**	**415**	**675**	**676**
total America	***3,850***	***850***	***1,870***	***2,720***	***6,570***
China	32	80	150	230	262
India	0	0	30	30	30
Indonesia	309	990	1,060	2,050	2,359
Japan	300	1,200	1,600	2,800	3,100
Philippines	1,445	455	1,000	1,455	2,900
Thailand	0	2	5	7	7
total Asia	***2,086***	***2,727***	***3,845***	***6,572***	***8,658***
Australia	1	0	50	50	51
New Zealand	286	160	0	160	446
Papua New Guinea	0	105	195	300	300
total Oceania	***287***	***265***	***245***	***510***	***797***
Ethiopia	7	5	100	105	112
Kenya	45	65	290	355	400
Mozambique	0	8	15	23	23
total Africa	***52***	***78***	***405***	***483***	***535***
Total capacity per period	***7,112***	***4,625***	***7,030***	***11,655***	***18,767***
Accumulated capacity	***7,112***	***11,737***	***18,767***		

Table 5.3 - Forecast for geothermal electricity generation market to 2005 and 2010

The estimate of new capacity that could be installed by 2005 and 2010 has been used as a basis to calculate the market value in terms of millions of ECU. For each market area an average cost for each KWe installed has been considered according to the optimal size of the plant that could be installed in that specific country.

The total value of the potential market (Millions of ECU (MECU)) for geothermal energy electricity production by 2005 is estimated to be about 7,300 MECU comprised of 1,500 MECU for the European market, 1,400 MECU for all the American market and about 3,850 MECU for the Asian market, while Oceania and Africa are worth 250 MECU and 400 MECU, respectively.

By the year 2010 the total world market is estimated to be worth about 11,100 MECU of which 1,200 MECU would come from Europe, 2,900 MECU from America and 5,700 MECU from Asia, with a further 350 MECU form Oceania and about 950 MECU from Africa.

Some Asian countries (i.e. India and Thailand) could offer attractive new markets by about the year 2010.

5.3 Direct heat uses market

Some estimate of the market for direct uses are presented country by country, on the basis of planned projects reflected in the recent forecasts outlined in the Country Papers in Annex 1.1.

These data are subject to significant modifications in the event of energy policy changes in the EU and other parts of the world and the estimates are heterogeneous: certain countries have indicated the number of projects that they wish to launch, others the total capacities that could conceivably be installed on their territory.

Estimates of investment forecasts in the direct uses within the geothermal sector could only be made for European countries. Reliable data on the size of potential markets is difficult to quantify because applications are spread across a number of different industrial sectors and no associations exist which cover the sector comprehensively.

Other than resource evaluations and feasibility studies specific to geothermal energy, all the other phases related to production and distribution of heat make use of existing technologies used in other sectors.

The market for direct use only exists when both resource and users are coincident. This is why geothermal resources are only used where there is a large local energy demand. It is conceivable that new direct heat markets could be opened up where geothermal resources exist, for example, horticulture.

Among the economic characteristics of geothermal energy are the high capital investments required (at the level of a private investor) and the long period required to amortise the debt.

Environment and energy saving aspects are becoming more and more important in developed countries, and geothermal energy could contribute largely to this objective.

Present status of the market

Direct utilisation of geothermal resources represent more than 31,000 GWh/year. (1997). The leading countries for installed thermal capacity are respectively USA (20%), China (20%), Iceland (15%) and Japan (12%). EU countries represent only the 11% of the total world thermal capacity installed and energy. Japan is however the leading country for annual thermal energy use, about the 21% of the world total.

As for the other continents, (Central and South America, Africa and Oceania) the development of direct heat use is modest and represents a limited part of the energy market. As indicated in the country papers in Annex 1.1, low-enthalpy geothermal energy is presently mostly exploited in developed countries.

European countries

France is the one of the main heat producer in the European Union. Geothermal district heating systems are highly developed, notably in the Paris basin region which represents 10% of heating energy sold by district heating networks and 4% in France. Presently geothermal district heating serve more than 170,000 dwellings, but it remain small % compared with the total population.

Figures for France highlight the fact that, whilst geothermal energy is not a common energy source at continental scale, it can have considerable economic, socio-economic and environmental impacts at a local level. These examples also show the importance of the support of governments or local authorities; major geothermal energy development happened in France during the 1970s, following the two oil crises.

At this time, vigorous government support for new forms of energy as substitutes for oil contributed considerably to geothermal development in the Paris area. Inversely, the development of geothermal projects stopped in the 1980s with the return to relatively cheap and available conventional energies. But the situation could move, taking into consideration the environmental aspects (geothermal contribute significantly to decrease air pollution in urban areas).

In Germany, there are favourable geological conditions, particularly in the south, in the area of the Rhine graben and in the north German graben , for thermic utilisation of the hydrogeothermal potential. The total installable potential capacity in the above regions with due consideration of the infrastructural conditions and their development, is about 40,000 MW_{th}.
The total installed capacity of 307 MW_t include 50 MW_t of the 18 hydrogeothermal plants which are in operation at present in Germany with 39 MW_t being contributed by the geothermal heating plants in the Federal Land of Mecklenburg-West Pomerania and the remanent 257 MW_t come from installed geothermal heat pumps.

Italy: main applications of geothermal energy include greenhouses (geothermal heat provides 1% of the total energy consumed) and spas/curative/heating plants in the Abano district. Here about 5 millions of m^3 of buildings (mostly hotels) are heated by means of the geothermal waters extracted from about 240 small wells. The total power equivalent is around 200 MW_t. But this figure generally is ignored by the statistics, because the exploitation is fragmented between more that 100 enterprises.
District heating with geothermal exist in two towns in northern Italy, Ferrara and Vicenza.
Nevertheless Geothermal energy covers only 1% of district heating needs and suffers from competition from traditional energy sources, gas in particular.

Iceland is the largest producer in terms of installed capacity and energy produced; 85% of space heating is provided by geothermal energy. Today it serves about 150,000 people or 99.8% of the population in Reykjavik and five neighbouring communities. Other uses such as greenhouses, industrial processes or bathing and swimming have also been developed, and represent 20% of geothermal energy consumption.

About 50% of the primary energy consumption in Iceland is geothermal energy: the highest ratio in the world. Hydro has also reached advanced stage of development and about 94% of the electricity generation in Iceland originates from it. This country is therefore in the unique situation that about 67% of the primary energy national consumption comes from renewable energy sources. The benefits from geothermal heating can be expressed as saving of about 85 MECU annually in imported oil. This is an annual saving corresponding to 340 ECU pro capita, and has therefore a large economical influence in the country.

Switzerland is a small user of low-enthalpy geothermal energy but makes extensive use of geothermal heat pumps.

Agenda 2000 and other Eastern European countries

The development of existing reserves is still small and employs older technologies. There are some installations dating from after 1980 and the recent major upheavals in terms of economic development and property rights have destabilised existing operations. The main sectors of development are district heating, agricultural uses and balneology.

Africa (Mediterranean area). Tunisia and Algeria currently use geothermal energy for greenhouses. Turkey uses it essentially for district heating (87% of the total GWht produced) and has an appreciable installed capacity of 160 MWt.

United States. Although the quantity of geothermal energy produced is relatively large in absolute terms, it is very small when compared with total energy consumption. The geothermal energy breakdown of usage is as follows: 24% space heating, 12% greenhouses, 26% aquaculture, 11% industrial, 27% spas.

Asia. Low-to-intermediate temperature waters are widely used in China and Japan. The main direct uses are space heating (mainly in northern China), greenhouses near

Beijing, fish farming and bathing. In Japan, the main direct uses of thermal waters are space heating, greenhouses, fish farming and snow melting. The main operations are concentrated in Hokkaido and Tohoku where heat demand is strong during winter, and in Kyushu where resources are abundant. A very large part (about 75%) of the annual thermal energy use indicated for 1997 (7,500 GWh_t/y) is allocated to bathing facilities.

Oceania. Low-enthalpy geothermal energy is little developed in Australia; New Zealand exploits mainly high-enthalpy geothermal energy with some industrial uses in cascade, the residual low-enthalpy water being used in balneology and tourist establishments.

Market Perspectives

There is considerable experience and expertise in European Union countries in the application of direct use geothermal energy, including engineering, management, and manufacturing. This ability is a positive factor for geothermal development both in and outside Europe.

An estimate of the market for direct heat uses as presented on the basis of expected planned projects up year 2005 (marketable resources) in the table 1.1.1 of Annex 1.1 are summarized in table 5.4 for the EU countries Iceland, Switzerland and Turkey, and in table 5.5. for some Agenda 2000 Countries, Russia and other European countries.

In Table 5.4 is estimated the geothermal capacity (heat production including geothermal heat pumps) that could be installed by the 2000/2005 in the indicated countries. This represent the minimum growth rate of the thermal power under the current world situation, with low price for oil and gas, no support and appropriate incentives in many countries and excluding the environmental benefits of geothermal energy over conventional energy sources.

In the same table the foreseable growth is given also for the period 2005/2010. The figures have been estimated considering an annual growth rate ranging from 5 to 10% depending on the local development considerations.

These values are expected to grow if the development of geothermal heat pumps in some countries is also considered. Geothermal heat pumps in some countries is also considered. Geothermal heat pumps use normal-temperature earth or groundwater for heating during the winter, cooling during the summer and supplying hot water year round. Since GHP systems deliver three to four times more energy than they consume their growing use will contribute to the decrease of energy demand.

However, the major issues that could enhance the growth of the geothermal market are energy policy decisions focusing on the reducing of energy demand and hence CO_2 emissions that EU and the rest of the world must build up and encourage in a near future.

The above metioned issues, together with the local energy policy development, are therefore the factors for the growing of the geothermal market in Europe, the figures here indicated are only a possible broad scenario foreseable up to year 2010.

Country	Thermal Capacity (MWt)				
	1997	1998/2005	2006/2010	1998/2010	Total at 2010
Austria	21	70	70	140	161
Belgium	4	0	2	2	6
Denmark	3.5	4	2	6	9
Finland	0.1	4	2	6	6
France	309	90	200	290	599
Germany	307	144	230	374	681
Greece	23	10	10	20	43
Ireland	0.7	0	2	2	3
Italy	314	50	140	190	504
Luxembourg	0	0	-	-	-
The Netherlands	0	20	10	30	30
Portugal	0.8	1	1	2	2.8
Spain	0	1	1	2	2
Sweden	47	10	25	35	82
UK	2	10	3	13	15
EU TOTAL	**1,032**	**414**	**698**	**1,112**	**2,144**
Iceland	1,443	290	210	500	1,943
Switzerland	190	100	50	150	340
Turkey	160	120	560	680	840
TOTAL	**2,825**	**924**	**1,518**	**2,442**	**5,267**

Table 5.4 Thermal capacity installed in the EU, Iceland, Switzerland and Turkey for direct heat use of geothermal energy and foreseeable growth to 2000/2005 and 2010.

European countries

According to the study «European Insurance scheme to cover Geological Risk related to Geothermal Operations, 1997» development of low-enthalpy geothermal operation for the next ten years can be broadly separated into three groups:

- a «high development group» concerning countries having good resources and potential of operation: Austria, France, Germany, Greece, Italy and Iceland. Each of five countries should have from 1 to 4 operations per year, and Iceland has forecast from 10 to 15 small-scale operations by the year 2002. The market is mainly for district heating, greenhouses (Greece), spa and balneology (even associated with space heating).

  These countries can easily develop their geothermal potential, with some support.
  In Germany, the process of development of geothermal energy is underway. Various projects combining space heating, thermal use and sauna applications are ongoing and three district heating projects are running in the new landers.

  In Austria, commercial exploitation of geothermal energy has not yet really begun. Only balneological applications are already developed and more are expected.

In France, the forecasts for new wells correspond to redrillings, some mixed thermal/industrial projects and some small operations such as greenhouses and fish farming.

- a very low potential group including countries such as Finland, Ireland, Luxembourg, Norway and Sweden where there are no major low-enthalpy geothermal reservoirs. However this group of countries have a good potential for geothermal heat pumps.

- A group «faced with dilemmas» concerning countries with geothermal resources, but having marginal projects because of competition from other energy sources (Belgium, Denmark, the Netherlands, United Kingdom), reluctance by users and/or Authorities (Spain), or conflicts of interest with the balneology industry (Portugal). Incentives are necessary to boost operations in these countries (financial support, environmental considerations, information,...)

The main investments are concentrated on district heating, representing 76% of total investment. The balneological sector is also a major end user some EU countries did not include this use in their production and consumption statistics). Finally, the development of geothermal energy for horticultural use appears promising, mainly in Mediterranean countries such as Greece (especially since financial incentives exist for energy savings in greenhouses).

The analysis of geothermal energy markets should therefore be developed by sector in order to assure an approach that corresponds to the energy development plans, since these are themselves sectorial.

Agenda 2000 and other European countries.

Several Eastern countries have good geothermal resources. Hungary, Poland, Romania, Slovakia, Slovenia, Bulgaria; have a tradition for the direct use of geothermal (mostly for balneology and horticultural) and most of the towns in these countries have district heating systems using water heated by coal or other fossil fuels. All these countries represent a large potential market for the future. The main obstacle is the lack of money for investments. With specific financial tools EU operators could participate and help to develop the market.

The Baltic countries have only medium to low geothermal resources. The exploitation of reserves located near urban areas is also to be expected in the next years; a number of preliminary explorations and feasibility studies are in progress.

Macedonia, Georgia and other CIS countries have good resources and have used them from many years; Macedonia in particular has a long tradition of using heat for agricultural applications such as greenhouses. The market could focus on modernisation and increasing the geothermal contribution, however there is a lack of financial available for longer-term investment.

Some parts of Russia, the Ukraine, Belarus and others have large medium to high enthalpy geothermal resources but they remain virtually unused. Preliminary exploration and feasibility studies would be necessary. With a dedicated financing mechanism and organisation the geothermal energy in these countries could be integrated as part of their energy supply modernisation.

In most of these countries the cost price of geothermal energy is considered to be attractive, two to four times cheaper than fossil fuel energies which one often imported. In table 5.5 a possible forecast up to 2005 and 2010 is given for a selection of Agenda 2000 countries and other European countries mainly based on the information and data provided by the questionnaires received and also by published data from Authoritative local sources and Energy Agencies.

Country	Thermal Capacity (MWt)				
	1997	**1998/2005**	**2006/2010**	**1998/2010**	**TOTAL At 2010**
Russia	**210**	**500**	**800**	**1,300**	**1,510**
Bulgaria	95	448	500	948	1,043
Hungary	750	200	400	600	1,350
Poland	44	150	400	550	594
Romania	137	320	600	920	1,057
Slovakia	75	184	450	634	709
Slovenia	37	64	150	214	251
Agenda 2000	**1,138**	**1,366**	**2,500**	**3,866**	**5,004**
Georgia	245	300	400	700	945
Macedonia	75	220	350	570	645
Yugoslavia	80	156	250	406	486
Ukraine	12	238	500	738	750
Other European countries	**412**	**914**	**1,500**	**2,414**	**2,826**
GRAN TOTAL	**1,760**	**2,780**	**4,800**	**7,580**	**9,340**

Table 5.5 Geothermal capacity installed and energy production in some Agenda 2000 countries, Russia and other European countries from direct utilisation of geothermal energy and foreseable growth of to year 2005 and 2010.

Several Mediterranean countries have geothermal potential which could be developed for agricultural purposes (greenhouses or open field). Turkey has a very high geothermal potential that is currently being developed. At present it is planned to install about 680 MWt (120 MWt were under construction in July 1994 and feasibility studies are completed for an additional 560 MWt capacity) for district heating, air-conditioning and hot water supply.

North America: Canada, despite its good resources, does not appear to envisage any large-scale development of geothermal energy. The United States also has very good resources. The forecasts for the year 2010 indicate a significant reinforcement of space heating which will represent 48% of the installed capacity (total forecast of 3070 MWt).

Asia: The reserves are large but, with the exception of China, the use of geothermal energy is generally concentrated on high-enthalpy resources. The available data from these countries are insufficient. All we know is that in Japan further development would combine direct uses of thermal waters with small-scale, binary cycle electric power generation.

Central and South America: Despite large reserves in these regions, little development is expected. Some investments in district heating and greenhouse projects are possible.

5.4 Geothermal Heat Pumps market

GHP resources are available in all countries.

The market for geothermal heat pumps (GHP) covers a large market spectrum from individual house owners (few kilowatts) to large public building complexes. This market sector is less influenced by political factors. The market is therefore characterised by a large number of potential investors and by a rapid decision-making process and low costs investments.

Since the double function of geothermal heat pumps (heating and air-conditioning) corresponds well to modern comfort demands, numerous promotional groups are appearing (in Switzerland, the Netherlands, France and the United States) and strong development in the heat pump market is expected in next future. GHP are presently in operation in all EU countries.

Present status of the market

The GHP market is quite different. The United States makes extensive use of heat pumps (1,444 MWt installed) for heating and air conditioning, while in Europe the market is growing rapidly in different countries.

In Europe, the market for geothermal heat pumps has developed mostly in areas such as Switzerland, Germany and Austria. In Sweden 3,000 GHP were installed in 1995. This market mainly concerns space heating and with 12% of installations in the residential sector.

It is particularly important in Switzerland where GHP are promoted by a Promotional Grouping that works on techniques, marketing, labels, training and monitoring of installations. The result today is that Switzerland has the most active geothermal heat pump market in Europe. In 1995 more than 4,000 GHP (ground water or ground sources) were installed mainly in new housing.

In USA there is a long tradition for the use of geothermal heat pumps and the market is highly developed. Air-conditioning needs generate sales of 20,000 geothermal heat pumps annually (compared with 2 million gas boilers), and the market share has been increasing since 1980.

In Japan the geothermal heat pump market is highly developed owing to the climatic conditions.

Market perspectives

Geothermal Heat Pumps can be developed in all the countries (taking in consideration the resources). Presently the market offers a great potential (on going market) mainly in EU countries and North America.

In several EU countries, the geothermal heat pump market is booming. In the Netherlands, the National Energy Agency, electricity producers and distributors, builders and designers are working together, following the example of Switzerland and Sweden to promote the use of GHP. In fact in these two countries are respectively planned by the year 2000 about 40,000 GHP and more than 3,000 GHP per year for the next years. For both countries the positive environmental impact and energy saving aspect of the GHP are the reason for the buoyant market.

The main motivation of the Swiss home owners is that the units (borehole heat exchange + heat pump) provide CO_2 free heating and that there is no risk of groundwater contamination as with oil boilers7tanks and transportation risks and cost fluctuations as with oil gas solutions. Furthermore, the local electrical utilities provided electricity rebates for environmentally favourable options, and there is a governement/local subsidy (up tp 4,400 ECU) when replacing and old oil furnace by a GHP unit. The environmentally favourable GHP solution is only slightly more expensive. (180-260 ECU/year, including annuity) than a conventional (oil based) system at present oil prices.

France, Germany are also potential markets, United Kingdom, Austria could develop GHP in a near future. A potential market are also the South European countries where air conditioning is needed : Italy, Spain and Portugal.

GHP are also developed in other EU countries (at a smaller scale). To boos the market a better organisation of the main operators is needed such the Netherlands and the USA.

Promotion and development programme could be planned at European level following the example seen.

In the USA an ambitious promotion and development programme for geothermal heat pumps was started in 1995. The Geothermal Heat Pump Consortium, which includes the Department of Energy, the American Environmental Agency, major electricity producers and other energy professionals, has taken up the challenge of increasing pump sales from the present figure of 20,000 units annually to 400,000 by the year 2000. To achieve this target, financial assistance schemes have been created, the costs of wells and installations have been subsequently reduced by the use of new technologies. The sector has been reinforced by a major communication and demonstration campaign.

The primary markets for GHPs include new homes and buildings (apartments, schools, commercial buildings,..) with both heating and cooling needs.
For exhisting buildings GHP could replace with high efficiency heating / cooling and domestic hot water electric systems, mainly in EU countries and North America.

BLUE BOOK ON GEOTHERMAL RESOURCES

Chapter 6

Chapter 6
ACTIONS IN FAVOUR OF THE GEOTHERMAL SECTOR

6.1 Introduction

The investigation and analysis of Geothermal energy carried out in the Blue Book, has reviewed the status of technical development and the availability of geothermal resources as well as the advantages and benefits that make geothermal energy competitive, environmentally beneficial, reliable and safe compared to most other energy sources.

Geothermal energy has been produced commercially on the scale of hundreds of MW for over three decades both for electricity generation and direct utilisation in many parts of the world.

A key aim of the Blue Book is to highlight what measures can be considered most effective to significantly increase the exploitation of this environmentally benign energy source, including its export potential, and its contribution to the overall reduction in the CO_2 emissions in Europe. Most emphasis is placed on the EU and associated countries as well as countries that are likely to become associated with the EU in the near future (Agenda 2000 countries).

The exploitation of geothermal energy, especially for direct heat uses, is at a relatively more advanced stage in European countries than in other parts of the world and offers a wide range of potential applications, both in terms of use and size of operation.

Large scale development of geothermal energy had already started in the 1930's in Italy for electricity production and in Iceland for district heating. There is now some direct utilisation of geothermal energy in more than 30 countries in Europe, and electricity is produced commercially in France (Guadeloupe), Iceland, Italy, Portugal (Azores), Russia and Turkey, and experimentally in Austria, Greece and Romania. Europe has been the pioneer in geothermics, and European operators, with sound experience and expertise, should maintain a leading role or at least strengthen their presence within Europe and world-wide.

Geothermal energy is in general commercially competitive with fossil fuels, hydro and nuclear and contributes to the protection of the environment. It should be strongly considered as one of the primary protagonist technologies in the EU's strategy to promote renewable energy.

Furthermore, the Blue Book identifies measures to increase the presence of European operators in the world market for geothermal energy. This global market is rapidly expanding (Chapter 5), however, European operators have lagged behind. This is at least partly due to essential aspects such as: the aggressive policy of the non-European industry which now provides a wide range of geothermal products and services and a weak industrial/political lobby in favour of geothermal in the national bodies.

The European Community could, however, play an active role to improve the presence and competitiveness of the European industry in all geothermal market sectors around the world, both for electricity production and direct uses.

6.2 Constraints to the geothermal resources and market

To support the development of geothermal resources in Europe and the presence of geothermal European operators, clear ideas are needed to tackle the main constraints that at present hamper the sector. A series of potential initiatives are outlined below.

A) Approach to the market

Important changes have occurred in recent years in electricity generation markets and the electricity utility companies. There has been a world-wide tendency to adopt a free market, with a shift to privatisation and liberalisation of energy markets. This change has affected many geothermal electrical power stations both in developing countries and industrialised countries. In fact about 50% of the electrical generation capacity in the world is now in private ownership. The role of the public sector is controlled through national utilities and governmental agencies, which in the past constituted both the promoter and developer of most geothermal projects. Public sector involvement has substantially decreased and the trend appears to have continued.

Private operators approach geothermal projects as a normal business venture in which the investment (and the risk) is strictly conditioned by the profit, the pay back time, and the internal rate of return from a project. The main incentives which attract private operators are suitable financial conditions and geothermal schemes which perform to productivity targets.

It is important to note that international financing institutions such as the World Bank, IFC, EBRD, ADB etc. strongly favour the direct presence and involvement of private sector operators in energy projects. Private companies and consortia (including financiers and technical operational partners) invest their own money in geothermal concessions and are successfully operating in many of the most attractive geothermal fields and in the most promising new geothermal areas.

Private operators (mainly from the USA) are gradually dominating the SE Asian markets for electricity production from geothermal energy and their presence appears to be overwhelming European competitors.

The Latin American market still seems partially open to penetration from European operators, which is generally positively received by local authorities.

Efforts should be made in this direction because non-European operators are presently moving to consolidate their presence in the Central and South American markets.
In Annex 5.4 some short to medium term opportunities are illustrated in this latter market.

Japanese operators are also applying the same approach together with other important economic inducements such as:

- systematic agreements and collaboration among national firms facing external competition in international tenders
- strong governmental support for credits as exemplified by the Overseas Economic Co-operation Fund (OECF)
- commercial support from national agencies and institutions.

These actors represent serious competition for the European geothermal operators. The European operators (manufacturers, engineering companies, utilities, etc.) have not been able to meet the strategic and financial risks that have been progressively imposed on the geothermal world market for electricity production.

As a consequence they risk being push progressively to the fringe of the geothermal world market for electricity production and related businesses, or remaining present only as subcontractors of services and components (with exasperate price competition). The leadership and management as well as most of the profits from projects will consequently remain in other hands.

The market for direct uses of geothermal energy is extensive in European countries where there are large resources to be exploited and a long tradition of using geothermal heat use. Opportunities both to extend this usage and to develop the related businesses exist, especially in Eastern European countries and in China, where large centralised district heating systems already exist which mainly use conventional fuels.

B) Mining risk

The concept and the economic assessment of mining risk has been fully discussed in Chapter 4 and Annex 4.1.

The European Commission has already paid attention to this issue, and a special study on the feasibility of an insurance system to solve the problem was produced in 1997.[1] The sound and deep analysis performed in this study is exhaustive. Such a scheme would enable easier access to both national and international financing for geothermal projects. The establishment of such an insurance system could be an effective measure to push and expand the geothermal market in Europe and to improve the exploitation of this renewable resource. This system could also be used as an example for similar initiatives in other parts of the world.

[1] Report on Insurance scheme to cover Geological Risk related to Geothermal Operations - Final report - 1977

C) Economic constraints

The overall competitiveness of geothermal energy is also determined by the comparison with other conventional and renewable energy sources. The cost of the alternatives has been based upon standard economic and financial analyses with geothermal projects. The main international financing agencies are currently applying a least-cost analysis as part of their procedure to grant loans for projects.

It should be stressed that at present in Europe, the low cost of fossil fuels, especially natural gas, make only the best geothermal resources competitive from a strict financial viewpoint. Nevertheless, geothermal energy could become much more competitive from an economical standpoint if the following criteria were considered:

- renewable (especially the low enthalpy resources)
- clean
- indigenous
- highly reliable

Each one of these factors results in a shadow price that may substantially, and positively, affect the economical evaluation of geothermal energy. This aspect has been based on a specific study[2] the argument for which has been presented in paragraph 4.5.

The external cost of traditional fuels has been estimated to be almost 10 times higher than the comparable cost of renewable energy sources and almost 50% of the overall economic cost (against 1% of the renewable sources case). Geothermal energy was unfortunately left out of this study and can not consequently be compared directly with other renewables and conventional fossil fuels. If, however, the external costs of geothermal energy were included they would be of the same order as other clean energy sources. Moreover, if external costs where included as part of an economic comparison between geothermal energy and conventional alternatives, geothermal energy would be regarded far more competitively favourable.

The characteristics of this energy source not only positively affect its economic value, but also fit the EU strategic targets in terms of environmental and energy supply policy.

D) Constraints from lack of information/confidence

Geothermal energy could be more widely developed, but often there is a lack of awareness particularly amongst small utilities who are unfamiliar with the technology.

This lack of information has multiple effects on the development of geothermal energy:

- the economic value of this energy is underestimated and misunderstood;
- the potential of existing resources is often unknown and not evaluated by local Authorities or appreciated by decision makers;
- planners and decision makers at local levels do not integrate this energy source into their development plans even when the resource is available and known about;

[2] Environmental costs of electricity, Pace University centre for Environmental Legal Studies, Oceana Publications, N.Y., 1990; and CESEN estimates.

- projects submitted to Financing Agencies often lack sufficiently detailed information which makes it difficult to raise funds for project implementation;

Moreover, as geothermal energy is a non-tradable product it has to be developed at a local level. Apart from large high enthalpy fields, where institutional and traditional investors deal directly with large operators, the exploitation of other resources, especially for district heating or heat supply, strongly depends on the involvement of local authorities. Other smaller scale projects and the GHP sector tends to involve individuals or small investors.

Local decision makers and individual investors are not, generally, geothermal specialists. A suitable and sound information support system is therefore an essential tool to promote the development of geothermal energy in the EU.

Extreme variability in production costs in different sites can also present a misleading picture to planners. A sound methodology based on the assessment and evaluation of the real cost of low enthalpy geothermal energy is crucial to support decision makers and therefore the spread of the technology.

In Europe there are National Geothermal Associations in ten countries and eight of these are affiliated with the International Geothermal Association (IGA). The European Branch of the IGA was established in 1992 as a scientific, educational, non-political and non-profit making organisation. These associations could play a very important role in technical co-operation between countries, the transfer of technology, and in maintaining a database for geothermal potential and development in individual countries. They could act collectively through the European Branch of IGA to conduct information campaigns, promote geothermal energy, assemble national data and identified promising geothermal projects in different countries. The European Branch of IGA would not, however, deal directly with industrial and commercial projects or the marketing of geothermal business.

Both in Japan and the USA other more commercially oriented geothermal energy associations have been established to consolidate and strengthen the market position of their geothermal manufacturers, consulting agencies, drilling contractors, logging companies and geothermal developers. These associations operate for the promotion of the member companies both on the home front and internationally.

A European Geothermal Energy Council (EGEC) operating within Europe and abroad, in a similar way to the Geothermal Energy Association in the USA, has been established with a key objective to strengthen the international market position of European geothermal manufacturers and service companies. The EGEC could offer incentives to European consortia amongst energy operators who want to invest in geothermal projects in Europe and abroad, and assist European companies in competition with existing Japanese and US consortia

Given their different roles, the European Branch of the IGA and the EGEC could serve as the principal EU contacts for EU geothermal data and statistical references, provide sound information for decision makers, organise promotional activities at different venues, provide contacts with other renewable technology associations and other European industrial associations.

6.3 Recommended actions

The former chapters have shown the complexity of the geothermal scene. Before defining further actions, it is advisable to outline different areas in which EU involvment could be carried out.

The EU action plan should have two goals:

- to increase the exploitation of geothermal energy in the EU and associated countries;
- to support European firms within the sector to increase their share of the world market

Moreover, future actions for the EU have to be established according to geographical and political criteria which cover:

a) EU countries
b) EU associated countries
c) Countries benefiting from specific EU aid programmes
d) Other regions

Support for the spread of exploitation and use of geothermal energy will be directed mainly within the EU and associated countries, while support to EU operators will be directed at all other countries.

The recent White Paper "Energy for the Future: Renewable Sources of Energy" describes the EU strategy and objectives, but suggests that each Member State should decide its own strategy according to its own potential and resources.

This implies that an effective action plan will be outlined and decided at Member State level. The EU would be responsible for the guidelines and pressing Member States and Local Authorities to drive the implementation of new geothermal initiatives and in some cases to implement direct actions in favour of them, aiming at the followings

1. *To stimulate the creation of European consortia and joint ventures among different subjects (engineering firms equipment manufacturers, electric power companies, financing agencies) interested in investing in geothermal projects in Europe and abroad to cope with the competition from non European companies. This could be achieved by giving priority to programmes and projects including co-financing of European industrial partners for preliminary identification studies, prefeasibility studies (of the advance type, reimbursable during execution of the work) and plant implementation.*

This action could be focused specifically at Latin American and Chinese markets which currently appear the most open and "free" to EU operators.

2. *To favour National Geothermal Associations, and the European Branch of IGA, in their non-profit making activities for the promotion, information, dissemination and transfer of experience and contacts within the world geothermal community. These organisations, together with the EGEC, should become the principal EU contact for geothermal energy matters such as the EU geothermal programmes and statistics reference, information for decision makers, awareness communication, promotion, contacts with other renewable sources association and other European industrial association, etc.*

3. *To support the newly created EGEC (European Geothermal Energy Council) among the European geothermal manufacturers and service companies which operate within Europe and abroad in a similar way to the Geothermal Energy Association in the USA. The EGEC would strengthen European consortia among energy operators wanting to invest in geothermal projects in Europe and abroad, and assist European companies in competition with existing Japanese and US consortia.*

4. *The maintenance and improvement of the EU's existing research and financing programmes, from DGI, DGXII, DGXIII, DGXVI and DGXVII dedicated to energy projects including Alure, Phare, Tacis, Joule, Inco-Copernicus, Structural Funds, Altener, Synergy and Thermie. These programmes have in the past positively influenced research, testing and promotion of new geothermal applications in recent years as the knowledge of geothermal problems and opportunities has grown.*

5. *To promote the environmental benefits of geothermal energy through favourable financing condition such as:*

   - *tax exemptions or reductions for RE products;*
   - *tax incentives to be addressed to geothermal projects financing*
   - *financial incentives for end-users to buy equipment and services*
   - *loans and special interest rates devoted to investments in RE resources in general.*

6. *Geothermal energy should be included in specific "target projects" and demonstration projects such as the European Green Cities, which is supported by the EU Thermie programme, both as an environmental friendly resource and as an indigenous energy supply for saving imported fossil fuels. Examples of special target projects could be:*

   - *partial or total replacement of fossil fuels by geothermal energy for the generation of electricity in the Azores, the Greek islands, as well as Italy's small islands and the Canaries which would provide environmental and economic benefits to these communities. Both technical assistance and public relations activities are needed to promote geothermal electricity production in these areas*

- *(see "Campaign for take-off, paragraph 3.2.4 of integration of RE in 100 Communities [3]);*

- *technical and financial support for demonstration projects in the use of medium temperature geothermal water for electricity production using binary fluids.*

7. *To establish an insurance system for EU countries in order to cover the geological risk which is an effective measure to stimulate and re-launch the geothermal European market and improve the exploitation of this renewable resource. This system could also be demonstrated within the EU and used as an example for analogous initiatives in other areas/countries of the world.*

8. *Implement proper actions devoted to the systematic integration of geothermal energy into existing and new EU and national RE development programmes. This action should move in two directions:*

   - *integration of geothermal energy in national and regional New and Renewable Energy development programmes since in some EU countries geothermal energy is not included and in some cases is not even considered as a renewable form of energy.*

   - *integration of geothermal energy use in the development of new district heating systems and the rehabilitation of existing networks within EU countries and especially in countries which could become associated in the near future. This integration could start for rehabilitation and modernisation projects of large diffused district heating systems in different European countries (Agenda 2000, Russia and other European countries) financed by EU programmes (TACIS, PHARE etc.) or international financing institutions (WB, EBRD etc.). The integration of geothermal energy could become a compulsory condition, when applications are made for investment funds.*

   Special attention should be paid to the possibilities offered by the rapid expansion of direct use applications for geothermal energy in Central and Eastern European countries and CIS countries, where unexploited but plentiful geothermal resources have been identified. There is a long tradition of using geothermal energy for direct applications (mostly for balneology and greenhouses) in many of these countries, and most of the towns have district heating systems using water heated by hydrocarbons.

   With education as well as financial and technical support, a significant reduction could be made in carbon dioxide emissions through replacement of coal and other hydrocarbons partly or totally with geothermal and other non-polluting energy resources. There is wide scope for the integration of indigenous energy sources in the space heating market in these countries.

[3] "Energy for the future: Renewable Sources of Energy - White Paper for a Community Strategy and Action Plan - 1997".

9. *Promote directives in order to acknowledge RE investments (including geothermal) with an extra price or a contribution for the KWh_e/KWh_t produced which corresponds to the external benefit derived from the substitution of conventional energy sources. The relative funds could be achieved by a tax (green tax) charged on the KWh_e/KWh_t produced through conventional sources. (Considering the present prevailing contribution from the latter the extra charge at the same should be negligeable in absolute terms).*

10. *Increase the use of information brochures and actions of the "Multi-energy" type, with the objective of increasing the level of information and confidence of using geothermal energy by decision-makers, private and public operators, town planners, designers, even within EU programmes. The establishment of a proper methodology for a cost evaluation of low enthalpy geothermal projects, possibly supported by software, would be a useful tool. Moreover, there is a great need for demonstration projects in individual countries to convince the public and decision makers of the viability of geothermal energy, both alone, and in integrated solutions with other locally available energy sources such as waste burning and biomass.*

11. *Promote a detailed study for the evaluation, in quantitative terms of the external benefits from substitution by geothermal applications. This evaluation should be based on statistical data from specific applications (electricity generation and direct uses) in EU countries and contrasted with comparable conventional options.*

12. *Considering the good development perspectives of this application, special attention could be devoted to the promotion and support for the GHP market via the followings steps:*

    - *decrease the cost for ground loop installation (standardised technologies with drilling companies, better access for the public to the drilling company information, etc.);*

    - *provide low interest loans for GHP installation;*

    - *provide better information for the public (full and easy access to information related to GHP technologies) and better co-ordination between active operators (drillings, companies, main features, engineering, etc.). A specific programme should be implemented, or the EGEC (European Geothermal Energy Council) could establish and manage a publicity campaign (similar to what has already been achieved in Switzerland and the USA), which is aimed at domestic users communities and even individual countries.*

    The general public and decision makers should be informed of the fact that geothermal resources exist in every country and that these can be used to substitute environmentally degrading fossil fuels for every day activities such as the heating and cooling of buildings.

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ABBREVIATIONS, DEFINITIONS AND UNITS

Availability	Time share of a power plant when it is ready and available to operate.
BLT	(Built, Lease and Transfer) is an alternative type of BOT (see below), but the running period phase is not managed by the promoter of the project but by the beneficiary local company to which the property of the new plant will be transferred after the full investment cost has been recovered.
BOO	(Build, Own and Operate) is a version of project financing where the plant is not transferred after the operating period normally used to repay the capital investment but remains the property of the JVC (see below) established in the beneficiary country, as a local company.
BOOT	(Build Own, Operate and Transfer) is a version of project financing which starts in a similar fashion to a BOO scheme but after a given period of time the property is re-transferred to the commissioner (host government, or other public authority, state owned enterprise).
BOT	(Build, Operate and Transfer) is a form of concession usually involving totally new projects. Typically in a BOT, a private party (or consortium, namely the JVC Joint-venture company) agrees to finance for a specified period and then transfer the facility to the commissioner.
Capacity factor	Characteristic of any generating installation which is a measure of its intended capability to supply electrical power or heat. This is normally expressed as a percentage calculated by dividing the actual operating time over one year by the theoretical output for that plant as if it were operating continuously for one year.
Coefficient of performance (COP)	The ratio of the energy output to operating energy input. The basic measure of the efficiency of a heat pump.

Exploitation	The useful application of geothermal resources obtained by extraction of geothermal energy from the subsurface by any technology, such as boreholes, borehole pumps, flashing etc.
Exploration	The search for geothermal energy in a broad sense covering several (tens of) square kilometres. It includes both generalised and concentrated prospecting for target reservoirs.
External cost or externalities	The cost of generating electricity which is not normally included in the "cash cost". The external cost accounts for damage caused by pollution, damage to health, protection of oil supply routes etc.
Installed capacity (MWe, MWt)	The installed geothermal capacity in megawatts for electricity (MW_e) or direct use, heat (MW_t). Installed capacity for electricity generation is usually specified in terms of the plate-rated capacity of the turbo-generators in a system rather than the more correct definition of the amount of electricity which can be generated from the available geothermal fluid. The installed capacity for direct use, however, is determined both by production from the well and by the temperature difference between inlet and outlet for each system, and hence depends on the particular application.
JOC	(Joint Operating Contracts) to be addressed to the different operators of the financing projects.
Kilowatt (kW)	A measure of power.
Kilowatt hour (kWh)	The energy consumed by using 1 kW for one hour
Load factor	The ratio of the average electricity/heat load over the year to the maximum demand or peak electricity/heat load of the year.
Megawatt (MW)	1000 kilowatt
Megawatt hour	The energy consumed by using 1 MW for one hour
Pay-back time	The time between the beginning of production and the moment when the cumulated cash flow becomes positive.

Plant factor — Average yearly percentage of time plant generates at rated power, during the whole economic lifetime.

Probable and Possible resources — Geothermal resources evaluated through surface surveys only (geochemistry, geophysics, etc.) or through simple reconnaissance studies such as geological evidence.

Proven resources — Geothermal resources evaluated through surface surveys and wells, both exploratory or development wells, and feasibility studies.

Temperature gradient — The rate of increase in temperature T, with depth z, usually expressed in degree Celsius per metre (°C/m). For a given system of co-ordinates the symbol is grad (T). In practice, only the vertical component is considered: $\Gamma = grad_z T = dT/dz$ and, if the temperature gradient is constant , $\Gamma = \Delta T/\Delta z = (T_2-T_1)/(z_2-z_1)$. The temperature gradient is a function of depth (z). It is therefore necessary to refer always to the considered depth interval, otherwise extrapolation could lead to incorrect values. Sometimes it is also called geothermal gradient or thermal gradient.

toe — tonne of oil equivalent 1toe = 41,868 GJ or 1toe=10^7 Kcal

BLUE BOOK ON GEOTHERMAL RESOURCES

Annexes

CESEN
BRGM
ETSU
GTN
ORKUSTOFNUN

Annex 1.1

GEOTHERMAL RESOURCES: "COUNTRY PAPERS"

Introduction

An initial selection has been made from all the world's countries where geothermal resources are known to exist was made, and as a result, about 104 countries have been investigated. The countries investigated are grouped according to geographical and organisational areas and ordered alphabetically.

The study has incorporated information from bibliographical data collection, mailing of specific questionnaires with local and international institutional and non-institutional entities, and interviews to local and international experts in the field; this knowledge has been used to update the status of the geothermal potential for each country and the level of geothermal exploration and exploitation.
As a consequence, a second selection of the countries has been made in accordance with the aim of the present study.
Many countries have been excluded because of the following criteria:

- countries with negligible geothermal potential for either electricity generation and direct uses
- countries with limited available data on geothermal investigation
- countries with a proven geothermal potential but with little or no realistic prospects of development activity within the time period under consideration in this study (up to 2010)

The 104 countries where geothermal resources are known to exist and considered in the Blue Book are listed in Table 1.1.1 and shown in Figure 1. Some countries (30) marked with a star (*), are those which have a high proven geothermal potential and/or have a high probability of implementing geothermal projects for electricity generation within 2010 (see also Annex 5.5).

In this appendix the available data on nature, size of the geothermal resources for each country investigated by the study and on present geothermal plants and activity are summarized in individual **"Country Papers".** Some general data on economics and total electricity production are given where available

Figures of installed capacity and energy produced for plants in operation, as indicated in the received questionnaires, referred mainly to 1995 as a reference year for the above electricity generation scenarios. For most of countries, in particular EU countries and major geothermal countries, data on installed capacity and energy produced have been updated to 1997 and presented in Table 1.1.2 and Table 1.1.3. as also in Chapter 1.
The label "Marketable resources" includes geothermal resources evaluated from wells or even exploratory and feasibility studies (proven resources). It also includes resources that will be exploited in plants and facilities under construction or planned.

	EUROPEAN COUNTRIES		NON- EUROPEAN COUNTRIES
•	**EU member countries**	•	**Asia**
1	Austria	1	Burma
2	Belgium	2	China*
3	Denmark	3	India*
4	Finland	4	Indonesia*
5	France*	5	Iran
6	Germany*	6	Israel
7	Greece*	7	Japan*
8	Ireland	8	Jordan
9	Italy*	9	Laos
10	Luxembourg	10	Lebanon
11	Netherlands	11	Nepal
12	Portugal*	12	Kazakhstan
13	Spain	13	Korea, North & South
14	Sweden	14	Kyrgyzstan
15	United Kingdom	15	Pakistan
		16	Philippines*
•	**EEA**	17	Sri Lanka
16	Iceland*	18	Taiwan
17	Liechtenstein	19	Thailand*
18	Norway	20	Turkmenistan
		21	Uzbekistan
•	**Agenda 2000 countries**	22	Vietnam
19	Bulgaria		
20	Czech Rep.	•	**Africa**
21	Estonia	23	Algeria
22	Hungary	24	Burundi
23	Latvia	25	Djibouti
24	Lithuania	26	Egypt
25	Poland	27	Eritrea
26	Romania	28	Ethiopia*
27	Slovakia	29	Kenya*
28	Slovenia	30	Madagascar
29	Cyprus	31	Malawi
		32	Morocco
30	Russia*	33	Mozambique*
		34	Rwanda
31	Switzerland	35	Tanzania
		36	Tunisia
32	Turkey*	37	Uganda
		38	Zambia
•	**Other European countries**	39	Zimbabwe
33	Albania		
34	Armenia	•	**North America**
35	Azerbaijan	40	Canada
36	Belarus	41	Mexico*
37	Bosnia & Herçegovina	42	USA*
38	Croatia		
39	Georgia	•	**Central-South America**
40	Macedonia, FYR	43	Argentina*
41	Moldova	44	Bolivia*
42	Ukraine	45	Brazil
43	Yugoslavia, FR	46	Chile*
		47	Colombia
		48	Costa Rica*
		49	Ecuador*
		50	El Salvador*
		51	Guatemala*
		52	Honduras
		53	Nicaragua*
		54	Panama
		55	Peru
		56	Venezuela
		•	**Oceania**
		57	Australia*
		58	Fiji
		59	New Zealand*
		60	Papua New Guinea*
		61	Other Pacific islands

Table 1.1.1- List of the geothermal countries assessed by the Blue book.

	Electricity generation				Direct utilisation			
	Plant in operation 1997			Marketable resources	Plant in operation 1997			Marketable resources
	(MWe)	(GWh/y)	(ktoe)	(MWe)	(MWt)	(GWh/y)	(ktoe)	(MWt)
Austria	-	-	-	-	21	84	5	140
Belgium	-	-	-	-	4	19	1.6	n.a.
Denmark	-	-	-	-	3.5	15	1.3	4
Finland	-	-	-	-	0.1.	0.5	-	n.a.
France*	4.2	24	2	8	309	1,359	117	90
Germany	-	-	-	-	307	806	69	144
Greece	-	-	-	210	23	37	3.2	10
Ireland	-	-	-	-	0.7	1	0.1	n.a.
Italy	742	3,762	324	228	314	1,026	88	50
Luxembourg	-	-	-	-	-	-	-	-
Netherlands	-	-	-	-	n.a.	-	-	20
Portugal**	8	46	4	n.a.	0.8	5	0.5	n.a.
Spain	-	-	-	-	-	-	-	n.a.
Sweden	-	-	-	-	47	351	30	10
UK	-	-	-	-	2	15	1.3	10
EU member countries	**754**	**3,832**	**330**	**446**	**1,032**	**3,719**	**317**	**478**
Iceland	**80**	**375**	**32**	**120**	**1,443**	**5,878**	**506**	-
Russia	**11**	**25**	**2**	**210**	**210**	**673**	**58**	**n.a.**
Switzerland	**-**	**-**	**-**	**-**	**190**	**265**	**36**	**100**
Turkey	**21**	**71**	**6**	**358**	**160**	**800**	**69**	**2,264**
Bulgaria	-	-	-	-	95	346	30	448
Czech Rep.	-	-	-	-	2	15	1.3	n.a.
Estonia	-	-	-	-	0	0	-	0
Hungary	-	-	-	-	750	3,286	283	200
Latvia	-	-	-	-	n.a.	-	-	16
Lithuania	-	-	-	-	n.a.	-	-	70
Poland	-	-	-	-	44	144	12	n.a.
Romania	-	-	-	1	137	528	45	320
Slovakia	-	-	-	-	75	375	32	184
Slovenia	-	-	-	1	37	217	17	64
Cyprus	-	-	-	-	n.a.	-	-	n.a.
Agenda 2000 countries	**-**	**-**	**-**	**2**	**1,140**	**4,911**	**432**	**1,302**
Armenia	-	-	-	-	n.a.	-	-	16
Bosnia & Herçegovina	-	-	-	-	-	-	-	33
Croatia	-	-	-	-	11	50	4.3	815
Georgia	-	-	-	-	245	1,000	86	n.a.
Macedonia	-	-	-	-	75	151	13	220
Ukraine	-	-	-	-	12	60	5.2	238
Yugoslavia, FR	-	-	-	-	86	670	58	156
Other European countries	**-**	**-**	**-**	**-**	**429**	**1,931**	**213**	**1,478**
Non EU countries	**112**	**471**	**40**	**690**	**3,572**	**14,458**	**1,314**	**5,144**
Grand total Europe	**866**	**4,303**	**370**	**1,136**	**4,604**	**18,177**	**1,631**	**5,622**

* Guadeloupe (for electricity generation) ** Azores

Table 1.1.2 - Geothermal utilisation for electricity generation and direct use in Europe.[1]

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[1] * Marketable resources: includes resources that will be exploited in plants and facilities under construction and resources evaluated through feasibility studies (proven resources)

* 1 GWh = 860×10^6 kcal - 1 toe = 10^7 kcal

	Electricity generation				Direct utilisation			
	Plant in operation 1997			Marketable resources	Plant in operation 1997			Marketable resources
	(MWe)	(GWh/y)	(ktoe)	(MWe)	(MWt)	(GWh/y)	(ktoe)	(MWt)
China	32	175	15	n.a.	1,914	4,717	406	n.a.
India	-	-	-	21	-	-	-	-
Indonesia	589	4,385	377	1,769	-	-	-	-
Israel	-	-	-	-	42	332	29	n.a.
Japan	530	3,530	304	2,870	1,159	7,500	645	672
Korea, N & S	-	-	-	-	-	-	-	-
Philippines	1,445	8,000	688	1,455	-	-	-	-
Thailand	0,3	2	0.2	5	2	8	0.7	n.a.
Vietnam	-	-	-	0,3	-	-	-	-
Asia	**2,596**	**16,090**	**1,384**	**6,120**	**3,117**	**12,557**	**1,080**	**672**
Algeria	-	-	-	-	1	5	0.4	640
Ethiopia	0	-	-	23	-	-	-	-
Kenya	45	390	34	514	-	-	-	0
Mozambique	-	-	-	25	n.a.	-	-	n.a.
Tunisia	-	-	-	-	70	350	30	n.a.
Zambia	0	-	-	0,2	-	-	-	-
Africa	**45**	**390**	**34**	**562**	**71**	**355**	**30**	**640**
Canada	-	-	-	70	3	13	0.2	n.a.
Mexico	753	5,682	489	435	n.a.	-	-	n.a.
USA	2,848	14,660	1,261	130	1,905	3,971	342	-
North America	**3,601**	**20,342**	**1,750**	**635**	**1,908**	**3,984**	**342**	**-**
Argentina	0,7	3,5	0.3	30	n.a.	-	-	-
Bolivia	-	-	-	36	-	-	-	-
Chile	-	-	-	100	-	-	-	-
Costa Rica	60	447	38	918	-	-	-	-
Ecuador	-	-	-	534	-	-	-	-
El Salvador	105	486	42	178	-	-	-	-
Guatemala	-	-	-	164	-	-	-	-
Honduras	-	-	-	7	-	-	-	-
Nicaragua	40	250	22	465	-	-	-	-
Panama	-	-	-	-	-	-	-	-
Peru	-	-	-	n.a.	-	-	-	n.a.
Central-South America	**206**	**1,187**	**102**	**2,432**	**-**	**-**	**-**	**-**
Australia	0.2	0.8	0.1	50	-	-	-	-
Fiji	-	-	-	25	-	-	-	-
New Zealand	365	2,900	249	78	5	25	2.2	n.a.
Papua New Guinea	-	-	-	300	-	-	-	-
Oceania	**365**	**2,900**	**249**	**532**	**5**	**25**	**2.2**	**-**
Grand total non-Europe	**6,813**	**40,909**	**3,519**	**10,281**	**5,101**	**16,921**	**1,455**	**2,152**
Grand total World	**7,679**	**45,212**	**3,889**	**11,417**	**9,705**	**35,098**	**3,086**	**7,774**

Table 1.1.3[1] - Geothermal utilisation for electricity generation and direct use outside Europe

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[1] * Marketable resources: includes resources that will be exploited in plants and facilities under construction and resources evaluated through feasibility studies (proven resources)

* 1 GWh = 860×10^6 kcal - 1 toe = 10^7 kcal

COUNTRY PAPERS

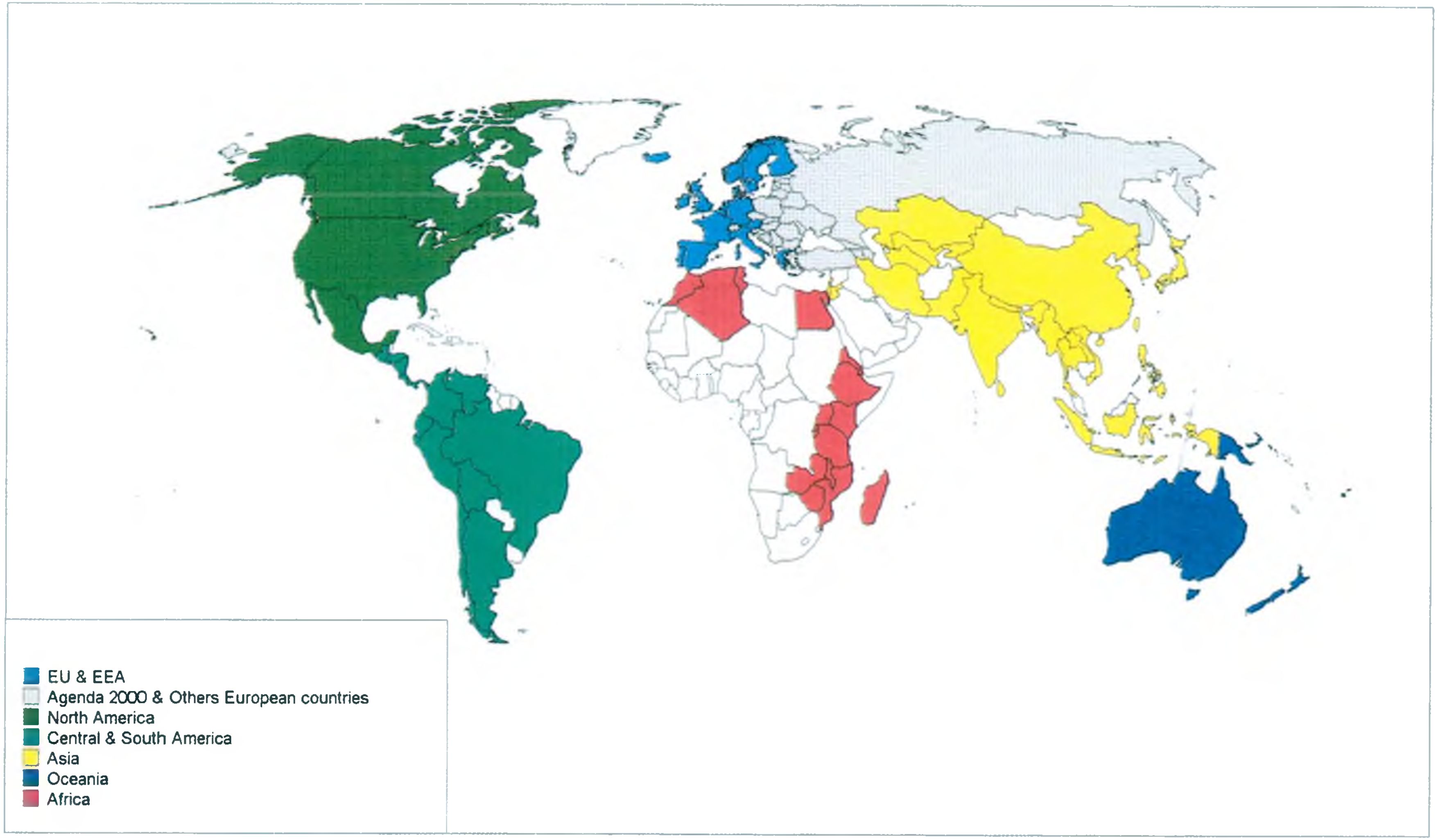


Figure 1.1.1. Study Areas and investigated countries of the study

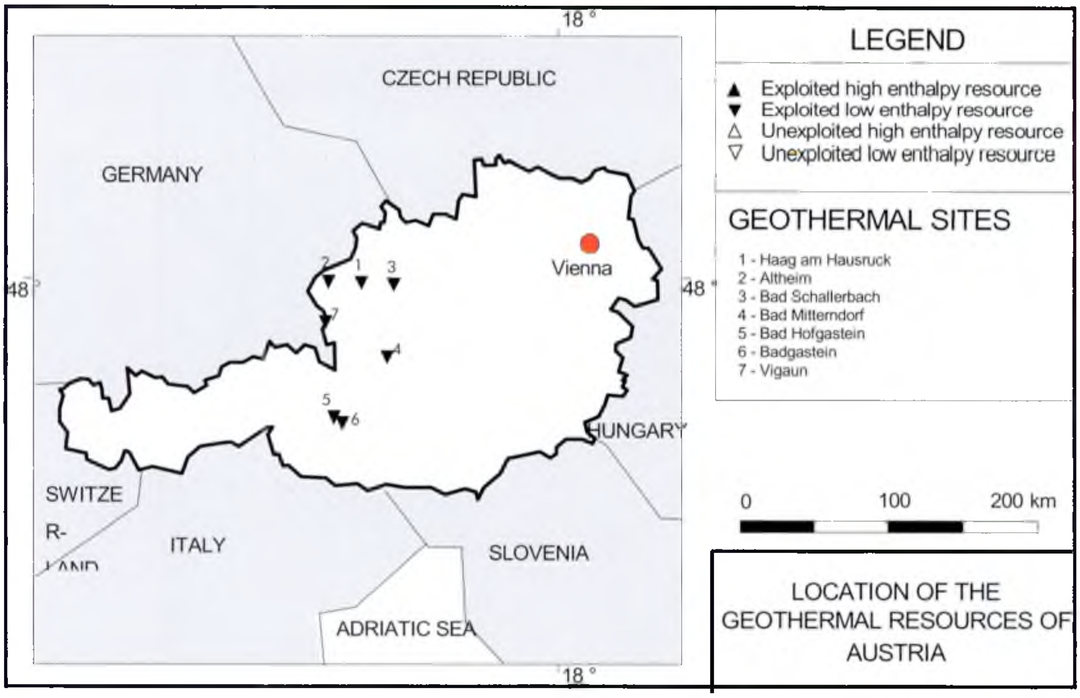
Annex 1.1

EU Countries

Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Italy
Luxembourg
Netherlands
Portugal
Spain
Sweden
United Kingdom

AUSTRIA

Size	83,853	km²
Population	7.968	million
Annual population growth rate (1985-95)	0.6	%
GNP per capita (1995)	26,890	USD per year
Average annual growth rate of GNP	1.9	%
Average annual inflation (1985-1995)	3.2	%
Annual energy use (1994) oil equivalent	3,301	kg
Average annual growth rate of energy use (199-9)		%
Annual CO_2 emission per capita (1992)	7.2	tonnes
Production of electricity (1994)	53,259	GWh
Geothermal	0	GWh
Fossil fuels	14,880	GWh
Hydro	36,894	GWh
Nuclear	0	GWh
Wind		GWh



Due to geological conditions large parts of Austria are unsuitable for hydrogeothermal development. Most regions which have been strongly influenced by Alpine orogen are unsuitable.

However good conditions exist in the Tertiary sediment basins in the north and the east of the country. These are the Molasse Basin, the Vienna Basin, and the Styrian Basin. The reservoirs within these basins may be even older than Mesozoic (e.g., Devonian limestones in the Styrian Basin).

1. The Molasse Basin: Predominantly in the western part, the so called Upper Austrian Molasse Basin, is located in front of the Alpine deformation front and is suitable for the development of deeper reservoir horizons. The regional geological conditions are well known, from hydrocarbon exploration however, the extent to which these results could be used for geothermal development is unclear. More than 700 wells have been drilled in the Molasse Basin.

The Upper Austrian Molasse Basin is about 130km long and limited in the north and northwest by the Bohemian Massif crystalline. Towards south, the molasse plunges beneath the Alpine orogenic belt. The regional dip is heightened by synthetic and antithetic downthrowns. The basin comprises sediments from the Eocene to the Pliocene; the strongest orogenetic phase was in the Oligocene.

The most important reservoirs for geothermal heat recovery are located in the Pre Tertiary basin, namely the limestones and dolomites of the Malm which may well be up to 500 m thick. These formations were karstified during a phase of emergence. Moreover, they comprise zones of high porosity along NNW-SSE and W-E striking pre-Tertiary faults. Locally, Upper Cretaceous sediments can form highly localised reservoirs. The Tertiary successions are the main target of hydrocarbon exploration, therefore in case of geothermal utilisation there could be a conflicts of interest.

In contrast to the Tertiary formation waters, the Malm waters are weakly mineralised with about 1-1.5mg/l. This younger formation probably occurs in the northeast, and the direction of groundwater flow is W-E or NW-SE.

The Styrian Basin is a marginal basin of the Hungarian Basin, where subsidence occurred earlier than in the Pannonian Basin. There is no morphological separation between the two basins. The Styrian Basin has hardly explored by drilling. For this reason knowledge is far from comprehensive. About 30 wells have now been drilled.
The exploration of the waters suitable for geothermal utilisation may be possible in the 3000m thick Tertiary series and in the Paleozoic (Devonian) carbonates. Generally, the high CO_2 concentration in the formation waters form a problem which makes their use difficult due to increased corrosion of the pipes and precipitation of carbonates. The main production target are the carbonates which have been locally sheared or fractured due to stress.

The Vienna Basin is filled with Tertiary series which may reach a thickness of 5500m. Hot water at loose was produced from the first well a depth of 3000m. Possible utilisation could be a problem due to existing hydrocarbon production wells.

ELECTRICITY GENERATION

There is no electricity generated from geothermal resources.

DIRECT USES

The major part of the developed thermal water occurrences are for balneological purposes only. Thermal use is mainly restricted to the supply of spas but this is a minor order of magnitude. More detailed data on the thermal utilisation of the water has been obtain from this wells in the Molasse Basin. According to these results the overall thermal capacity amounts to 16.3MW which could be increased in case of the Altheim well where the return temperature is as high as 60°C. During recent years the capacity has been increased significantly which can be seen from the great number of wells, although this has not been fully documented yet.

In the Styrian Basin, fewer wells are being used for geothermal heat recovery but amount to an overall capacity of 4.8MW. Here, also, capacity may be increased up to about 40MW. In the technical literature, 140MW of thermal capacity which could potentially be developed in the short to medium term from other wells.

Summary of Resources	
Exploited - plant in operation	21.1 MW_t
Unexploited - plant under construction or planned	-
Unexploited - proven resources	140 MW_t
Unexploited - probable and possible resources	-

BELGIUM

Size	30,513	km^2
Population (1994)	10.08	millions
Annual population growth rate (1994)	0.3	%
GNP per capita (1994)	22,500	USD per year
Average annual growth rate of GNP (1994)	+2.3	%
Annual inflation (1994)	22.2	%
Average annual inflation		%
Consumption of energy (1994) oil equivalent	50.8	millions t
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity	69,560	GWh
Geothermal	0	GWh
Fossil fuels	29,928	GWh
Hydro	335	GWh
Nuclear	39,288	GWh
Wind	0	GWh

LOCATION OF THE GEOTHERMAL RESOURCES OF **BELGIUM**

The Geology of Belgium is dominated by partially metamorphosed, clastic to carbonate formations of Palaeozoic age related to the Caledonian *Brabant* Massif which are covered by clastic and carbonate rocks of Devonian to Triassic age. In the southern part of the country, these formations are overlain by Mesozoic rocks which form the rim of the Paris Basin. Late Cretaceous and Tertiary clastic and chalk formations are found in the *Campine* Basin, North Belgium, which was affected by pronounced subsidence related to the *Roermont* (Lower Rhine) Graben formation.

Geological conditions allow the occurrence of low enthalpy geothermal resources only. Dinantian anhydrite rocks in the Hainaut Basin (S Belgium), Triassic sandstone and Dinantian limestone in the *Campine* and *Liege* Basin (NE and E Belgium) contain aquifers which represent the highest potential for the exploitation of geothermal resources. The main information about these basins are listed below.

DIRECT USES

The use of geothermal energy in Belgium was promoted in the 1970's when energy prices climbed steeply, due to the international energy situation. Public organisations like the Belgian National Geological Survey, the Directorate-General for Science and Research and development of the European Community, initiate researches to acquire further fundamental knowledge in order to implement low enthalpy geothermal energy production. This led to the development of low enthalpy exploration and limited exploitation, the geological conditions do not allow high enthalpy geothermal energy to be developed. The low energy prices today is a limitation to further development.

Nine wells (5 in production, 4 shut down) have been drilled for geothermal purposes tapping either the Dinantian or the Cretaceous reservoirs. At the end of 1995, 5 geothermal exploitations are operating. Their total operating capacity is 3,89MWt, including 2,14MWt for space heating, 1,18MWt for fish farming, 0,5MWt for waste sludge heating and 0,07MWt for bathing and swimming.

Estimated resources have been assessed based on: a maximum aquifer depth of 2500m, a minimum reservoir temperature of 25°C and a recovery rate of 0,33 :

Campine Basin:	Dinantian reservoir	$44{,}5\times10^{8}$ GJ
	Neeroeteren reservoir	$1{,}23\times10^{8}$ GJ
	Triassic reservoir	$50{,}8\times10^{8}$ GJ
	Cretaceous reservoir	$17{,}7\times10^{8}$ GJ
Liege Basin:	Dinantian reservoir	$18{,}5\times10^{6}$ GJ
	Hainaut Basin	
	Dinantian reservoir	$29{,}0\times10^{8}$ GJ

Campine Basin

The main aquifer is located within Dinantian limestone affected by fracturing and subsequent dissolution leading to karstification. Its main characteristics are: extent 2096km^2; depth: 700-2500m; thickness of the karstified reservoir: 5-60m; water temperature: 30-125°C; salinity: 100-135g/l; porosity: between 4% - 20%.

A small-scale reservoir is developed within the Neeroeten Upper Carboniferous Sandstones. Its main characteristics are: extent: 50km^2; depth: 620-730m; thickness: up to 400m; water temperature: 30-40°C; permeability: 35-200md; porosity: 15-20%.

Triassic Buntsandstein sandstones also present a potential reservoir. Its main characteristic are: extent: 530km^2; depth: 700-2500m; thickness: 200m; water temperature: 40-130°C; low salinity; porosity: 10%.

At least, one upper aquifer occurs within the Cretaceous chalk arenite formations. Its main characteristics are: extent: 2155km^2; depth: 500-900m; thickness: 80m; water temperature: 30-37C; salinity: 10-30g/l; porosity: 20-40%; permeability: 35-300md; flow rate: 0,5 to 0,1m^3/h..

Campine Basin (Cretaceous Chalk reservoir)
Turnhout: swimming pool heating;
Herentals: "
Dessel: fish farming.

Liege Basin
A small-scale reservoir is known within the Dinantian limestones: extent: 113km^2; depth: 500-1500m; water temperature: 30-50°C; low salinity; high permeability.

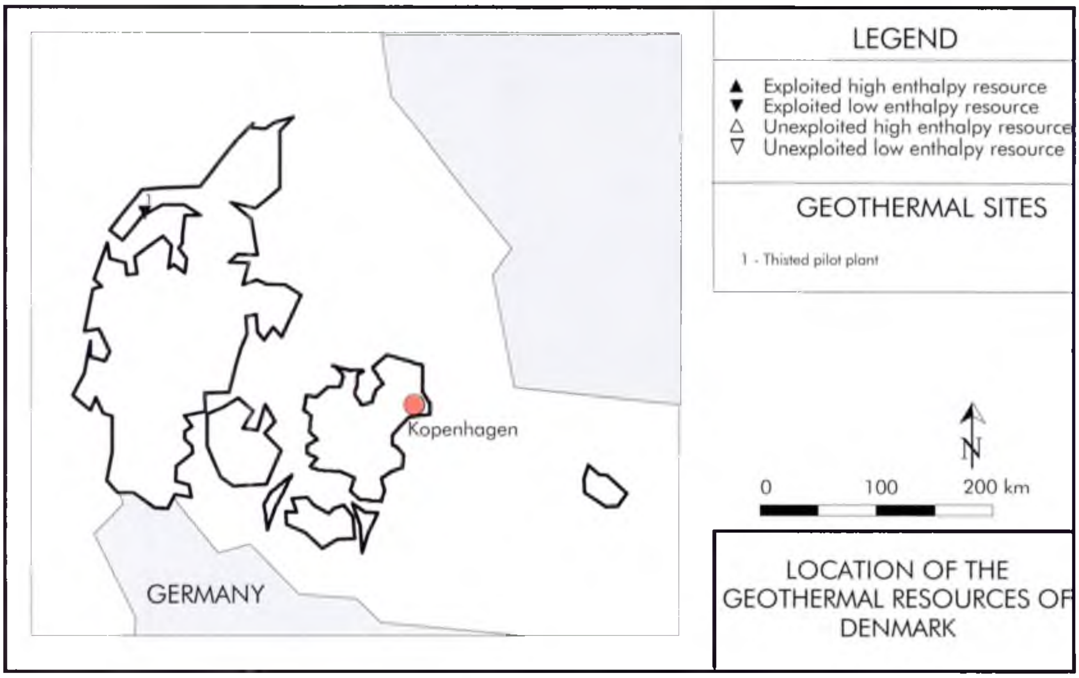
Hainaut Basin
Karsic horizons within Dinantian anhydrite rocks represent the main reservoir. Its main characteristics are: extent: 373km^2; depth: 500-2500m; thickness: 50-250m; water temperature: 30-90°C; salinity: 2g/l; very high permeability; artesian flow rate: 90-100m^3/h. Due to the high permeability, cold water entry has lowered the temperature in the eastern part of the reservoir.

Hainaut Basin (Dinantian reservoir)
St Ghislain: multipurpose exploitation of 70°C waters produced by one well (650,000m^3/yr.) for space heating, swimming, greenhouses, waste heating; this exploitation is run by the local company IDEA.
Douvrain: air conditioning for an hospital (75 000m^3/yr).

Summary of Resources	
Exploited - plant in operation	3.9MWt
Unexploited - plant under construction or planned	
Unexploited - proven resources	
Unexploited - probable and possible resources	

DENMARK

Size	43,077	km^2
Population	5.181	millions
Annual population growth rate (1985-95)	0.6	%
GNP per capita (1995)	29,890	USD per year
Average annual growth rate of GNP (1985-1995)	1.5	%
Average annual inflation (1985-1995)	2.8	%
Annual energy use per capita (1994)oil equivalent	3,977	kg
Average annual growth rate of energy use (1992)		%
Annual CO_2 emission per capita (1992)	10.4	tonnes
Production of electricity (1994)	40,097	GWh
Geothermal	0	GWh
Fossil fuels	38,136	GWh
Hydro	33	GWh
Nuclear	0	GWh
Wind	1,137	GWh



The geological conditions in Denmark are characterised by two basins which are separated by a barrier. In the southern part of Denmark, which is located along the northern rim of the NW German Basin, and in the Norwegian-Danish Basin in the northern part of Denmark, there are good conditions for the exploration of geothermal resources. Only on the sill, the *Ringkobing-Fyn* High, are conditions unsuitable.

The Danish Basin strikes from WNW to ESE and covers an area of about 400 x 150km^2. In the north, it is separated from the Baltic Shield by the *Fennoscandic* marginal zone, i.e. the northern extension of the *Tornqvist-Teisseyre* zone. The complicated fracture pattern of this boundary can be found in the base and is expressed in the superstructure of the Danish Basin. Another factor with strong influence on bedding and structural geology is the occurrence of *Zechstein* salt in the sedimentary succession. In particular in *Jutland* the bedding conditions were influenced by halokinesis, whereas in the more northern parts of the basin, there is no salt.

The Mesozoic-Permian sediments in the Danish Basin have a maximum thickness of 6000m. In the section towards the eastern *Fennoscandic* marginal zone, this succession is reduced to 3000m.
Potential reservoir horizons were formed predominantly in the Triassic-Jurassic period. These sandstones are at depths from 500-3500m and have an effective thickness exceeding 100m.

Electricity Generation

There is no electricity generated from geothermal resources.

Direct Uses

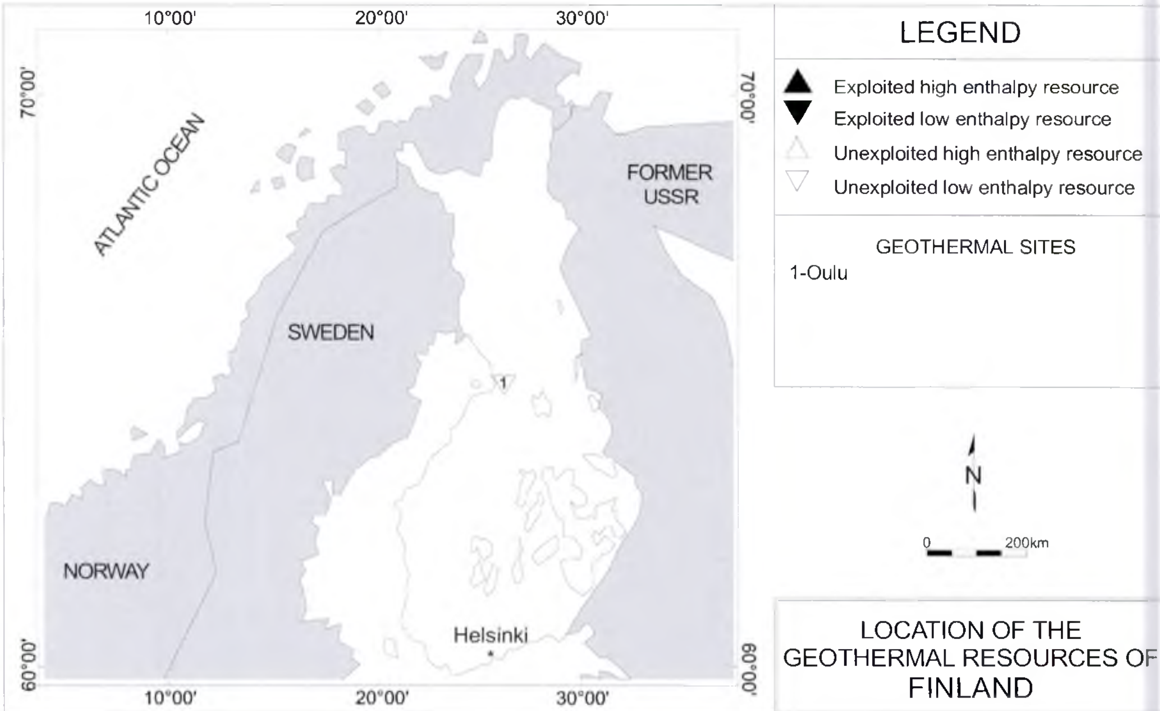
At present, there is only a demonstration plant in *Thisted* / North Jutland where brine with a salt content of 15 % is extracted from the Upper Triassic Gassum formation. It can be assumed that the deep water in the Danish Basin is generally saline. The wells there were drilled in 1982 and 1983 and produce geothermal water from the Gassum formation at 1250 m. The plant was re-designed in 1988 and equipped with an absorption heat pump which was removed again in 1994. The plant is working temporarily at a rate of 145 m^3/h at a temperature of 46°C. A capacity of 3.5 MW could be installed, although there are already plans to construct another plant by 2005; no implementation has taken place. However, the relevant Ministries stress that the recovery of geothermal energy shall be continued in future.

In Denmark, the climatic conditions with an annual mean temperature from 7.5 to 10°C are suitable for the utilisation of geothermal energy.
Likewise, the geological conditions allow for the exploration of the geothermal potential with a few exceptions. The reservoirs under consideration are porous aquifers and whose properties are known quite well thanks to data obtained from a certain number of wells and seismic profiles. Due to conditions existing in Denmark the utilisation of geothermal energy will always be restricted to district heat supply.
In spite of these favourable conditions it has to be assumed that in Denmark geothermal energy will not be utilised in extensively way in the near future. All the present district heat supply concepts are based on co-generation plants and it is planned to extend these. This development is supported by national reserves of hydrocarbons which make energy supply possible at reasonable costs. In order to make the costs of utilising geothermal energy comparable, the support would have to be substantial making a balanced cost benefit ratio unlikely. Compared with other renewable sources of energy at a national level, geothermal energy is competed mainly with wind power which is well established for small-scale users, at low risk and is relatively comprehensible to them.

Summary of Resources	
Exploited - plant in operation	3.5MW_t
Unexploited - plant under construction or planned	4.0 MW_t
Unexploited - proven resources	
Unexploited - probable and possible resources	

FINLAND

Size	338,145	km^2
Population (1994)	5.099	millions
Annual population growth rate (1993-94)		%
GNP per capita (1993)		USD per year
Average annual growth rate of GNP (1990-93)		%
Average annual inflation (1994)		%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1995)	60,574	GWh
Geothermal	0	GWh
Fossil fuels		GWh
Hydro	12.67	GWh
Nuclear	18.13	GWh
Wind	0	GWh



There is a very low geothermal potential in Finland for economic exploitable resources due to the very low temperature of the water and low rock porosity. Temperatures are usually below 20°C at 1km depth.

No drilling have been made for geothermal purposes.

There are 16 sites where Vertical Heat Exchangers (VHE) have been installed in shallow bore holes with depths ranging from 120 to 200m with a heat power output typically of the order of 50W/m. The total number of VHE applications in use is not known exactly, but it is estimated to be between 50 to 100. The use of this technology seems to be the only practicable way to develop geothermal energy uses in Finland in the near future.

Prospects for producing electricity in Finland are obviously not evident.

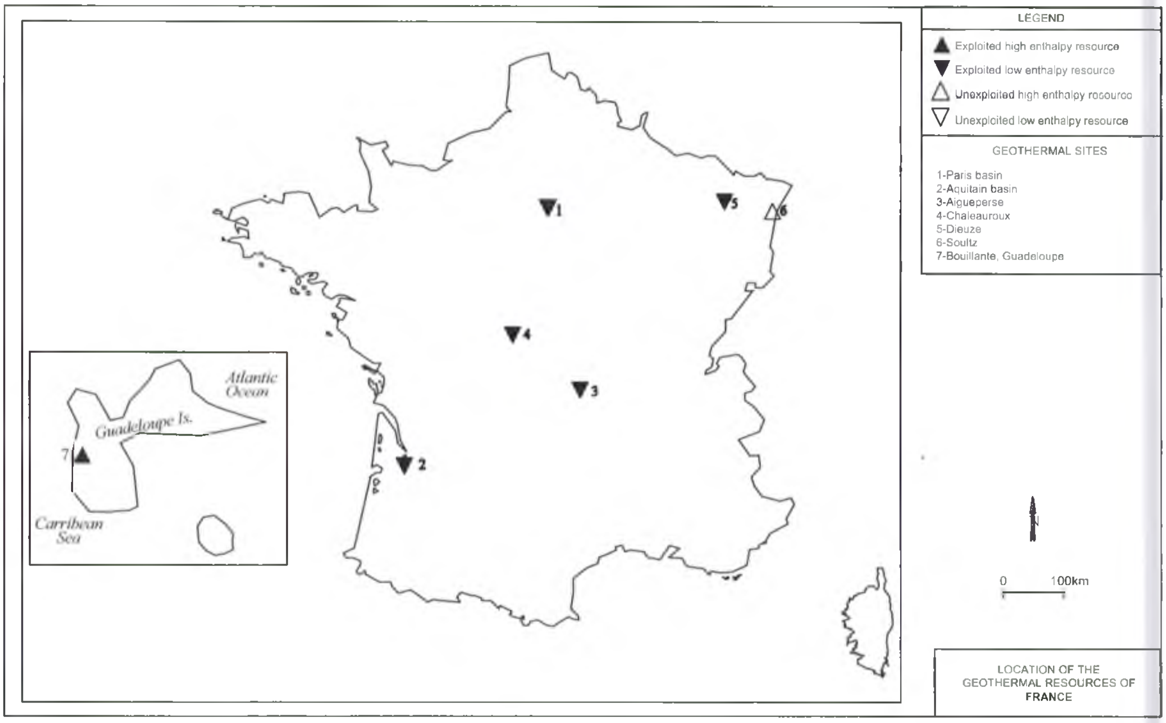
DIRECT USES

In southern Finland, where the temperatures are highest, shallow depth ground water in Quaternary deposits has a temperature of about 3-6°C. In this area a few VHEs have been installed in shallow bore holes for heating purposes in family-houses, agriculture and industry for a total capacity of about 0.1 MWt.

The Muhos formation in northern Finland, near the city of *Oulu*, have temperatures from 5 to 10°C higher in the sedimentary rocks in comparison to the surrounding crystalline basement. This formation may have potential for hot dry rocks applications. Prospecting for other hot dry rock formation should be preferably directed in southern Finland. Thermal models suggest that 40°C temperature would be encountered at a depth between 2 and 3km but will depend on the success of this experimental approach at other localities, notably at Soultz where the European HDR programme is centred.

FRANCE

Size	549,000	km^2
Population (1994)	58	millions
Annual population growth rate (1994)	3.3	%
GNP per capita (1994)	22,800	USD per year
Average annual growth rate of GNP (1993-94)	+2.2	%
Annual inflation (1994)	1.7	%
Average annual inflation		%
Consumption of energy (1994) oil equivalent	223.9	millions t
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity (1993)		GWh
Geothermal	4.2	GWh
Fossil fuels	23.5	GWh
Hydro (1992)	25	GWh
Nuclear (1994)	57.2	GWh
Wind		GWh



Both national and regional inventories have been carried out for the geothermal resources of France. In France geothermal energy amounts to 4% of the total energy produced for district heating; in the Ile de France region it accounts for the 10% and in Val de Marne department it provides more than 10%. The low temperature (low-enthalpy) and high enthalpy geothermal resources of France are fairly well known. In addition, local inventories of potential end users were prepared in the 1980s, mainly for resources destined for district heating.

Potential high temperature geothermal resources are restricted to the French Overseas Territories (Guadeloupe and Martinique in the West Indies; *La Réunion* in Indian Ocean) in connection with active volcanism. Drilling in the 1970's at *Bouillante*, Guadeloupe, evidenced a 240°C shallow reservoir.

Low temperature resources are developed principally in the two main sedimentary basins: The *Paris* Basin and the *Aquitaine* Basin.

At least, the use of the geothermal potential of the *Rhine* Graben, *Alsace*, is under investigation at the *Soultz* Hot Dry Rock experimental site.

Electricity Generation

A 4.2MWe double flash power plant was built at *Bouillante*, Guadeloupe in 1984 by EDF, the French Electricity Company. The power plant has been back on line since 1996 after a few years of operation and a period of suspension.

Summary of Resources	
Exploited - plant in operation	4.2MWe
Unexploited - plant under construction or planned	
Unexploited - proven resources	8 MWe
Unexploited - probable and possible resources	

Direct Uses

Geothermal energy in France is used mainly for urban heating, for more than 150,000 dwelling equivalents, with the owners mainly being local communities. Various operations however, mainly located in *Aquitaine*, show the diversification of potential uses for geothermal energy: agriculture, fish farming, tourism, etc.. About 55 geothermal operations are at present active in France. there is also an unknown number of operations that use heat pumps to exploit shallow aquifers (resource temperature generally less than 30°C).
Total geothermal heat production represents more than 220,000TOE saved every year.

Paris Basin

The most exploited geothermal resource of the *Paris* region is the Dogger (oolitic limestone) aquifer where a large concentration of geothermal operations exist in the urban outskirts of *Paris* (37 active operations at the end of 1996). This is in part due to the characteristics of the resource and in part to the density of end-users which led to a development focused entirely on urban heating. The *Paris* Basin also contains other exploitable aquifers (Neocomian and Albian) that are subject to limited development (2 heat pump operations for the Albian and 2 operations, one still in the development stage, for the Neocomian). Although the Albian aquifer is subject to regulatory restrictions, exploitation of the Neocomian aquifer for heat and/or industrial purposes could expand over the next few years.

A total of 37 geothermal operations tap the Dogger aquifer in the *Paris* region with water temperatures ranging between 58 to 83°C. Most of these were developed in the 1980s and are all connected to urban heating networks, providing heat for about 180,000 housing equivalents. The oldest geothermal operation, which came into service in 1971 at *Melun l'Almont*, now uses three wells. They all run on the doublet system, i.e. a reinjection well associated with the production well.

Aquitaine Basin

The second major geothermal zone of France is the *Aquitaine* region with a dozen active operations and several others projected for existing boreholes. Three aquifers are tapped for geothermal waters in *Aquitaine*:

The Middle Eocene aquifer, which has long been used for drinking water supplies and is thus strictly protected; only a few very specific geothermal projects have been authorised for this aquifer.

The Upper Cretaceous aquifer, which is the most tapped by the geothermal wells,

The Dogger aquifer, which is also tapped, but less so, for geothermal purposes.

There are 12 active operations in the *Aquitaine* Basin tapping different aquifers with temperatures ranging from 20 to 60°C. The high quality of the geothermal waters makes it possible to use a single well since there is neither the necessity nor the obligation to reinject in *Aquitaine.*

They provide heating for housing, fish farms and swimming pools. In certain cases, the energy factor of the geothermal fluid can by completed through a direct use of the water (possibly after cooling) such as for thermal spas or drinking water supplies. The exploitations are smaller than those tapping the Dogger aquifer of the *Paris* Basin.

Other areas

Shallow aquifers disseminated in France are used for heating and/or cooling buildings with heat pumps. Operations based on rehabilitating old oil wells for geothermal purposes are also possible (one is now operating in *Aquitaine* Basin).

Five operations within three different regions tap resources with temperatures between 30 and 55°C. These all function with a production well only and are used for greenhouses, fish farms and heating.

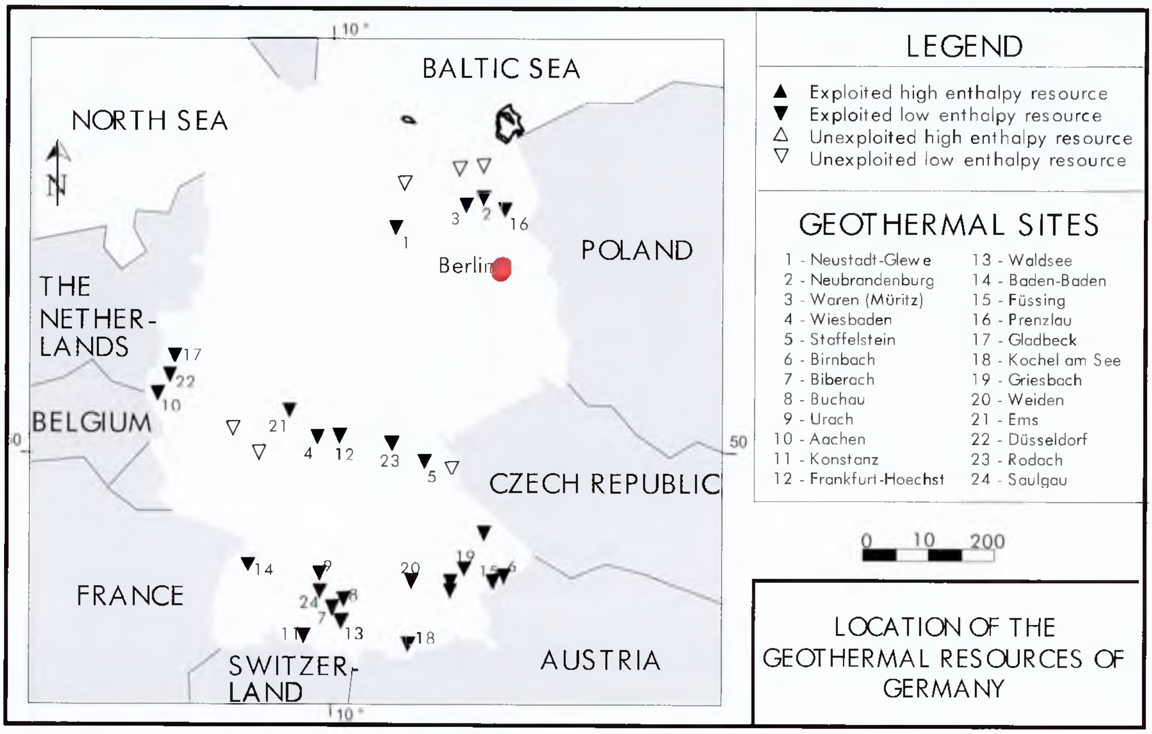
Although France has large exploitable geothermal resources and different types of utilisation, this energy source has seen little increase in France since 1985. The drop in prices for fossil fuel and the establishment of a new national economic and energy policy have restricted its development.

It would appear that the immediate future for geothermal energy in France is the use of lower temperature and shallower resources using heat pumps to supply heating and air conditioning needs. These operations, which are smaller than those required for urban heating, can be set up by independent private operators. The operations potential to year 2010 is about 40 MWt for "conventional" geothermal heating plants and about 50 MWt more if considering geothermal heat pump development.

Summary of Resources	
Exploited - plant in operation	309 MWt
Unexploited - plant under construction or planned	
Unexploited - proven resources	90 MWt
Unexploited - probable and possible resources	

GERMANY

Size	356 978	km^2
Population	81.539	Millions
Annual population growth rate (1985-95)	0.55	%
GNP per capita (1995)	27, 510	USD per year
Average annual growth rate of GNP		%
Average annual inflation (1984-1994)		%
Annual energy use (1994) oil equivalent	4,128	Kg
Average annual growth rate of energy use (199-9)		%
Annual CO_2 emission per capita (1992)	10.9	Tonnes
Production of electricity (1995)	528,221	GWh
Geothermal		GWh
Fossil fuels	346,185	GWh
Hydro	22,461	GWh
Nuclear	151,203	GWh
Wind	1,420	GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF GERMANY

The geological conditions in Germany are characterised by big regional differences and vary from Proterozoic crystalline basement to Pleistocene glacial sediments resulting in a range of possibilities for using geothermal resources. These include the utilisation of shallow glacial deposits for heat storage to HDR technology in the crystalline basement. At present, work is concentrated in Germany on the utilisation of hydrogeothermal resources, for which there are three prospective areas:

1. the North German Basin (east and west), characterised by porous permeable beds;
2. the Upper Rhine Graben, where the development of thermal waters is directed at zones of fractures and faults, predominantly);
3. the South German Molasse Basin, characterised by aquifers and only low-mineralised thermal water.

ELECTRICITY GENERATION

At present, there is no electricity produced from geothermal resources in Germany.
The introduction of ORC units for the generation of electric energy from cooler geothermal waters compared to HDR technology is rather uncertain. Another positive impulse for the generation of electric power may be given by the Soultz-sous-Forets HDR demonstration project.

DIRECT USES

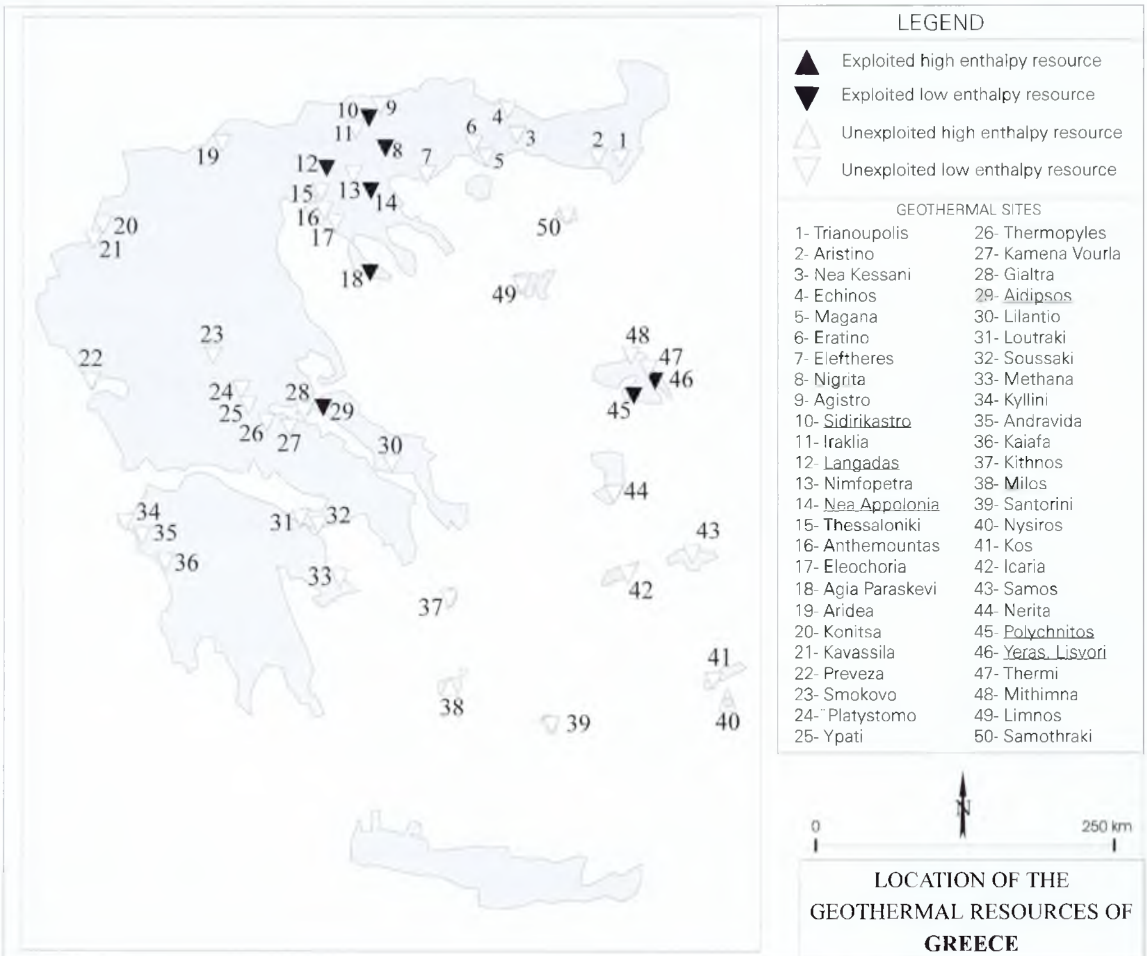
By the end of 1995, direct thermal use of geothermal energy in Germany amounted to an installed thermal power of roughly 307MW_t. Of this sum, approximately 39MW_t are generated in 22 major centralised installations. These are geothermal heating stations, thermal baths with residual heat recovery and greenhouses as well as major ground source heat pump units for the heating of buildings. Small, decentralised earth-coupled heat pumps and groundwater heat pumps are estimated to contribute an additional 285MW_t. The water or brine temperature is less than 110°C, respectively. Multiple and cascade-type utilisation increases the economic profitability and the acceptance of geothermal heat recovery under present economic and political framework conditions. Based on present knowledge, 13 more plants will be completed by the year 2000. An increase in total installed capacity of about 144MW_t is expected, with 115MW_t from major central systems and 29MWt from small, decentralised installations. This would bring direct thermal use in Germany close to an installed thermal power of 467MW whose annual final energy consumption at present amounts to about 9,200PJ. Final energy is defined as the fraction of primary energy which is supplied to the consumer. It is less than the corresponding primary energy because of losses, mainly due to conversion and distribution. Within one year this is equivalent to a total consumption power of approximately 90,000MW. Almost 6% of this energy is required as heat.

The maximum technical potential for direct thermal use of geothermal energy in Germany is estimated to be 2,580$PJyr^{-1}$ from hydrothermal applications and shallow heat exchanger systems; this is equivalent to a maximum thermal power generation of about 81,800MW_t. This corresponds to about 29% of the country's annual final energy consumption, or roughly 49% of its demand for heat. However, at present only about 4‰ of the existing maximum technical potential for direct thermal use of geothermal energy meets the demand for heat. If the vast potential of geothermal energy for direct thermal use was utilised to substitute fossil fuels, roughly 110 million tonnes less of CO_2 would be released to the atmosphere annually, equivalent to about 12% of Germany's CO_2 output in 1994 (C. Clauser, 1997).

SUMMARY OF RESOURCES	
Exploited - plant in operation	307MW_t
Unexploited - plant under construction or planned	144MW_t
Unexploited - proven resources	
Unexploited - probable and possible resources	

GREECE

Size	131,944	km^2
Population (1994)	10.42	millions
Annual population growth rate (1994)	0.6	%
GNP per capita (1994)	7,450	USD per year
Average annual growth rate of GNP (1993-94)	+1.5	%
Annual inflation (1994)	10.9	%
Average annual inflation		%
Consumption of energy (1994) oil equivalent	22.88	t
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity (1995)	343.6	GWh
Geothermal		GWh
Fossil fuels	318.41	GWh
Hydro	2.519	GWh
Nuclear		GWh
Wind		GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF **GREECE**

Favourable conditions for the development of geothermal resources prevail in Greece. The Volcanic islands of the South Aegean volcanic arc (*Milos*, *Nysiros*) have high enthalpy geothermal resources while low to medium enthalpy geothermal fields are widespread across the Greek mainland and North Aegean Islands.

ELECTRICITY GENERATION

Two high temperature geothermal fields have been explored and drilled on *Milos* and *Nysiros* Islands. Results highlighted elevated temperature conditions (320-325°C) and promising potential for electricity generation (200MW$_e$ expected on *Milos*).

A small 2MW$_e$ pilot plant was operating on *Milos* between 1986-88. Now, there is no electricity generation either on *Milos* or *Nysiros* Islands, due to strong opposition from local inhabitants and organisations quoting environmental problems.

Drilling activity is foreseen in Lesvos Island for testing high temperature geothermal field in the NE section of the island where surface investigations indicate promising potential for electricity generation.

SUMMARY OF RESOURCES	
Exploited - plant in operation	
Unexploited - plant under construction or planned	10MW$_e$
Unexploited - proven resources	200MW$_e$
Unexploited - probable and possible resources	

DIRECT USES

About 40 low to medium temperature geothermal systems have been evidenced. The depth of investigated reservoirs varies between 100 and 500m. Water temperatures range from 30 to 90°C and salinity is 1 to 50 g/l. They are mainly concentrated in the largest graben structures filled with sediments located in Northern Greece (*Macedonia, Thrace*) and Central Greece (*Sterea Hellas*); other fields are disseminated throughout the territory and Aegean islands

Thrace (Aristino, Nea Kessani, Magana, Eratino), Macedonia (Sidirikastro, Nigrita, Langadas, Nimfopetra, Nea Apollonia, Iraklia, Aridea), Thessalonique (Anthemountas, Eleochoria), Sterea Hellas (Soussaki, Thermopyles), Peloponese (Andravida), Eubee (Aidipsos, Gialta, Kamena Vourla, Lilantio), Lesbos (Polichnitos, Lisvori, Argenos, Stipsi-Napi, Kalloni, Thermi Yera, Thermi, Mytilini, Petra-Mythimna), Chios (Nerita), Milos, Santorini, Nysiros.
These well-documented geothermal resources are not extensively exploited for various reasons.

Despite the large existing potential, direct uses of geothermal waters are limited to greenhouses (160 acres), space heating (1 site) and balneology (38 sites recorded). Total installed capacity is estimated to be 22,6MW$_t$ with energy utilisation of 133TJ/yr (load factor 0,18). The geothermal exploitations currently operating are:

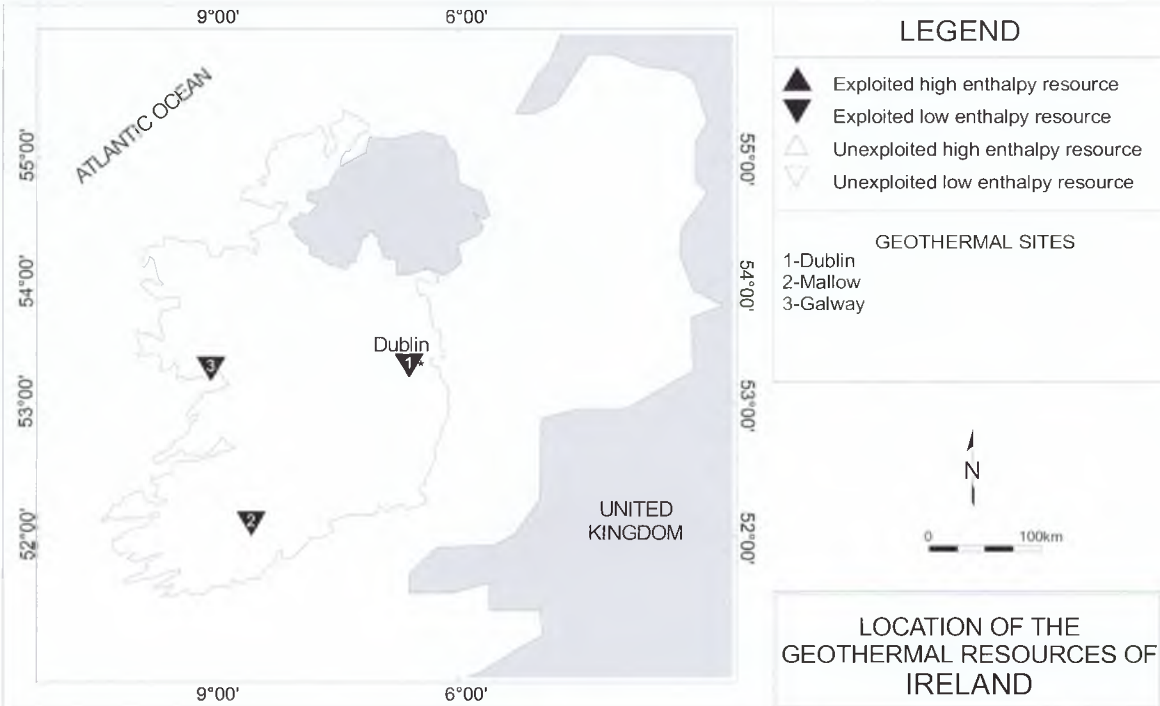
Greenhouses *Sidirikastro, Nigrita, Nea Appolonia, Langadas, Lisvori, Yeras, Polychnitos, Milos.*
Space heating *Aidipsos*
Balneology *most of the geothermal localities listed above.*

The most promising use seems to be geothermally heated greenhouses. This application will be supported by public (Greek and European) funds in the framework of a 1994-1999 incentive plan. The most promising geothermal fields for development of direct uses are *Magana*, *Nea Kessani*, *Aristino*, *Nigrita*, *Langadas*, *Nymfopetra*, *Appolonia*, *Soussaki*.

Summary of Resources	
Exploited - plant in operation	22.6MW$_t$
Unexploited - plant under construction or planned	10.0 MW$_t$
Unexploited - proven resources	
Unexploited - probable and possible resources	

IRELAND

Size	70,285	km^2
Population (1994)	3.526	millions
Annual population growth rate (1993-94)		%
GNP per capita (1993)		USD per year
Average annual growth rate of GNP (1990-93)		%
Average annual inflation (1994)		%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1995)	16,416	GWh
Geothermal		GWh
Fossil fuels		GWh
Hydro	0.709	GWh
Nuclear	0	GWh
Wind		GWh



While Ireland has very abundant ground water resources, knowledge of deeper aquifers is poor, due to the limited oil & gas exploratory effort and due the fact that there is no need to prospect for water at depth.

Temperatures measured in the few oil wells drilled indicate a low geothermal gradient. At a depth of 1500m values of 35-45°C are given for southern Ireland and 45 and 56°C for the northern part.

Shallow geothermal drilling was carried out in the Eighties: a 500m slim well was drilled at *Mallow* and produced a fresh water flow with a temperature of 19.8 °C which feed a swimming pool and a 100kW heat pump to heat the pool installation. Two other wells (61m and 100m depth) have been abandoned; another well (94m and water at 11°C) is used in Mallow hospital.

A 500m well was drilled at *Ballynagoul* spring and another 510m at *Enfield*, West of Dublin which encountered the presence of permeable limestones and a maximum temperature of 21°C.

Geothermal activity in Ireland is steady. In the short to medium term no geothermal drilling or development is likely to occur except for the possibility of drilling one well (depth ~2000m) before the year 2001.

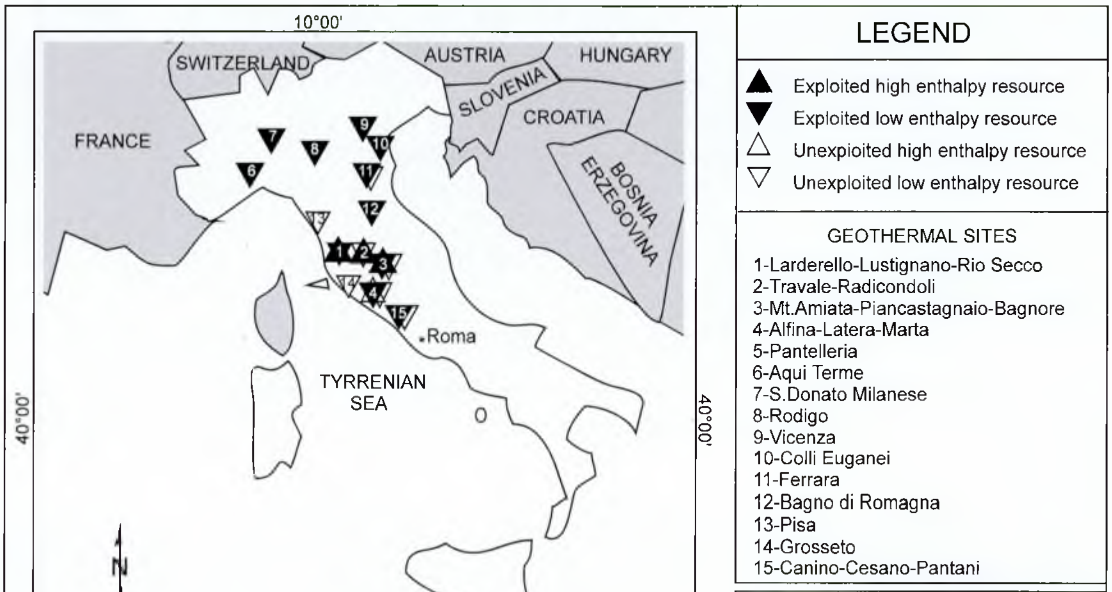
DIRECT USES

Using geothermal water with temperatures of 10-19°C, two small demonstration projects were carried out at *Mallow* (swimming pool heating).
The installed geothermal power at Mallow hospital is 0.7MWt and total energy saving is estimated less than 80TOE/yr.
Two similar small plants at the *Dublin* Trinity College with the support of heat pumps and in *Galway* were operational (Tuam swimming pool).

SUMMARY OF RESOURCES	
Exploited - plant in operation	0.7MWt
Unexploited - plant under construction or planned	
Unexploited - proven resources	
Unexploited - probable and possible resources	

ITALY

Size	301,302	km^2
Population (1994)	57.3	millions
Annual population growth rate (1993-94)	0.35	%
GNP per capita (1993)	19840	USD per year
Average annual growth rate of GNP (1990-93)	4.8	%
Average annual inflation (1995)	5.3	%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1996)	222,883	GWh
Geothermal	3,762	GWh
Fossil fuels	174,638	GWh
Hydro	44,483	GWh
Nuclear	0	GWh
Wind	225	GWh
Solar	5	GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF ITALY

Since the beginning of the century a substantial number of geothermal sites have been explored and exploited in Italy, the main targets being Tuscany and Latium areas.

ELECTRICITY GENERATION

Electric power capacity from geothermal resources has grown from 459MW (production 2840GWh/yr) in 1985, to 545MW (production 3150GWh/yr) in 1989, to 681.7MW in 1995 to 742.2MW in 1996 with yearly generation amounting to 3,762GWh, equivalent to 1.6% of the total electricity produced in Italy.

In Italy 39 power plants are now operating with a total capacity of 742.2MW of which 149.7MW are reserve.

The construction of additional units, with a total capacity of 87.5MW, is underway and another 140MW are planned to be installed.
If decommissioned plants are included, by the year 2000, a total of about 830MW will be generated by geothermal.

The main geothermal areas are *Larderello* with 315MW installed, *Radicondoli* with 90MW installed, *Lago* (a few kms south of *Larderello*) with 247.7MW installed.
1×20MW unit in *Lago* area, 1×20MW in the *Mt.Amiata* area, 2×20MW and 3×2.5MW in *Latera* are under construction.
4×20MW units in *Lago* area, and 3×20MW in *Mt.Amiata* area are planned to be constructed.

All plants use dry steam condensing units. The plants under construction will also be of this type except in *Latera* where there will be 2×20MW double flash and 3×2MW binary cycle plants.

Surface exploration has been extensively carried out which has included geophysical (gravity, seismic, magnetotelluric and electricity surveys) and thermal gradient wells.
Drilling has been aimed exclusively at the research and development of high enthalpy geothermal resources for electricity generation. Most wells were drilled inside or at the margins of the areas already under exploitation, to find fluids with better thermodynamic characteristic or to improve field optimisation.
74 wells were drilled between 1985 and 1989 with depths from 800m to 2500m.
A total of 108 wells were drilled from 1990-1995: 40 exploratory wells (45% successful, average depth of 2573m) and 68 for field development (75% successful, average depth of 2831m).
A total of 958 wells were drilled up to 1995 with a total metrage of over 300,000m.

Summary of Resources	
Exploited - plant in operation	742.2MWe
Unexploited - plant under construction or planned	227.5MWe
Unexploited - proven resources	-
Unexploited - probable and possible resources	-

Direct uses

Direct uses represent a total capacity of 313.6MW with a direct energy use of 3666.9TJ/yr.
Utilisation of heat pumps has been moderate up to now and mostly in the private sector.

Space and greenhouse heating is the most common utilisation in Italy. In most instances steam or double phase flow is used. Inlet temperatures range 60-120°C (in *Larderello* area are much higher reaching 200°C) and output temperature range 20-100°C.
Installed thermal power is as follows: 49.73MW for space heating in 15 localities; 63.79MW for greenhouses in 7 localities; 10.86MW for industrial process in 3 localities; 2.58MW for fish/animal farming in 2 localities and 186.65MW for bathing/swimming.

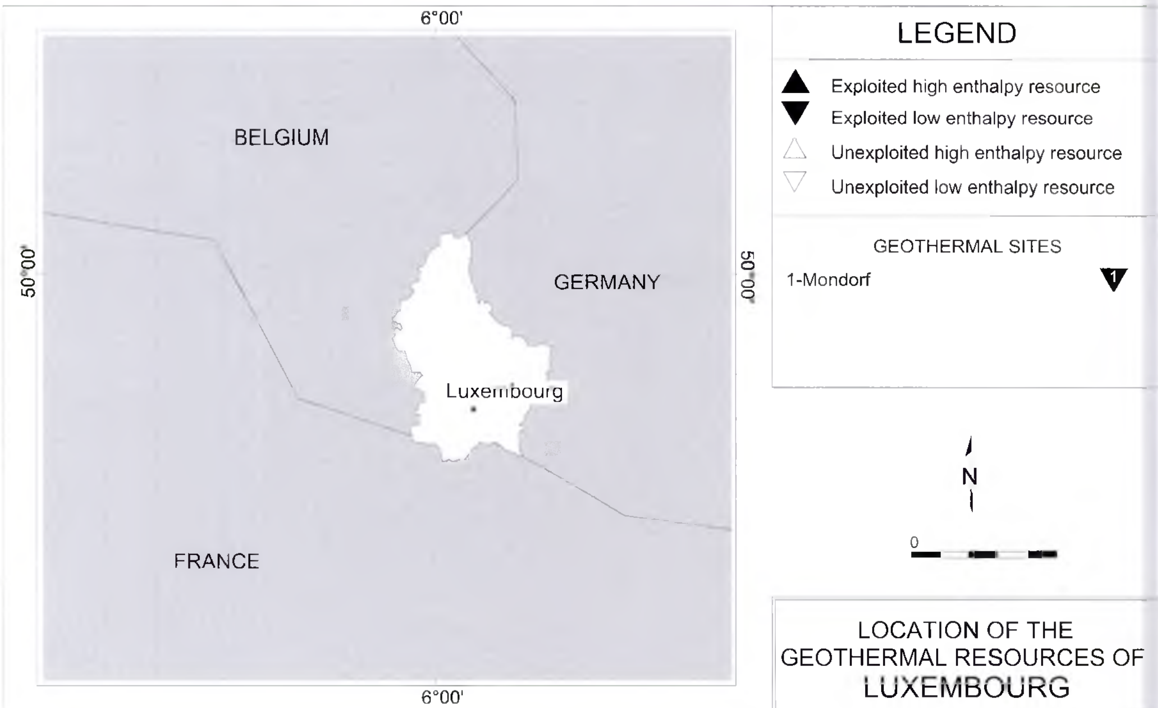
One district heating system is under construction in *Grosseto* and 3 are planned in *S.Flora*, *Piancastagnaio* and *Pisa*.
Three greenhouse heating systems are under construction in *Latera*, *Alfina* and *Travale* and one is planned in *Ferrara*.
A couple of industrial plants utilizing geothermal heat are under construction in the *Travale-Radicondoli* area while one is planned in *Cesano*. Increased use of the uncondensable gas associated with geothermal fluid capacity for CO_2 recovery is foreseen (one plant is already operating in *Torre Alfina* with a capacity of over 30,000 tonnes/yr) together with the exploitation of *Cesano* hypersaline brine for the extraction of potassium salts.

SUMMARY OF RESOURCES	
Exploited - plant in operation	313.6MW$_t$
Unexploited - plant under construction or planned	50.0 MW$_t$ (1)
Unexploited - proven resources	-
Unexploited - probable and possible resources	-

[1] Planned unexploited resources

LUXEMBOURG

Size	2,586	km^2
Population (1994)	0.407	millions
Annual population growth rate (1993-94)		%
GNP per capita (1993)		USD per year
Average annual growth rate of GNP (1990-93)		%
Average annual inflation (1995)		%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1995)	1,067	GWh
Geothermal	0	GWh
Fossil fuels		GWh
Hydro	0.083	GWh
Nuclear	0	GWh
Wind	0	GWh



Geothermal resources are not very well known in Luxembourg and the potential for geothermal operations in the short to medium term can be considered as non-existent.

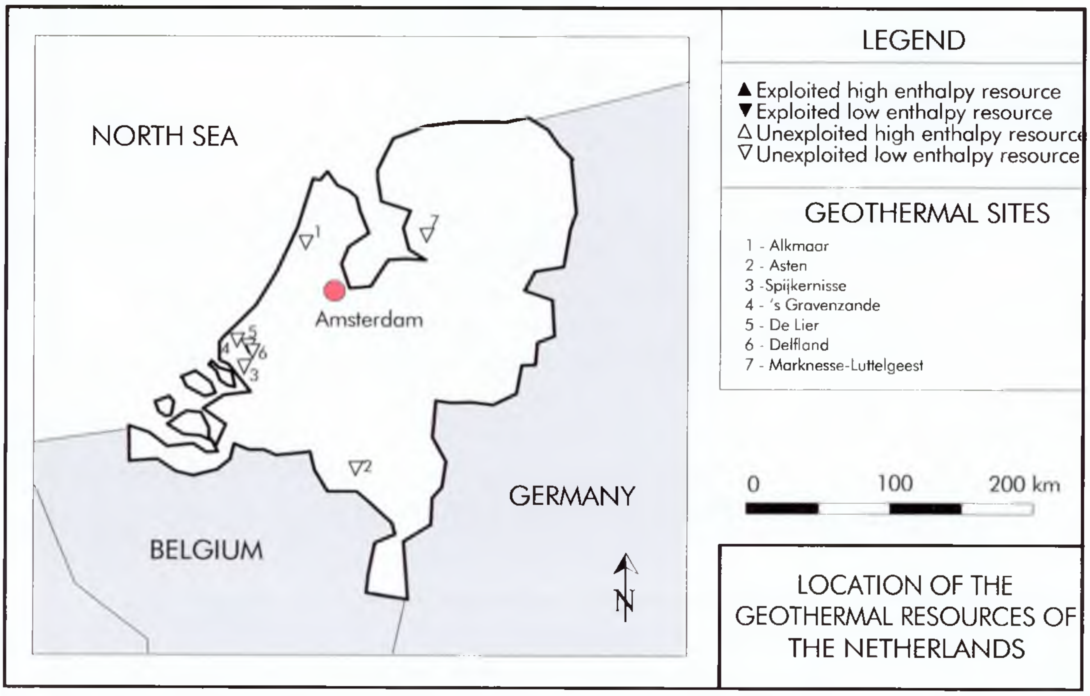
DIRECT USES

The *Mondorf* thermal station taps groundwater with a temperature of almost 30°C and is highly charged with chlorides. This is the only known example of geothermal utilisation in the country.

There are almost certainly, small private operations that use heat pumps to exploit low-temperature (<20°C) groundwater, but no register exists of these operations or users.

THE NETHERLANDS

Size	40,844	km^2
Population (1995)	15.503	millions
Annual population growth rate (1985-95)	0.55	%
GNP per capita (1995)	24,000	USD per year
Average annual growth rate of GNP (1985-1995)	1.8	%
Average annual inflation (1985-1995)	1.7	%
Annual energy use per capita (1994)oil equivalent	4,580	kg
Average annual growth rate of energy use (1992)		%
Annual CO_2 emission per capita (1992)	9.2	tonnes
Production of electricity (1994)	79,647	GWh
Geothermal	0	GWh
Fossil fuels	73,862	GWh
Hydro	101	GWh
Nuclear	3,967	GWh
Wind, Solar	239	GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF THE NETHERLANDS

The geological structure of the Netherlands is characterised by three basins - the Western Netherlands, the Central Netherlands and the Broad Fourteens Basin which are limited in the south by the strongly folded Paleozoic of the Brabant massif. The basins subsided in the Mesozoic (Jurassic and Cretaceous), caused by motions along pre-Variscan faults. The basins were inverted in the upper most Cretaceous and the Tertiary, and a horst-trench structure was formed. The Zechstein evaporites were deposited with only a limited thickness in the north and the east of the Netherlands. The overlying sediments, however, were not overprinted later by halokinesis. A potential reservoir rocks formed in three periods which cannot be assigned to the individual basins. These reservoirs have formed in series of the Rotliegendes, Lower Triassic and Lower Cretaceous.

Only in the southern part of the country does the Lower Triassic series form reservoirs and is similar to the Buntsandstein, which consists of continental sands facies which are subdivided into various cycles. According to their characteristics, different sandstones are suitable for reservoir use. In the area concerned, the sandstones lie at depths of 400m-1500m. Their deposition was also influenced by Cretaceous tectonics.

Only within a small area to the west, around Amsterdam, are Createaceous sands suitable for geothermal utilisation. These are marine sandstones structured cyclically by alternating regressions and transgressions. They are characterised, partly, by outstanding reservoir properties and occur at a depth of about 2,000m with minimal deformation.

The knowledge of individual reservoir horizons from wells differs. The Slochteren formation which is also important for hydrocarbon exploration, drilling activities in extensive in the north of the Netherlands and around the Ijsselmeer. More than 200 wells have been drilled. In the southern part of the country, considerably less drilling has been done (there are <100 wells). Major parts of the country have been covered by recent 3D seismic investigations into hydrocarbon exploration; moreover, this data has been compiled with data from production activities since the 1950s which includes the behaviour of different reservoirs during re-injection of oil field waters.

Electricity Generation

There is no electricity generated from geothermal resources.

Direct Uses

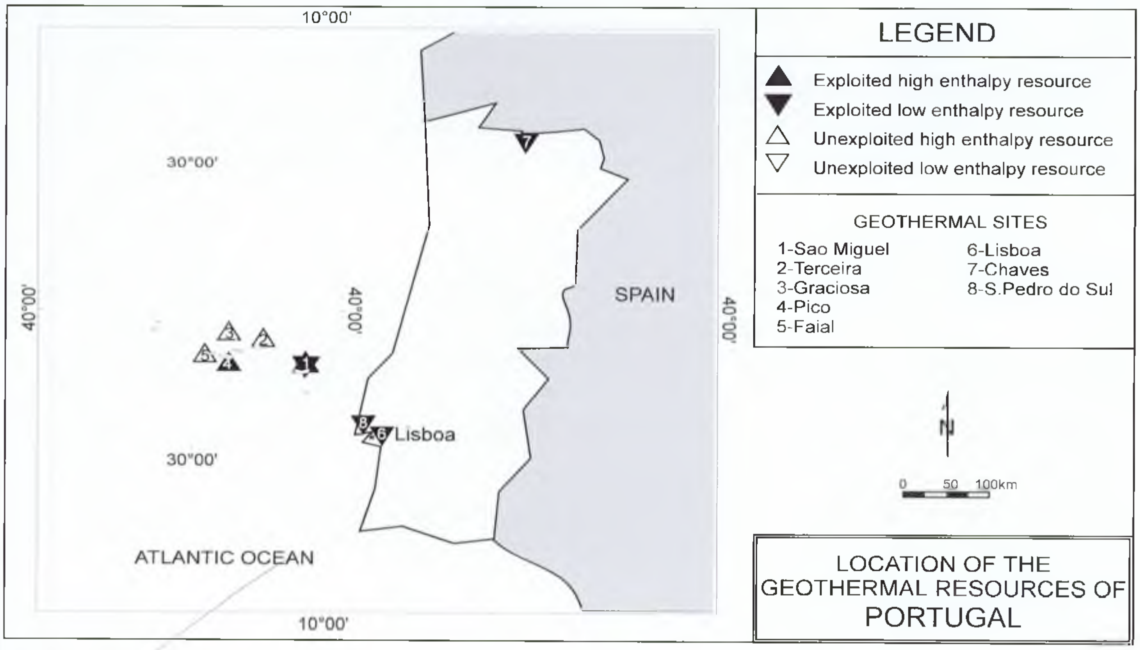
At present, geothermal energy is not recovered from deep reservoirs. However, there are plans to put a doublet into operation in 1997 for greenhouse heating and pre-heating of natural gas. On the other hand, shallow geothermics are being applied successfully in some minor projects. It is planned to commission other doublets before 2010.
There is political support for these which stimulates interest from potential investors.

In the Netherlands, the conditions for the utilisation of geothermal energy are relatively favourable. The annual mean temperature is low, there are potential porous aquifers located beneath about 30% of the country, with prospects for good recovery.
The geological knowledge of the reservoirs is good.

Summary of Resources	
Exploited - plant in operation	
Unexploited - plant under construction or planned	$20MW_t$
Unexploited - proven resources	
Unexploited - probable and possible resources	

PORTUGAL

Size	92,082	km^2
Population (1994)	9.9	millions
Annual population growth rate (1993-94)	0.51	%
GNP per capita (1993)	9130	USD per year
Average annual growth rate of GNP (1990-93)	0.14	%
Average annual inflation (1994)	5.2	%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (199)	109,347	GWh
Geothermal	42	GWh
Fossil fuels	24,751	GWh
Hydro	84,54	GWh
Nuclear	0	GWh
Wind	0	GWh



Geothermal projects for power generation are underway in the Azores islands, in the Atlantic Ocean at around 2000km west of the country, aligned along a NW-SE tensional axis.
Low enthalpy fluids are exploited mostly on the mainland.

ELECTRICITY GENERATION

At *São Miguel* temperatures of 200°C were encountered at around 600m depth. Four deep wells were drilled. A 3MW power plant was installed at *Pico V.* and a 2×3MW units were installed at *Riberia Grande* rift valley (north of *São Miguel*). Another 4MW are planned to be installed in the Azores.

Summary of Resources	
Exploited - plant in operation	8 MWe
Unexploited - plant under construction or planned	4 MWe
Unexploited - proven resources	-
Unexploited - probable and possible resources	-

Direct uses

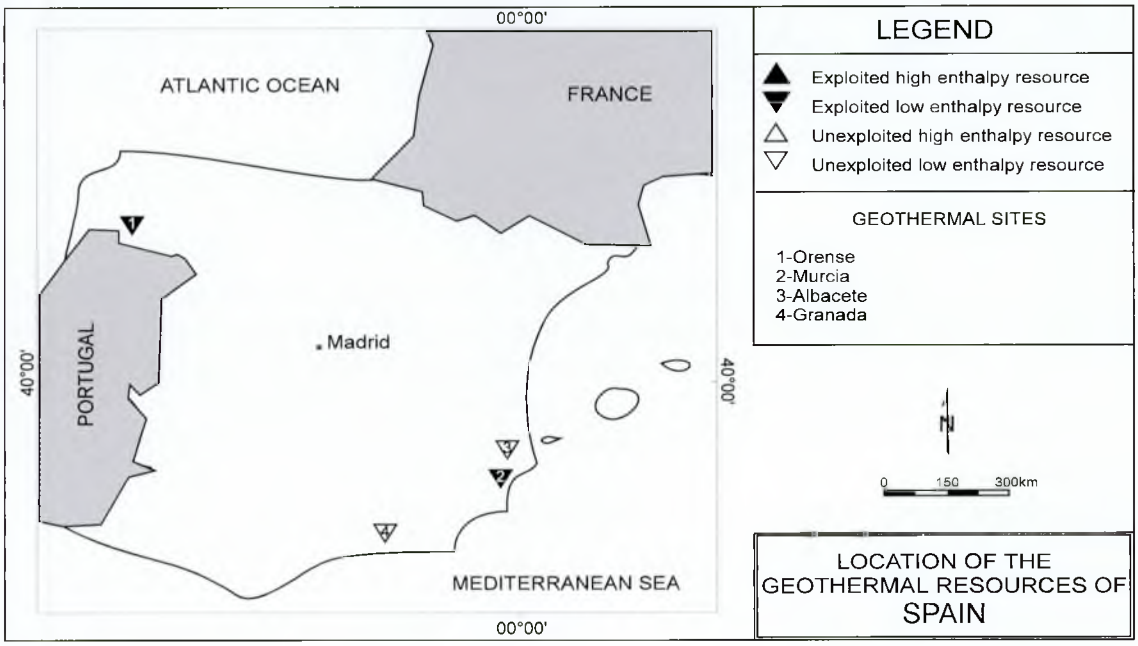
At *São Miguel* the waste from the geothermal station already operating will provide sufficient thermal energy for direct heat usage (each 10" production well produces 100-200t/h of fluid which provides 9-19MW_t). The project proposes six futuristic family-sized greenhouses for pineapple, cape gooseberry and melon production.
At *Lisboa* hot tap water and district heating are provided by geothermal energy at the Air Force Hospital which uses 3.3TJ/yr and district heating at the Army Social Installations (Oeiras) which uses 3.2TJ/yr by heat pumps.
At *Chaves* bathing/swimming, space heating and greenhouses total 6.7TJ/yr.
At *S.Pedro do Sul* geothermal energy use is 3.2TJ/yr for greenhouses.

Total installed thermal power is 0.84MW.

Summary of Resources	
Exploited - plant in operation	0.84 MWt
Unexploited - plant under construction or planned	-
Unexploited - proven resources	-
Unexploited - probable and possible resources	-

SPAIN

Size	504,750	km^2
Population (1994)	39.1	millions
Annual population growth rate (1993-94)	0.0	%
GNP per capita (1993)	13590	USD per year
Average annual growth rate of GNP (1990-93)	7.3	%
Average annual inflation (1994)	4.7	%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (199)		GWh
Geothermal		GWh
Fossil fuels		GWh
Hydro		GWh
Nuclear		GWh
Wind		GWh



In the years 1974 to 1979 an evaluation of the geothermal resources was performed and in 1979 the exploration of the most promising resources started.
Most resources are low enthalpy type but only a few of them are utilised for direct uses because of technical problems, reluctance and lack of users.

DIRECT USES

Spanish potential for low-to-medium resources is quite attractive, in particular the most interesting areas are:

Duero Basin: in *Burgos* one geothermal well was drilled in 1982 to the depth of 2543m and 85°C water with high flow rate was encountered. The well was abandoned because of the lack of nearby customers, although the results were interesting.

Ebro Valley margins: in *Lerida* one geothermal well was drilled in 1987 and found a reservoir at 54°C. This well was abandoned as well.

Basque country: near *Victoria* (*Antezana*) a former oil well was recompleted with geothermal purposes and a new geothermal well was drilled (*Gatzelu*) to a depth of 2123m. Both well were unsuccessful. At *Jafre* another oil well was recompleted in 1988 and found high flow rate fluid at 48°C. No use is made of the resource.
In the *Jaca-Seeralbo* gas field drilling a fluid at 160°C was found.

Pyrenees: in *Andorra* there is at least one productive well (*Escaldes*) with a temperature of 70°C at 125m of depth. A shallow well is planned to be drilled shortly at *Tresdos* spa.

Cataluña: geothermal exploration was performed in this area from 1981 to 1986.
In the *Valles* graben, an 80°C fluid at a depth of 500-1000m was found in several wells located fractured granite in *Samalus*. Two other wells produce over 360m^3/h of 58°C fluid in *San Cugat*, and a 55°C fluid with over 100m^3/h was encountered in a well at *Mula*.
In *Montbui* 4 wells were drilled near a thermal spring with water at 70°C.
The Montbrio well was drilled in 1989 to a depth of 603m and produced a fluid at 70°C. Non these resources has been exploited.

Orense: 7 shallow wells (<300m) were drilled before 1984 and produced good flow from a fluid at 70-80°C. These resources are partially used for greenhouses and granaries.

Madrid area: from 1982 and 1990 three successful geothermal wells were drilled at *Tres Cantos* (2417m), *San Sebastian* (2130m), *Madrid* (2000m). These resources yielded up to 250m^3/h and a temperature ranging from 70 to 80°C, but institutional problems and the reluctance of the potential users has frozen further activities.
Another development well in *Madrid* was abandoned due to technical failure without reaching the target reservoir.
A geothermal project for greenhouses is scheduled in *Albacete*.

Betic chain graben: this area is located in the quadrangle *Granada-Cartagena-Murcia-Mallorca* island were several hot springs occur. The main reservoir is shallow with fluid at 40-50°C.
In *Murcia* area the fluid is used for heating greenhouses or for osmosis desalination.
A geothermal well is scheduled to be drilled in *Granada* to heat greenhouses.

Canary islands: in the *Gran Canaria* island an aquifer with 40-50°C water has been located at about 1500m in depth.

SWEDEN

Size	449,964	km^2
Population (1994)	8.837	millions
Annual population growth rate (1993-94)		%
GNP per capita (1993)		USD per year
Average annual growth rate of GNP (1990-93)		%
Average annual inflation (1995)		%
Annual energy use per capita (199)oil equivalent		Kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		Tonnes
Production of electricity (1995)	144,311	GWh
Geothermal		GWh
Fossil fuels		GWh
Hydro	67.1	GWh
Nuclear	66.47	GWh
Wind		GWh

The geothermal potential of Sweden, excluding resources at temperature lower than 30°C, is negligible.
Very low temperature aquifers which are exploitable only with the support of heat pumps are however abundant.

Geothermal prospecting in Sweden has focused on the *Malmö* area since 1977. Here several wells have been drilled for oil exploration and temperatures up to 81°C at 2280m have been recorded (Ljunghusen 1 well).Some potential is believed to exist in *Gotland Island* in the Baltic Sea

DIRECT USES

Only one geothermal application has been developed, the large 47MWt geothermal district heating plant of *Lund.*

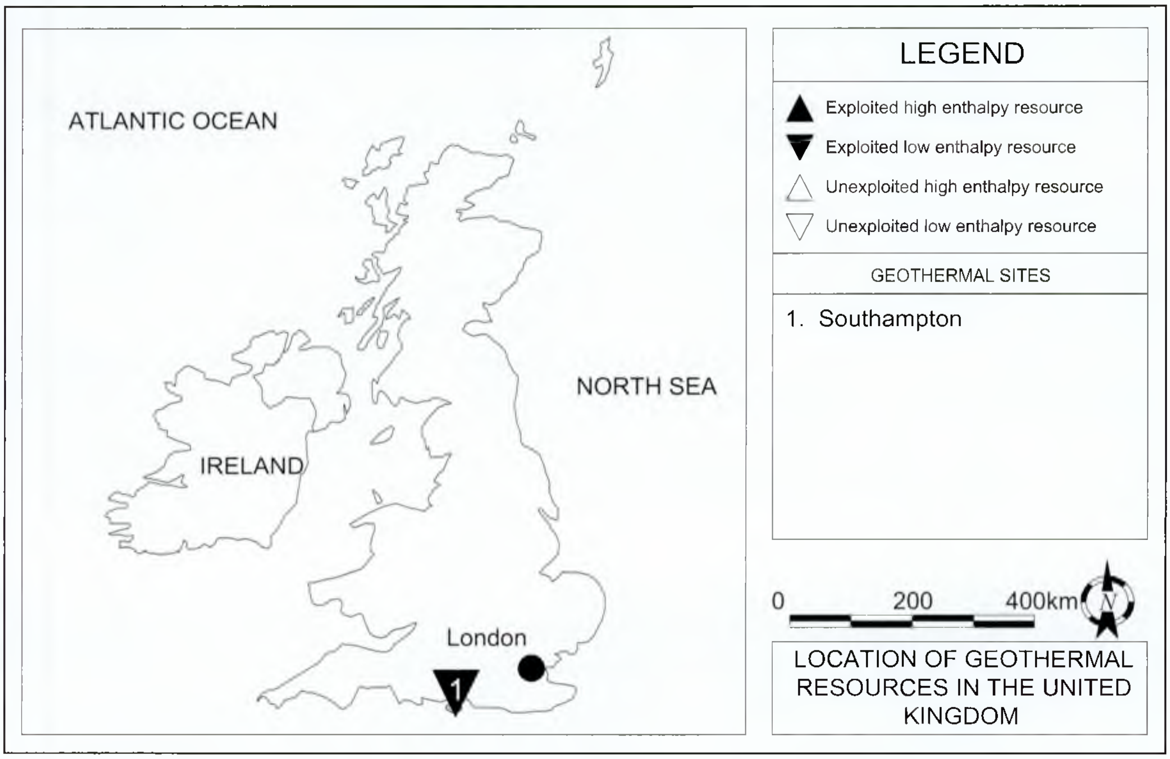
A detailed study in the outskirts of *Lund* (Malmö area, Scania region) led in 1982-83 to the drilling of two shallow geothermal wells (depth 684m and 764m). Campanian sands were extensively tested in a doublet configuration (producer-reinjector). Saline (6g/l) water with a temperature of 23°C and a stabilised flow-rate (on pumping) of $400m^3/h$ was produced.
In 1984, a geothermal plant was developed to feed the town's existing conventional district heating system. Two production and two injection wells (average depth 700m) were drilled and the geothermal plant, including electric heat pumps, went into operation in 1985.In 1986, the plant was enlarged and operated with 4 production, 4 reinjection and 2 observation wells. In 1993, one of the observation wells was converted into an injection well. Water is produced at 20-23°C and reinjected at 4-8°C.Geothermal heat capacity is 47MWt and the associated heat production was 351GWh in 1993, covering about 45% of the total heat demand for the district heating system (the rest being provided by gas, oil and sewage).

The probability of additional geothermal plants in *Scania* region with resources at the same or higher temperatures (especially in Cretaceous and Jurassic aquifers) is dependent on energy prices and on the Swedish fiscal policy for electricity and fuels. *Lund* experts, however, consider new geothermal projects highly unlikely in the foreseeable future.

Summary of Resources	
Exploited - plant in operation	47MWt
Unexploited - plant under construction or planned	
Unexploited - proven resources	10 MWt
Unexploited - probable and possible resources	

THE UNITED KINGDOM

Size	241,800	km^2
Population (1994)	58.4	millions
Annual Population growth rate (1994)	0.3	%
GNP per capita (1994)	18,410	USD per year
Average annual growth rate of GNP (1985-1994)	1.4	%
Average annual inflation (1988-1994)	5.1	%
Annual energy use per capita (oil equivalent)	3916	kg
Average annual growth rate of energy use	1.6	%
Annual CO_2 emission per capita	11.7	tonnes
Production of electricity (1993)	323,029	GWh
Geothermal	0	GWh
Fossil fuels	225,201	GWh
Hydro	5,686	GWh
Nuclear	89,353	GWh
Wind	342	GWh
Biomass	922	GWh
Wastes	1,525	GWh



UK geothermal gradients are generally less than 30°C/km. Despite this, two rock formation types have been assessed for their geothermal energy potential; sandstone formations of Permo-Triassic age and Carboniferous limestone of Palaeozoic age. The latter supplies the famous Roman baths with water from hot springs in the *Bath/Bristol* area.

Studies by the British Geological Survey (BGS) identified five potential aquifers:

The west of the *Wessex Basin* appeared to offer the UK's best geothermal aquifer resource, but most of the aquifer underlies a rural area offering few opportunities to use the heat apart from in the *Bournemouth-Poole* and *Southampton* areas.

The *Sherwood* sandstone in the *East Yorkshire and Lincolnshire Basin* also contains a potential aquifer at 40-60°C, in an area extending from *Scarborough* down to the *Wash*.

In the *Worcester Basin,* thick layers of *Sherwood* sandstones (about 2000m) underlie *Cirencester*, *Cheltenham* and *Gloucester* but temperature gradients are low resulting at best, in the possibility of a considerable resource at 40-60°C under *Cirencester*.

Permo-Triassic sandstones are thick in the *West Lancashire* and *Cheshire Basin* and extend down to 4000m. Unfortunately, heat flow is particularly low so that aquifers only reach 80°C at depths greater than 2500m. Once again, much of the area is rural apart from *Crewe*.

In the *Northern Ireland Basin,* assessment was limited to the *Sherwood* sandstone but aquifers may exist in the deeper Permian sandstones although there are major uncertainties about their thickness and hydrological characteristics.

In the UK, it is unlikely that aquifers with very low-grade heat, i.e. below 40°C, would ever be exploited. Although the heat resource at 40°C, estimated to be equivalent to 8,300TWh (1100Mtce) appears large, the coincidence of the resource with likely heat loads is poor; it is uneconomical to transport the hot fluids over a significant distance.

Based on a detailed assessment of the heat requirements of several urban centres, the highest theoretical projection for new schemes is unlikely to exceed more than 50 geothermal schemes across the UK. A more realistic estimate, which assumes one scheme producing 26 GWh_t/yr could be developed within each geothermal field by the year 2005 followed by a further twenty by the year 2025, reveals a maximum practicable resource of 650 GWh_t/yr.

There are no high enthalpy resources.

Direct uses

Currently the only operating UK geothermal plant is at *Southampton*. Several municipal buildings are linked by a 2km hot water main running to and from a 'heat station' located close to the wellhead of the *Southampton* borehole.

The UK Government financed drilling and testing of the borehole. The City Council had intended to develop the group heating scheme, but early test pumping of the aquifer fell short of the specified targets. It was concluded that pumping should not exceed 12 l/s to ensure a 20-year life. As a result, the original plan for a large-scale scheme was abandoned. A more limited scheme was developed

Low grade geothermal heat is not sufficient to supply all the heat requirements to the buildings. The central plant and equipment are located in a heat station about 200m south of the geothermal wellhead. By cooling the borehole brine from 70°C to 30°C, geothermal energy provides approximately 2MW of heat, achieved by use of a heat pump which enables more heat to be extracted from the brine. The scheme cost £1.24M to construct and costs £46k per year to operate. Heat is supplied to approximately 5000 people for a unit cost of 1.4p/kWh.

The geothermal component represents approximately 10% of the power produced by the scheme, which includes a combination of boilers and generators.

Further geothermal development in the UK is unlikely during the foreseeable future.

SUMMARY OF RESOURCES	
Exploited - plant in operation	$2MW_t$
Unexploited - plant under construction or planned	0
Unexploited - proven resources	$10MW_t$
Unexploited - probable and possible resources	$70MW_t$

EEA Countries

Iceland
Liechtenstein
Norway

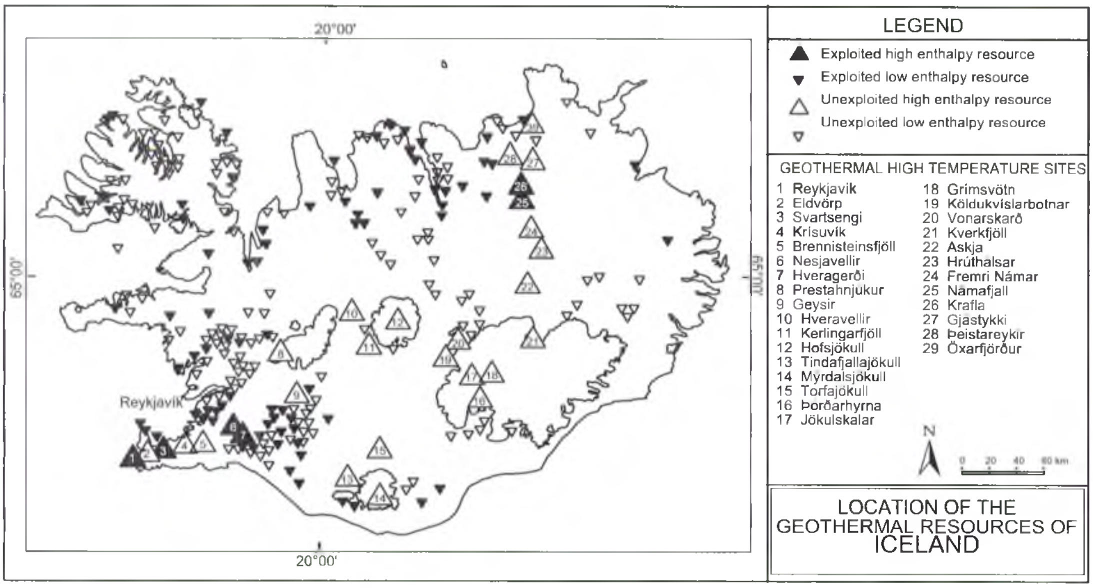
Russia

Switzerland

Turkey

ICELAND

Size	103 000 km^2
Population	0.268 million
Annual population growth rate (1994)	0.7 %
GNP per capita (1994)	24 630 USD per year
Average annual growth rate of GNP (1990-1994)	0.3 %
Average annual inflation (1984-1994)	14.9 %
Annual energy use per capita (oil equivalent)	8 800 kg
Average annual growth rate of energy use (1990-1994)	0.9 %
Annual CO_2 emmission per capita	9.6 tonnes
Production of electricity (1995)	5,581GWh
Geothermal	375 GWh
Fossil fuels	3 GWh
Hydro	5,203 GWh
Nuclear	0
Wind	0



GEOTHERMAL POTENTIAL

Iceland is located astride the Mid-Atlantic Ridge and has therefore large geothermal potential. The following table gives a summary of the geothermal potential of Iceland.

Geothermal potential of Iceland			
Type of energy	10^{18} joule	TWh	TWh/year for 50 years
Technically exploitable thermal energy at wellhead (T>5°C)	3,500	972,000	19,400
Usable thermal energy from plants (T>40°C)	1,700	486,000	9,500
Usable thermal energy for electricity generation (T>130°C)	540	150,000	3,000
Usable electrical energy from high-temperature fields	5.6	1,550	31
Harnessed in 1995		14	

GEOTHERMAL UTILIZATION

The annual primary energy supply in Iceland (1997) is 106,000 TJ or 387 GJ per capita, which is among the highest value in the world. In the year 1997, geothermal energy provided 48% of the total primary energy supply, hydropower 18%, and fossil fuels 34%. Nuclear energy and wind energy are not utilized in Iceland. The exceptional conditions of the energy balance in Iceland are that geothermal energy provides higher share (about 50%) of the primary energy supply than in any other country in the world, and that renewable energy sources (geothermal and hydro) provides 66% of the primary energy in the country, which is also the highest ratio in the world.

The main use of geothermal energy is for space heating. About 85% of all houses in Iceland are heated with geothermal energy and the remaining 15% are mostly heated by electricity. Electricity is mainly generated from hydro (94%) and only 6% from geothermal energy. This ratio is expected to change in the future, and the installed geothermal power will increase from about 80 MW_e in 1997 to 170 MW_e by 2000.

Electricity is generated in four high-temperature geothermal fields, Krafla, Námafjall, Svartsengi, and Reykjanes, and a 60 MW_e power plant is under construction at Nesjavellir. In addition to electricity generation, the geothermal energy is used for industrial purposes in Námafjall, and hot water production for district heating is the main utilization in Svartsengi and Nesjavellir. The high-temperature field at Reykjanes has also been utilized for salt production.

Electricity generation (1997)	Installed capacity MW_e	Production GWh/a	Average load %	Under construction MW_e
Krafla	60	228	48	
Námafjall	3	22	93	
Svartsengi	16.4	122	95	30
Reykjanes	0.5	2	47	
Nesjavellir				60
Total	80	374		90
Average			60	

There are more than 30 public district heating services in Iceland utilizing geothermal energy. The amount of geothermal heat for different categories is given in the following table.

Direct uses (1997)	Installed power MW_t	Net energy use GWh/year	Average load %
Space heating	1,150	4,528	45
Bathing and swimming	60	278	53
Greenhouses	45	231	59
Fish and animal farming	25	175	80
Industrial process heat	105	556	60
Snow melting	55	106	22
Heat pumps	3	5	19
Total	1,443	5,878	47

At present, about 1% of the most economical geothermal resources for electricity generation have been developed in Iceland. If the total geothermal potential for electricity generation is regarded, the present development is only 0.1% of the total. Present utilization of geothermal energy for direct use is about 0.1% of the estimated useable geothermal energy above 40 KC.

SUMMARY OF THE RESOURCES				
	Electricity		Direct Use	
In operation	80 MW_e	374 GWh/y	1,443 MW_t	5,878 GWh/y
Planned or under construction	90 MW_e	720 GWh/y	-	-
Estimated potential	4,000 MW_e	31,000 GWh/y	1,900,000 MW_t	9,500,000 GWh/y

LIECHTENSTEIN

Size	160	km^2
Population (1994)	0,031	millions
Annual population growth rate (1993-94)		%
GNP per capita (1993)		USD per year
Average annual growth rate of GNP (1990-93)		%
Average annual inflation (1995)		%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1995)	0.081	GWh
Geothermal		GWh
Fossil fuels		GWh
Hydro		GWh
Nuclear		GWh
Wind		GWh

No data are available.

NORWAY

Size		km^2
Population (1994)		millions
Annual population growth rate (1993-94)		%
GNP per capita (1993)		USD per year
Average annual growth rate of GNP (1990-93)		%
Average annual inflation (1995)		%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1995)		GWh
Geothermal	0	GWh
Fossil fuels		GWh
Hydro	120.71	GWh
Nuclear	0	GWh
Wind		GWh

Geothermal energy is not being used in Norway at present.

The geological setting of the country means that geothermal reservoirs worthy of geothermal development do not exist.
For the general geological and energy situation it has to be assumed that geothermal heat recovery is neither being implemented nor planned in Norway.

RUSSIA

Size	17,075,400	km^2
Population (1994)	148.6	millions
Annual population growth rate (1994)	0	%
GNP per capita (1994)	1,927	USD per year
Average annual growth rate of GNP (1993-94)	-15	%
Annual inflation (1994)	302	%
Average annual inflation		
Annual energy use per capita (199) oil equivalent		kg
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity (1995)	912	GWh
Geothermal	0.028	GWh
Fossil fuels	622	GWh
Hydro	165	GWh
Nuclear	125	GWh
Wind		GWh

LOCATION OF THE GEOTHERMAL RESOURCES OF **RUSSIA**

In Russia, geothermal resources are widely distributed throughout the country. Low to intermediate temperature aquifers (50°-200°C) are found within the *Scythian* and West Siberian, sedimentary platforms, as well as in regions of recent tectonic activity and young foredeep and inner depressions of the Alpine Belt (i.e. the Caucasus, the *Baikal* rift zone). The East-European and Siberian Pre-Cambrian platforms also contain aquifers with lower temperature conditions (50-100°C).

High temperature geothermal systems (>200°C) occur in regions of recent volcanism (*Kamchatka*, *Kuril* Islands), as well as in regions of recent tectonic activity (*Caucasus*, *Baikal* rift zone).

ELECTRICITY GENERATION

The *Kamchatka* and *Kuril* Regions show a very high potential for high enthalpy geothermal resources, related to active volcanism. Moreover, their distance promotes the development of local resources. There are a total of 9 fields in *Kuril-Kamchatka* with high enthalpy resources and an estimated capacity of 380-550MW$_e$.

The only operating geothermal plant in 1995 is the 11MW$_e$ *Pauzhetsky* single flash plant in *Kamchatka*, built in 1966 and enlarged in 1980, which produces about 28.3GWh/year. This installation comprises three units of 2.5, 2.5 and 6.0MW$_e$ respectively. 79 wells have been drilled on this field. 11 production wells produce fluids with low TDS (3-4g/l) and 210°C maximum temperature at a depth of 300-500m. By the year 2010, the installed capacity of *Pauzhetsky* is planned to be 18MW$_e$.

Other 15MW$_e$ plant is under construction at *Mutnovsky*. 58 wells were drilled in this field, within a depth range from 255-2100m. Of special interest is the presence of a 2100-2700 kJ/kg steam resource sandwiched between two liquid-dominated reservoirs of lower enthalpy. Water temperature range is 250-310°C.The installation of 2x20 Mw$_e$ plant is planned for 1999 and other 40+5Mw$_e$ .in 2002. Other 80 Mw$_e$ could be implemented up to 2010. By the year 2010, the installed capacity at *Mutnovsky* is planned to be 210MW$_e$.

Other sites in *Kamchatka* where high enthalpy geothermal resources have been evidenced are :
Nizhne Koshelevskoe (220-240°C); *Khodutkinskaya* (200°C); *Bolshe-Bannoe* (171-200°C); *Karimskaya* (200°C); *Apapelskaya* (200°C); *Kireunskaya* (200°C).

On *Iturup Island in the Kurils,* a 5x6MW$_e$ power plant is planned for 1996-1999. To date, 9 wells have been drilled there and are ready for exploitation.

Other sites in *Kurils* where high enthalpy geothermal resources have been evidenced are *Kunashir* Island (*Gorjachij Pljazh* and *Golovnina* volcano) and *Paramushir* Island (*Ebeko* site).

In the Northern Caucasus, a 3MW$_e$ pilot plant is planned at *Kayasulinskaya*. However, high TDS (>100g/kg), relatively low temperatures (150°-170°C) and injection pressures of up to 7 MPa make this project problematic.

SUMMARY OF RESOURCES	
Exploited - plant in operation	11MW$_e$
Unexploited - plant under construction or planned	130MW$_e$
Unexploited - proven resources	80MW$_e$
Unexploited - probable and possible resources	380-550MW$_e$

DIRECT USES

Direct uses of thermal waters are mainly developed within 6 towns and 8 big settlements. There are also a lot of small-scale geothermal exploitation scattered throughout the Russian Federation. Total installed capacity at the end of 1994 was 210MW$_t$, producing 673GWh/yr. Total heat flow was 1,40 kg/s, producing 8.80TJ/yr.

Thermal waters are mainly used for space and district heating (45%) and greenhouses (48%); industrial process heat, animal farming and bathing are secondary. By the end of 1994, 367 geothermal wells had been drilled, 185 for production, 10 for re-injection and 86 for observation. The total number of inhabitants using thermal waters for heating was 220,000. The total area of greenhouses heated by thermal waters was about 340,000m^2. About 150 bathing resorts and 40 bottling factories were operating.

Kamchatka:
Thermal waters with TDS 5g/l and temperature of 80-100°C are used for greenhouses, space heating and bathing, in rank order. Main sites are *Paratunka* (60,000m^2 greenhouses), *Pauzhetka*, *Esso*, *Anavgay* and *Nachikin*.

Baikal-Amur:
The occurrence of several hydrothermal systems is related to recent volcanism and tectonic activity in the *Baikal* Rift Zone and surroundings (*Bouriates* and *Tuva* Regions). Thermal waters are used for resort and building space heating near the *Baikal* Lake and along the *Baikal-Amur* Railway. The main sites of geothermal exploitation are :

Il'inka near *Ulan-Ude*, for greenhouses (67-74°C waters at 300-400m.depth, with TDS 2g/l, flow rate 12l/s);
Pitatelev, for greenhouses;
Bouriates Republic (*Gorjachinskoe*, *Okusidan*), for greenhouses and space heating;
Tuva Region (*Ush Beldyrskoe*), for greenhouses and space heating;
Tunka for *balneotherapy* and heating (41°C waters);
Along the *Baikal-Amur* Railway (*Baunt*, *Barguzin*, *Severomysk*, *Kul'dur*), for space heating.

The Pacific coast:
Direct uses of thermal waters are developed for space heating mainly. Main sites of exploitation are:
Chaplinsk (*Chukches* Peninsula) where 80°C waters [TDS: 18g/l; flow rate: 15l/s] are used for farming heating, greenhouses and swimming;
Magadan area (*Talaja*, *Motyklej*, *Til'minlinejskij*) where 85-91°C waters are used for balneotherapy, heating and greenhouses;
Sakhaline Island where extensional Neogene Basins show elevated thermal gradients. Deep wells (2000-3000 m) in *Nekrasov* area produce 80-90°C waters with TDS 8-23g/l.

Western *Siberia*:
It is the biggest artesian basin in the world (3×10^6km^2), and can be considered as a huge, low to intermediate temperature, geothermal reservoir. Hydrothermal resources are estimated about 180,000l/s of 40-80°C waters (TDS 10-25g/l) at depth of 2000-3000m. Oil and gas drilling has provided much information. The main aquifers are Aptian-Cenomanian and Neocomian Formations.
Direct uses are mostly for space heating. Several geothermal exploitation are mentioned:

Omsk: a 2000-2500m.deep aquifer produces 75-80°C waters (TDS: 27g/l; flow rate: 30l/s) for space heating and fish farming;
Tjumen: oil well and reservoir heating;
Tobolks, *Cherkashin*: a multipurpose geothermal project uses 81°C waters (TDS: 18g/l)) for space heating, domestic hot water, greenhouses, swimming and fish farming. These waters also contain $1m^3$ gas/m^3 water;
Malyj-Atlyn: 142°C waters at 2700m.depth contain about $2m^3$ methane/m^3 water;
Kospashevo: 65°C waters (flow rate: 10l/s) are used for greenhouses;
Tara: 40°C waters produced by 1200 m-deep wells are used for wool washing.

Precaucasus:
The *Krasnodarsk* and *Stravropol* Territories and the *Karatchais-Tcherkesses* Republic (Southern Russia) have large geothermal resources related to the occurrence of low to intermediate temperature (40-200°C) waters in sedimentary aquifers of the *Kuban'* Plain. High temperature systems are expected at great depths around the *Temrjuk* Golf (220°C at 6320m.depth). Development of geothermal resources was promoted by the abundance of large aquifers with low salinity waters. Extensive oil exploration also provided a lot of data.
Geothermal exploitations mainly concern heating for agricultural purposes (greenhouses, fish farming), space heating and balneotherapy.

The main sites in *Krasnodarsk Territory* are : *Mostovskoy*, *Abadzekh*, *Alexandrovsk-Rovnensk*, *Shirvan*, *Gorjachij-Kljuch*, *Brjukhoveckij*, *Novo Titarovsk*, *Novo-Dimitrievsk*, *Belorechensk*. 70-130°C waters are produced from Lower Cretaceous and Majkop aquifers mainly, located between 1000-4000m.depth. Flow rates range from 2 to 40l/s. In the *Mostovskoy* Region, 75°C waters are used for multipurpose utilisation: greenhouses (180,000m^2), space heating, farm heating, concrete block fabrication, wood drying. Residual temperature waters (20-30°C) are used form swimming pools and fish farming.

The main sites in *Stravropol Territory* are: *Georgievsk*, *Praskove*, *Cherkessk*, *Nevinnomysk*, *Kajasula*, *Neftekumsk*, *Majkop*, *Labinsk*. 70-200°C waters are produced from aquifers at a depth of 1500-4500m. located within Cretaceous and *Majkop* Formations. Flow rates range from 3 to 60l/s and fluid salinity from 1 to 100g/l. In some places, high temperature conditions could allow the installation of electricity power plants (*Praskove*, *Kajasula*, *Neftekumsk*).

Northern *Caucasus*:
Dagestan Republic
This region bordering the Caspian Sea has large geothermal resources which have been exploited since 1950. Their assessment has largely benefited from oil and gas exploration drilling. Many abandoned oil wells have been used for thermal water production.
In the *Terek*-Caspian Trough, the top of the basement is 3000 to 11,000m deep and large aquifers have developed within the sedimentary pile. The main thermal water reservoirs are: Mezosoic sandstones and limestones (160- 240°C; 60-210g/l), Miocene sandstones (600-4000m.deep; 85-125°C; flow rates: 2-5l/s; salinity: 3-10g/l; pressure: 10-30 bars), Pliocene sandstones (500-1000m.deep; 25-55°C).
In the Caucasus Foothills, three main aquifers are developed: Jurassic Formations (700-2500m.deep; 10-70g/l), Cretaceous Formations (600-2000m.deep; 40-70°C; 10-70g/l;

5-12l/s; 25-30 bars), Middle Miocene Formations (55-106°C; 3-10g/l; 6-40l/s). Highest temperature conditions and flow rates are observed along the *Kuma* River, in North *Dagestan* and South *Kalmuk* Republic.

Thermal waters are widely used for space heating (200,000 inhabitants), greenhouses (60,00m^2 at *Ternair*), industrial process heat (oil reservoir heating), mineral extraction (I,Br), balneotherapy.
Main sites of geothermal exploitation are: *Makhach-Kala*, *Ternair*, *Izberbash*, *Terekly-Mekhteb*, *Chervleny-Buruny*, *Tarumovka*, *Kizlyar*, *Kayakent*, *Berikej*, *Sukhokumsk*.

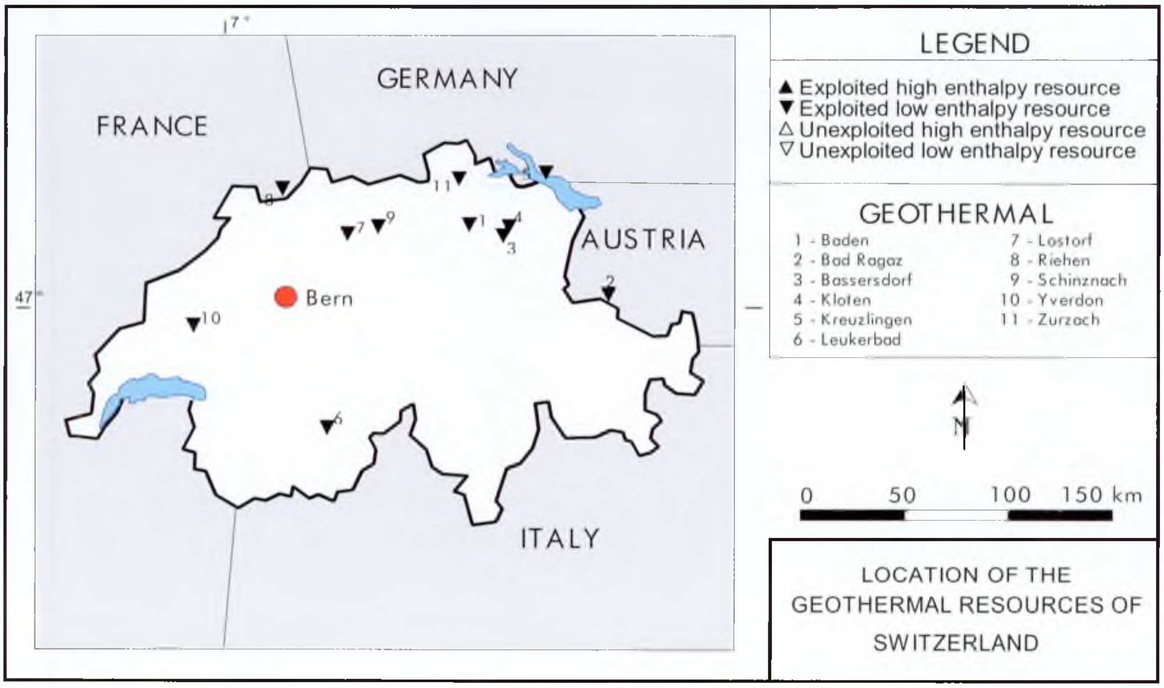
Chechene Republic, *Kabardino-Balkariya* Republic
These two republics are located on the Caucasus Foothills. The same aquifers as those described above in *Dagestan* (Cretaceous and Middle Miocene Formations) are exploited for thermal waters. They are mainly used for space heating and greenhouses.

Main sites of geothermal exploitation are: *Grozni*, *Datykhskij*, *Gudernes*, *Nal'Chik*. At *Grozni*, 80-90°C waters with TDS 5g/l provide district heating for 5,000 inhabitants.

Summary of Resources	
Exploited - plant in operation	210MW$_t$
Unexploited - plant under construction or planned	
Unexploited - proven resources	
Unexploited - probable and possible resources	

SWITZERLAND

Size	41,293	km^2
Population	7.202	millions
Annual population growth rate (1985-95)	0.8	%
GNP per capita (1995)	40,630	USD per year
Average annual growth rate of GNP (1985-1995)	0.2	%
Average annual inflation (1985-1995)	3.4	%
Annual energy use per capita (1994)oil equivalent	3,629	kg
Average annual growth rate of energy use (1992)		%
Annual CO_2 emission per capita (1992)	6.4	tonnes
Production of electricity (1994)	65,724	GWh
Geothermal	0	GWh
Fossil fuels	757	GWh
Hydro	39,946	GWh
Nuclear	24,363	GWh
Wind	5	GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF SWITZERLAND

The early 1990s marked a turning point in Swiss geothermal development. Deep drilling projects gave momentum to countrywide borehole heat exchanger (BHE) installations (the so called geothermal heat pumps). Since 1990 significant steps have been taken in energy policy development towards the utilisation of indigenous and environmentally benign forms of energy. A governmental risk coverage system for deep drilling (>400m) introduced in 1987 is still effective; 15million Swiss francs were awarded by the federal government to cover activities in the period 1987-1997; six wells have been drilled to depths of between 650 and 2550m since 1991. As a generalisation flow rates have been too low for sensible utilisation.

ELECTRICITY GENERATION

There is no electricity generated from geothermal resources.

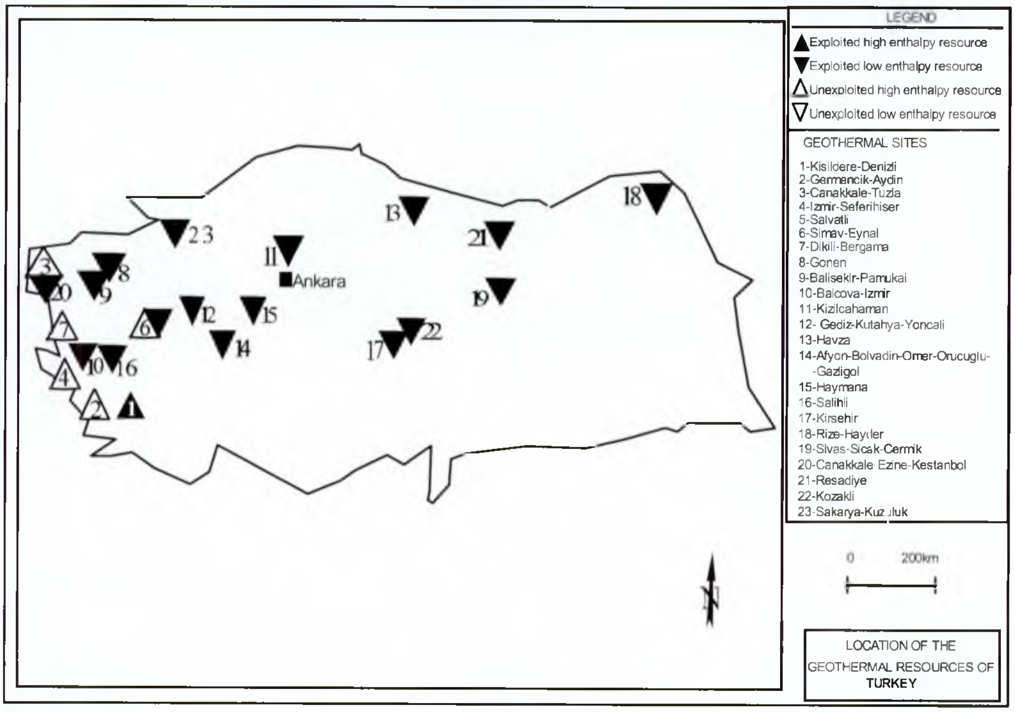
DIRECT USES

Wells drilled in the late 1980s were more successful and resulted in the start of a geothermal doublet system of 4.7MWt in 1993 at *Riehen*. Shallow geothermal surveys (15-400m deep bores) have resulted in BHEs and their derivations (energy piles, multiple BHE, combined heat extraction/storage, etc.) providing a new impetus to geothermal development in this country. More than 6000 such systems have now been installed, representing heating amounting to 820TJ/yr (Switzerland used 346,000TJ for space heating in 1993). In addition to the extensive use of BHEs, Alpine tunnel waters are also used in heat pump installations. In 1997 total installed rated capacity is 190MWt. Seven professional person-years of effort in 1994 were expended and the total investment in the past was US$ 177M, of which 85% was from private funds.

SUMMARY OF RESOURCES	
Exploited - plant in operation	190 MW_t
Unexploited - plant under construction or planned	10 MW_t
Unexploited - proven resources	
Unexploited - probable and possible resources	

TURKEY

Size	780,576	km^2
Population (1994)	61. 6	millions
Annual population growth rate (1994)	2.3	%
GNP per capita (1994)	2,200	USD per year
Average annual growth rate of GNP (1993-94)	-3.9	%
Annual inflation (1994)	106.3	%
Average annual inflation		%
Consumption of energy (1993) oil equivalent	59.16	million t
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity (1995)	73.80	GWh
Geothermal		GWh
Fossil fuels		GWh
Hydro	33.93	GWh
Nuclear	0	GWh
Wind		GWh



In Turkey, recent volcanism and active faulting related to the Alpine tectonic Belt have created highly favourable conditions for the development of geothermal systems. More than 1000 hot springs are known. 140 geothermal localities have water temperature in excess of 40°C. At least 7 sites are suitable for electricity generation.

High enthalpy geothermal systems are mainly located in graben structures in Western *Anatolia* whereas low to intermediate temperature resources are disseminated in Middle and Eastern *Anatolia*, along fault zones (Northern *Anatolian* Fault) and in volcanic areas.

ELECTRICITY GENERATION

Only one high temperature geothermal field is currently exploited (*Kisildere-Denizli*). Two other sites have been drilled and their potential estimated (*Germencik-Aydin* and *Canakkale-Tuzla*). Four other sites with electric power generating potential have been investigated (*Izmir-Seferihiser*, *Salvatli*, *Simav* and *Dikili-Bergama*).

Installed capacity is 20.9MW_e. Plans are in place to exploit 125MW_e from *Germencik*, *Kisildere* and *Canakkale* (and possibly other fields) by the year 2000, 150MW_e by 2005 and 258MW_e by 2010.

Kisildere-Denizli Field: a 0.5MW_e pilot plant was built in 1975, followed by a 20.4MW_e single flash power plant in 1984. They are fuelled by 9 production wells. Reservoir temperature ranges between 198-212°C. Extensive Calcium-carbonate scale deposition require frequent cleaning, until the use of the scale inhibitor Dequest 2066;

Germencik-Aydin Field: 9 wells ranging in depth from between 285 and 1500m. have encountered a 216-232°C water reservoir within metamorphic rocks. Its potential capacity is estimated to be 100MW_e and a 30MW_e plant is planned;

Canakkale-Tuzla Field: 2 exploratory wells up to 1020m deep have located a 174°C water reservoir, but permeability is low. Further drilling will be devoted to the identification of deep resources.

Summary of Resources	
Exploited - plant in operation	20.9MW_e
Unexploited - plant under construction or planned	258MW_e
Unexploited - proven resources	100MW_e
Unexploited - probable and possible resources	200-300MW_e

Direct Uses

In Turkey, geothermal energy is mostly used for heating (87%). The installed capacity is 160MW_t and 121MW_t are under construction (July 1994). Feasibility studies have been completed on an additional 563MW_t capacity. Total proven capacity for direct uses in Turkey is 2,264MW_t. The geothermal heat production capacity is expected to be increased to 2,520MW_t by the year 2000, and 6,500MW_t by the year 2010.

Over 30 geothermal district heating systems exist and, with a few exceptions, use geothermal waters through heat exchangers due to their chemical composition. Also, scaling and corrosion problems have been solved by fluid treatments and suitable equipment designs.

The largest geothermal heating districts are:

Gönen, operating since 1987 (16.MW_t capacity) for space heating (dwelling, hotel), greenhouses, industrial heat process (tanneries). Average flowrate and water temperatures are 80l/s and 80°C, respectively;

Simav (33-66MW_t), operating since 1992 for space heating and balneology. It is fed from a 720m deep well producing 143°C geothermal fluids at a 70 l/s flow rate;

Kirsehir (18,25MW_t) operating since 1994 for space heating and domestic hot water supply. The average flow rate of geothermal fluids is 240 l/s;

Balcova (17,80MW$_t$) operating since 1983 for space heating and domestic hot water supply.

Other geothermal district heating systems on operation are: *Kizilcahaman* (0.6MW$_t$), *Gediz* (0.1MW$_t$), *Havza* (0.7MW$_t$), *Afyon-Bolvadin* (1.5MW$_t$), *Haymana* (0.9MW$_t$) *lihli* (0.6MW$_t$) *yon-Omer* (2.MW$_t$), *Afyon-Orucuglu* (2.3MW$_t$), *Simav-Eynal* (2.MW$_t$), *Rize-Ayder* (0.4MW$_t$), *Sivas-Sicak Cermik* (0.7MW$_t$).

Geothermal district heating systems under construction are : *Canakkale-Ezine-Kestanbol* (3.7MW$_t$), *Balikesir-Pamuka* (1MW$_t$), *Kutahya-Yoncali* (0.3MW$_t$), *Dikili* (56MW$_t$), *Kutahya-Simav* (12MW$_t$), *Salihli* (47MW$_t$).

Feasibility studies are completed for the following systems which will be mostly used for space heating, air conditioning and domestic hot water supply: *Izmir* (168MW$_t$), *Aydin* (174MW$_t$), *Resadiye* (7.6MW$_t$), *Kozakli* (11MW$_t$), *Afyon* (107MW$_t$), *Kirsehir* (65MW$_t$), *Simav* (20MW$_t$), *Sakarya-Kuzulik* (11MW$_t$).

Summary of Resources	
Exploited - plant in operation	160MW$_t$
Unexploited - plant under construction or planned	685MW$_t$
Unexploited - proven resources	2,264MW$_t$
Unexploited - probable and possible resources	6,500MW$_t$

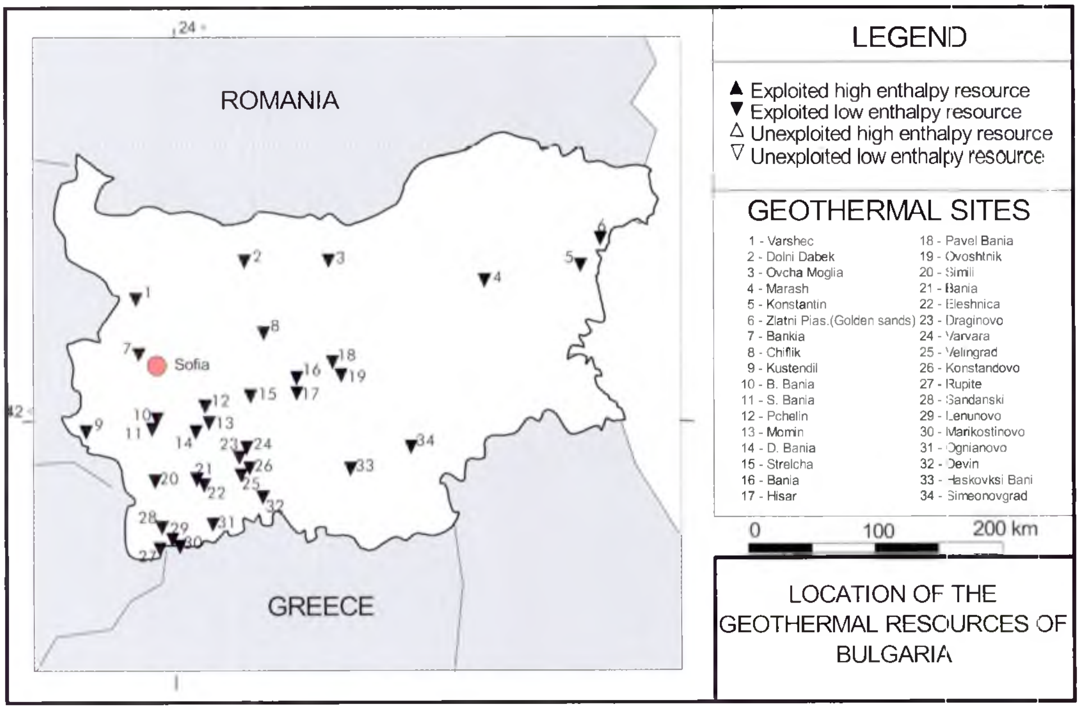
Annex 1.1

AGENDA 2000 Countries

Bulgaria
Czech Rep.
Estonia
Hungary
Latvia
Lithuania
Poland
Romania
Slovakia
Slovenia

BULGARIA

Size	110,912	km^2
Population (1995)	8.769	millions
Annual population growth rate (1985-95)	-0. 6	%
GNP per capita (1995)	1,330	USD per year
Average annual growth rate of GNP (1985-1995)	-2.2	%
Average annual inflation (1985-1995)	45.3	%
Annual energy use per capita (1994)oil equivalent	2,438	kg
Average annual growth rate of energy use (1992)	6.4	%
Annual CO_2 emission per capita (1992)		tonnes
Production of electricity (1994)	38,133	GWh
Geothermal	0	GWh
Fossil fuels	21,330	GWh
Hydro	1,468	GWh
Nuclear	15,335	GWh
Wind		GWh



Bulgaria is rich in low-enthalpy geothermal energy. About 1000 thermal aquifers and thermal springs have been discovered. The total dynamic resources of thermal and sub-thermal waters reach about 5100 l/s. The temperature of artesian thermal waters varies between 20°C - 100°C, 2/3 of which are within the 42°C - 50°C range. Water mineralisation in Bulgaria varies from 0.1 to 100g/l; in southern Bulgaria the thermal waters are of the nitrogenous type with less than 1g/l TDS.

The heat potential estimated for thermal waters discovered in Bulgaria amounts to 448MW$_t$, a third of which could be obtained by heat exchangers, while the remaining two thirds are produced by heat pumps. Waters with temperatures from 32°C to 42°C are not included, as according to the Bulgarian legislation, these waters are reserved for balneological use.

Electricity Generation

There is no electricity produced from geothermal resources in Bulgaria which is due to the low temperature of the geothermal water.

Direct Uses

Until 1980 thermal waters were used only for medical treatment needs in the big resort centres, swimming pools, for flax and hemp processing, derivative production, bottling, bathing, etc. Their complex utilisation both for heating and medical treatment was limited to only a few sites. The thermal waters were directly used for the heating of buildings and greenhouses.

After 1980 the number of spas increased to 70, and complex thermal utilisation was extended. The total capacity of the systems for direct geothermal energy uses in Bulgaria which are of simple design amounts to $62MW_t$, with one half being used for space heating and the other half for greenhouses.

After 1990 several simple systems for direct application were installed at two sites (*Dolna Bania* and *Maritza*). At present, for space heating only 20 % of the country`s $488MW_t$ heat capacity is used.

Within the same period no progress was observed in the geothermal water utilisation for balneological purposes, swimming pools and baths.

The mineral water consumption per capita doubled compared to 1985. A part of the natural mineral water production is exported.

The thermal water utilisation in Bulgaria is related mainly to balneological needs (15% of the total), space heating (9.4%) and greenhouses (4.9%), bottling of potable water and soft drinks (1.4%), swimming pools (4.5%), and some industrial uses (7.6%); the rest (49.5%) is labelled as free capacity, suggesting that the estimated full potential of $488MW_t$ is not utilised. The average duration of the heating season in Bulgaria is 180 days, so load factors are moderate and many systems have heating and ventilating capability.

The results of feasibility studies and estimations based on all the projects which have been conducted in Bulgaria show that the price of 1GJ of produced energy from geothermal resources is two to four times lower than from fossil fuels. The pay back period for the capital investments is 2.5-8 years. Drilling cost are not included in the analysis as all sites use existing wells.

The *Struma* rift valley (graben system) is one of the most interesting areas on the Balkan Peninsula and rich in thermal waters. The geothermal activity is manifested from nearly 100 natural and borehole thermal sources, and many temperature and hydrogeochemical anomalies produced from concealed thermal in the basement and in sedimentary successions within the grabens.

The hydrogeothermal activity of the *Struma* Valley is evident from 39 autonomous or conjugate deposits of thermal waters. Seventeen of them are still not exposed, although they have been identified from temperature and geochemical indicators. A significant number of unidentified sources occur in the granite-metamorphic basement and along the sides of grabens. Considerable studies are needed to outline and evaluate the stratified hydrogeothermal reservoirs within the Neogenic sedimentary successions of the *Sandanski* and *Serres* graben.

The total reproducible potential of the non-stratified (fault- and fracture-bound) deposits is estimated at 1450l/s of thermal waters with temperatures between 50°C and 115°C and a total thermal capacity of about $350MW_t$. At present, only 322l/s of thermal waters with temperatures from 21°C to 101°C and a total capacity of about $60MW_t$ have been quantified.

There are a number of basic problems with the use of thermal waters and thermal energy application in Bulgaria. These include:

Old equipment
Most of the existing production wells were drilled in the sixties have deteriorated. The organisations responsible for their maintenance, namely the Ministry of Health and the Municipalities do not have the funds required for their improvement. There are also cases of complete geothermal water loss due to technical reasons.

Laws and regulations in the country
In accordance with existing laws and regulations, the regimes of geothermal reservoir utilisation are determined by the Ministry of Health if the reservoirs are of national importance, and otherwise the Municipalities are responsible. This is determined by means of resolutions issued by the Council of Ministers, and not by special laws.

National energy policy
There is still no national policy for preferential pricing of products and materials, needed for the development of non traditional systems to provide economically efficient energy. High interest rates exist on credits for the construction of renewable energy systems.

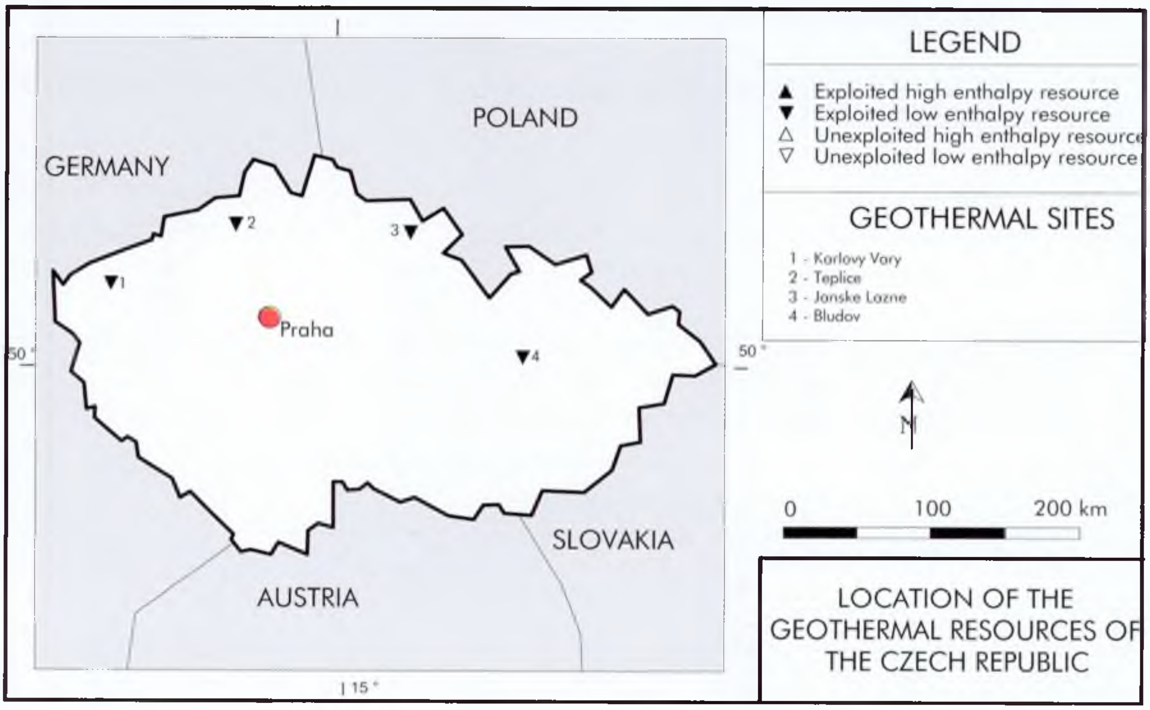
Land ownership
The economic and social changes in Bulgaria include restoration of private land ownership. Because legal claims are still pending there are many unsolved problems consequently, the process of greenhouse construction has practically stopped.

Fifteen wells have been drilled since 1990, ranging in depth from 300 to 2000m with 24 person-years of effort in 1994 and US$ 0.82M, of mainly public money, spent on geothermal research and development during the last 10 years.

Summary of Resources	
Exploited - plant in operation	$94.5MW_t$
Unexploited - plant under construction or planned	0
Unexploited - proven resources	$448MW_t$
Unexploited - probable and possible resources	$1800MW_t$

CZECH REPUBLIC

Size	78,864	km^2
Population (1995)	10.296	millions
Annual population growth rate (1985-95)	0	%
GNP per capita (1995)	3,870	USD per year
Average annual growth rate of GNP (1985-1995)	-1.8	%
Average annual inflation (1985-1995)	12.2	%
Annual energy use per capita (1994)oil equivalent	3,868	kg
Average annual growth rate of energy use (1992)		%
Annual CO_2 emission per capita (1992)	13.1	tonnes
Production of electricity (1994)	57,980	GWh
Geothermal	0	GWh
Fossil fuels	43,543	GWh
Hydro	1,460	GWh
Nuclear	12,977	GWh
Wind		Gwh



Due the complicated geological conditions in the Czech Republic the value of the heat resources has not been calculated. However, reasonable estimates have been made for three potential reservoirs: *Krušne Hory* foreland rift zone, *Bohemian* Cretaceous Basin, West *Carpathian* Foredeep which covered about 25 % of the overall territory.

The warmest and most important geothermal natural spring with a tradition that has been lasting for centuries is *Karlovy* Vary in the *Krušne Hory* foreland rift zone. Its temperature is 72°C, the total yield of 12 springs is 40 l/sec with total dissolved solids (TDS) of 6g/l. This mineral water is of the Na-HCO_3-SO_4-Cl-type. These springs rise on the crossing of a three-fault system: the transversal, north-south and west-east faults confining the *Krušne Hory* foreland rift zone.

Electricity Generation

Electricity is not generated from geothermal resources.

Direct Uses

The *Teplice* spa with its thermal springs is situated in the same rift structure. Thermal water circulates in the fractured system of carboniferous quartz porphyry. There are many small springs with differing temperatures. Actually the thermal water is captured in a deep well (900m), its yield is about 25 l/sec with a temperature of 42.0 to 45.8°C. The *Pravridlo* spring has a mineralisation of about 1g/l of the Na-HCO_3-type. Some of the small mineral springs are radioactive.

In the same tectonic structure, there are radioactive thermal springs in *Jachymov*, but their temperature is only 32°C. These thermal waters have accumulated in a 600m deep old silver and uranium mine.

The spa *Janske Lazne* with thermal springs of 18 to 32°C is on the S-W-E border of the *Krkonoše* granit massif.

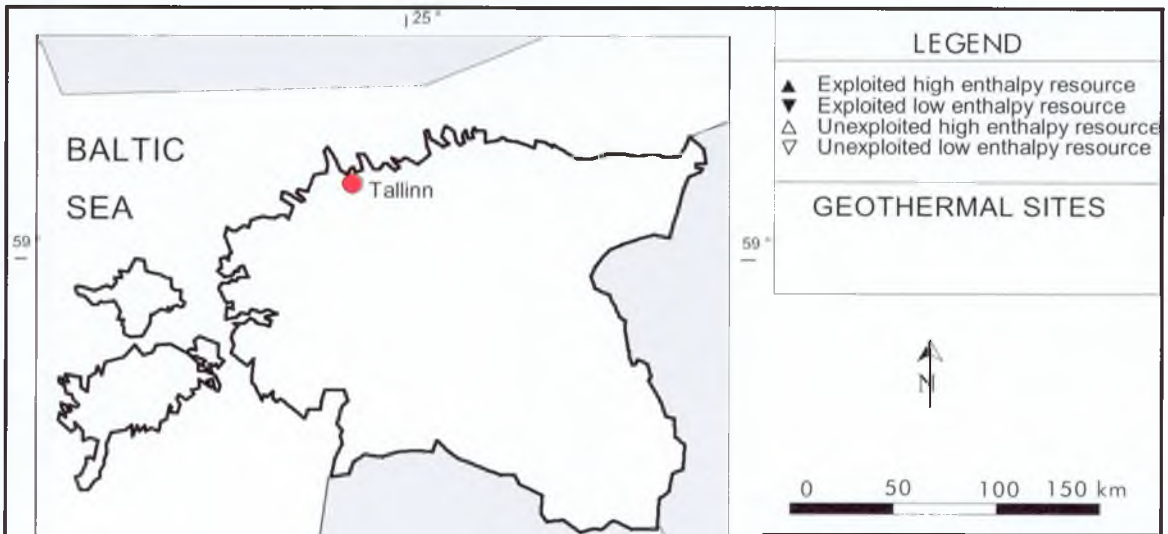
There are also several springs in *Moravia* such as: *Teplice* and *Becvou* (22.5°C, 16 l/sec yield), *Slatinice* (21°C, 10 l/sec yield), *Velke Losiny* 36°C, 15 l/sec yield) and *Bludov Lazne* (28°C, 7 l/sec yield).

The geothermal low-enthalpy heat is used for domestic and swimming pool heating, and for some small industries. More than 1,000 localities were assessed for use with heat pumps. About 100 heat pumps have been installed with a total heat capacity of 2MW.

Summary of Resources	
Exploited - plant in operation	2MWt
Unexploited - plant under construction or planned	
Unexploited - proven resources	
Unexploited - probable and possible resources	3,300MW_t

ESTONIA

Size	45,215	km^2
Population (1995)	1.530	millions
Annual population growth rate (1985-95)	-0.3	%
GNP per capita (1995)	2,860	USD per year
Average annual growth rate of GNP (1985-1995)	-4.3	%
Average annual inflation (1985-1995)	76.2	%
Annual energy use per capita (1994)oil equivalent	3,709	kg
Average annual growth rate of energy use (1992)		%
Annual CO_2 emission per capita (1992)	13.5	tonnes
Production of electricity (1994)	9,151	GWh
Geothermal	0	GWh
Fossil fuels	9,148	GWh
Hydro	3	GWh
Nuclear	0	GWh
Wind		GWh



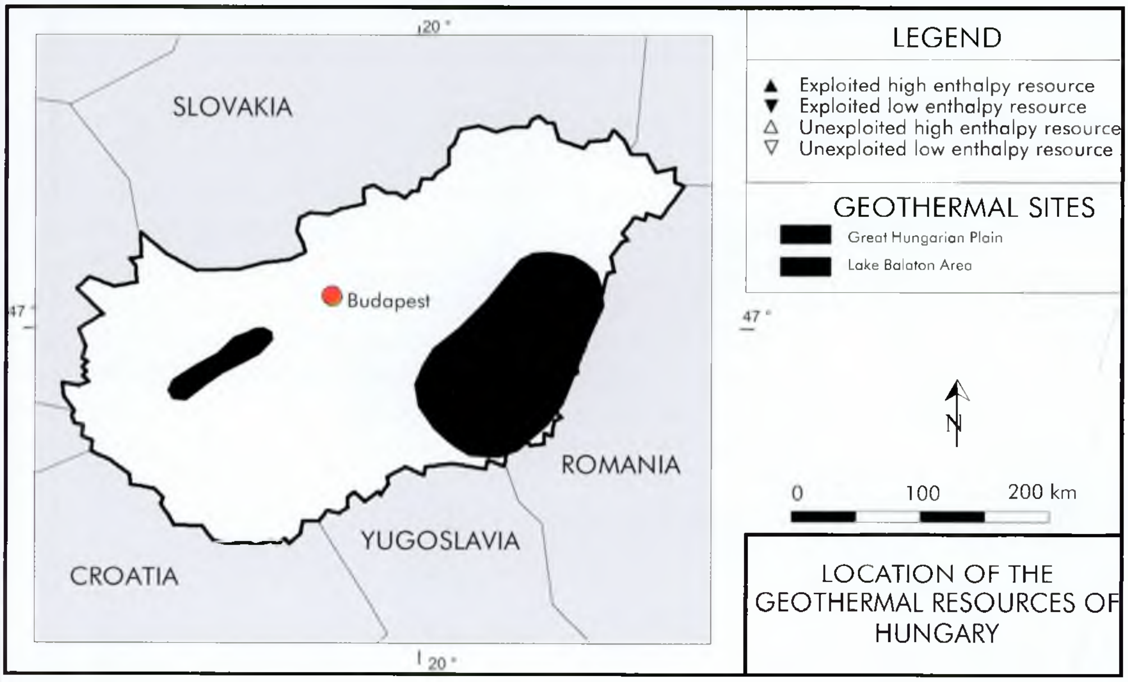
LOCATION OF THE GEOTHERMAL RESOURCES ESTONIA

Estonia is situated on the Northern Slope of the Baltic Shield which has been described as a relatively low heat flow area. The thickness of the Phanerozoic sedimentary rocks that cover the Early Proterozoic basement increases from 150m in the north to 600-700m in the south. The sedimentary cover is represented by Vendian, Cambrian, Ordovician, Silurian and Devonian sediments. Geothermally, the most interesting aquifers are in Cambrian and Vendian sandstones and siltstones. Due to comparatively low heat flow from the Precambrian basement, and the small thickness of sedimentary rocks, the groundwater temperatures in the Phanerozoic aquifers are below 15°C and do not represent useful geothermal resources in terms of typical geothermal aquifer techniques. However, these formations could well be used for producing geothermal energy for space heating with heat exchanger techniques. Potential targets can also be found in the basement for hot dry rock applications.

The limited thickness of the sedimentary cover and the relatively low heat flow density are responsible for the lack of geothermally useful aquifers. For HDR technique, northeastern Estonia is the most potential area and temperatures of 30°C can be expected at depths of about 1km. The origin of increased heat flow density in the area is not yet well understood. Since there is no thermally important regional groundwater flow, the anomaly can be more likely attributed to crustal heat sources in the basement.

HUNGARY

Size	93,032	km^2
Population (1995)	10.115	millions
Annual population growth rate (1985-95)	- 0.3	%
GNP per capita (1995)	4,120	USD per year
Average annual growth rate of GNP (1985-1995)	-1.0	%
Average annual inflation (1985-1995)	19.9	%
Annual energy use per capita (1994)oil equivalent	2,383	kg
Average annual growth rate of energy use (1992)		%
Annual CO_2 emission per capita (1992)	5.8	tonnes
Production of electricity (1994)	33,302	GWh
Geothermal	0	GWh
Fossil fuels	19,092	GWh
Hydro	161	GWh
Nuclear	14,049	GWh
Wind		GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF HUNGARY

Hungary has one of the largest geothermal energy potentials for low and medium enthalpy in Europe. As a consequence of the abnormally thin lithosphere the heat flux of 80-100mW/m^2 is above the average for the continent and the mean geothermal gradient of 20°C/Km is steeper than the normal 30-33°C/Km value.
The highest surface temperature of low enthalpy thermal waters is 97°C and geothermal brine from geopressured reservoirs 171°C, the highest aquifer temperature registered 140°C and 220°C, respectively.
The utilisation of geothermal energy in Hungary has to be in harmony with a wide range of demands for supplies of thermal water, protection of hydrological reserves and the requirements for environmental protection. The utilisation of geothermal energy in Hungary could be profitable in cases of multistage utilisation using an energy-cascading system, with electric power generation for direct use. There is also an increase in the efficiency of heat conversion from abandoned hydrocarbons wells.

Most of the thermal water resources occur in the Upper Pannonian as high temperature water-dominated systems which consists of sand and sandstone and to a minor extent clays and silts.

In the basement of Great Hungarian Plain, geopressured reservoirs have been found. These systems are characterised by high reservoir dissolved natural gas (3 to 12 grams per litre in liquid phases).

Electricity Generation

The is no electricity generated from geothermal resources.

Direct Uses

The former and present conditions of domestic thermal water utilisation, show that the greatest demand for geothermal energy are direct heat and balneology

Balneological applications are seasonal covering up to 180 days per year. Hot water for direct heat applications is not recirculated but discharged to surface water reservoirs. Heat pumps have not be used in Hungary to increase utilisation efficiency.

The number of active thermal wells reported (1995) was 810, with 342 closed wells as at 31 December 1993, i.e. a total of 1152. A total of 1045 were reported in 1990, 138 of which were closed (1995). The current extraction rate is 6032kg/s (9533kg/s in 1990), nearly half of which has a temperature in the range 30-40°C. The drinking water supply utilises 29.9 % of the total, balneology 27.3 %, agriculture 26 %, and space heating 1.3 %, with typical load factors of 0.5 for space heating of buildings, 0.4 for greenhouses and 0.4 for hot water supply. Thermal water production in recent years has declined from 493 Mm^3/yr in 1989 to 190 Mm^3/yr in 1993. Geothermal energy accounts for 0.25% of the total energy consumption of Hungary but only one system was commissioned in the period 1990-1994. Since 1990 there have been no funds injected into geothermal developments.
To date, total installed thermal power amounts to 750MW.

Summary of Resources	
Exploited - plant in operation	750MWt
Unexploited - plant under construction or planned	
Unexploited - proven resources	200 MWt
Unexploited - probable and possible resources	[1]

[1] Resources unexploited (probable and possible) amount to 380million m^3/a

LATVIA

Size	64,589	km^2
Population (1995)	2.490	millions
Annual population growth rate (1985-95)	-0.4	%
GNP per capita (1995)	2,270	USD per year
Average annual growth rate of GNP (1985-1995)	-6.6	%
Average annual inflation (1985-1995)	73.2	%
Annual energy use per capita (1994)oil equivalent	1,569	kg
Average annual growth rate of energy use (1992)		%
Annual CO_2 emission per capita (1992)	5.6	tonnes
Production of electricity (1994)	4,440	GWh
Geothermal	0	GWh
Fossil fuels	1,135	GWh
Hydro	3,305	GWh
Nuclear	0	GWh
Wind	0.02	GWh

Geothermal aquifer zones of primary interest are in the Middle Cambrian Deimena Formation (Cm_2 dm) and in the Lower Devonian Kemeri Formation (D_1km).
The Devonian aquifers lie in a depth of 400 - 1100m, the Cambrian aquifers lie at a depth between 960 - 2000m. In comparison with the Devonian aquifers the Cambrian aquifers have attracted interest for geothermal energy use, because the average temperature in the Devonian layer is only 24 - 28°C .

Geothermal heat-in-place

Parameter	Lower Devonian D_1km	Cambrian Cm_2 dm
Geothermal area 25°C,km^2	1,000	12,000
Gross aquifer rock volume, 10^{9m3}	150	1,260
Net aquifer rock volume, 10^{9m3}	99	604
Water volume, 10^{9m3}	22	85
Average aquifer temperature,°C	24	44
Technical heat resource, 10^{18} J	5.4	46.4
Economic heat resource, 10^{18} J	3.4	35.4

Lower Devonian:
Position of depth: 400 to 1100m
Thickness: 90-175m
Reservoir rocks are sandstones and siltstones
Reservoir temperature up to 30°C
Thermal water mineralisation up to 40g/l (Na, CL, Mg, Cl)

Cambrian:
Position of depth: 960 to 2000m
Reservoir rocks are sandstones and siltstones
Thickness ranging from 40 to 90m
Storage temperature up to 55°C
Thermal water mineralisation 100-130g/l (Na, CL, Mg, Cl)

Present state of work:
Regional geological assessment
Pre- and feasibility studies at different sites (e.g., *Liepaja*, *Dobele*, *Eleja*, *Jelgawa*)

Electricity Generation

There is no electricity generated from geothermal resources.

Direct Uses

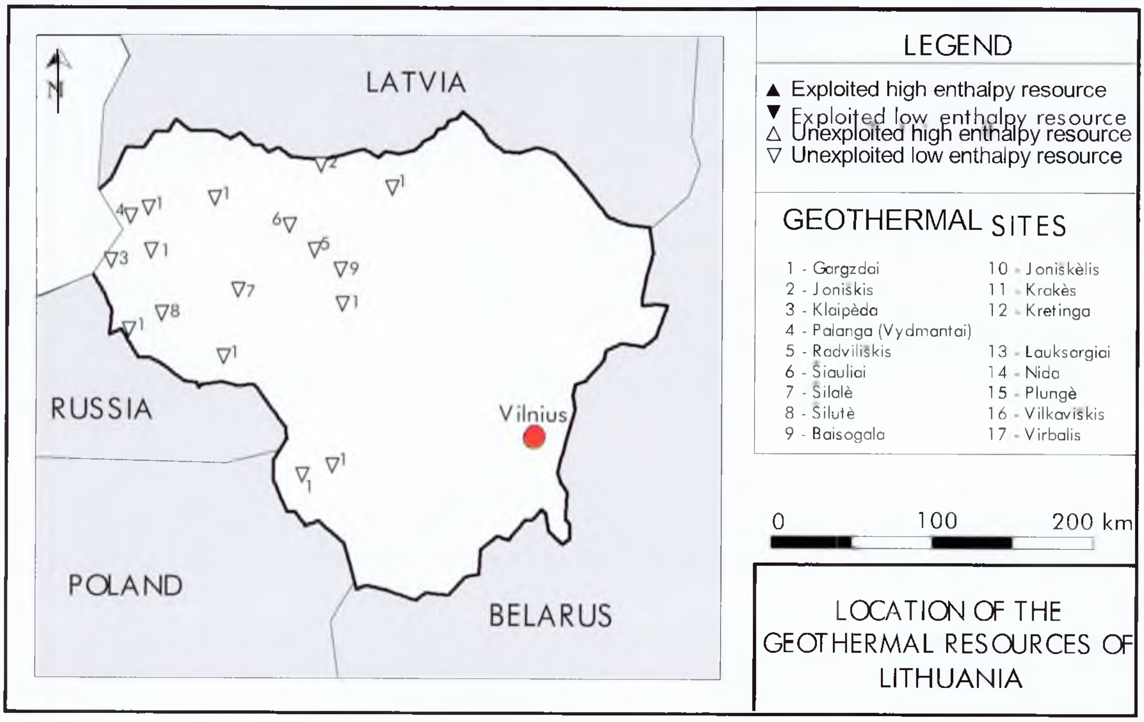
Evaluations compiled so far show that there are good geological, technical, economic and political conditions for the installation of a geothermal heating plant for municipal heat supply in Latvia. Preferred locations are *Dobele* and *Liepaja*.
Moreover, spas and recreational resorts and tourism could develop along the coast of the Baltic Sea (*Kurland*) to a major extent. Thermal waters could be used for balneological purposes and thermal swimming pools to stimulated tourism along the Baltic coast. More possible fields of application are fish-breeding and agriculture.

Summary of Resources	
Exploited - plant in operation	0
Unexploited - plant under construction or planned	16MW$_t$
Unexploited - proven resources	
Unexploited - probable and possible resources	[2]

[2]Resources unexploited (probable and possible) amount to $51.8 \cdot 10^{18}$ J

LITHUANIA

Size	65,300	km^2
Population (1995)	3.715	millions
Annual population growth rate (1985-95)	0.5	%
GNP per capita (1995)	1,900	USD per year
Average annual growth rate of GNP (1985-1995)	-11.7	%
Average annual inflation (1985-1995)	151.0	%
Annual energy use per capita (1994)oil equivalent	2,030	kg
Average annual growth rate of energy use (1992)		%
Annual CO_2 emission per capita (1992)	5.9	tonnes
Production of electricity (1994)	10,055	GWh
Geothermal	0	GWh
Fossil fuels	1,633	GWh
Hydro	716	GWh
Nuclear	7,706	GWh
Wind		GWh



Lithuania is located at the western margin of the East European fore-reef platform which is characterised by a high geothermal potential. Optimum conditions for the utilisation of geothermal energy exist in the western regions of Lithuania in the coastal area of the Baltic Sea. In West Lithuania maximum values of the geothermal gradient exceed 4 K per 100m, and heat flow density reaches 108mW/m^2.
In the geothermally optimum area of the West Lithuanian Geothermal Field (anomaly), several cities and towns (*Klaipeda*, *Palanga*, Plunge, *Gargzdai*, *Nida*, Š*ilute*, Šilale) and numerous settlements are situated.

In West Lithuania hot ground water can be used for municipal heating systems from three hydrothermal complexes: Upper and Middle Devonian, Middle and Lower Devonian, and Cambrian. These complexes are separated from each other by practically impermeable aquicludes and make up independent, hydraulically separate aquifers. Moreover, heat can be extracted from hot dry rocks of the crystalline basement.

Geothermal potential:
Upper/Middle Devonian - 36.45 million t of CF (conventional fuel) covering an area of $13284km^2$
Middle/Lower Devonian - 120.1 million t of CF covering an area of $22626km^2$
Cambrian - 122.2 million t of CF covering an area of $42444km^2$
Crystalline - $298 \cdot 10^3$ million t of CF covering an area of $65200km^2$

Upper/Middle Devonian - thermal water complex:
Position of depth: 100 to 600m dipping SW
Overall thickness: 170-200m
Reservoir rocks are aleurites and sandstones
Reservoir thickness ranging from 1 to 25m - inter-stratified by impermeable beds
Reservoir temperature up to 30°C
Thermal water flow from the wells partly artesian
Thermal water mineralisation 15-35g/l (Na, CL, Mg, Cl)

Middle/Upper Devonian - thermal water complex
Position of depth ranging from 200 to 900m, dipping SW
Overall thickness 200-300m
Reservoir rocks are sandstones inter-stratified by schluff, clayey stones
Reservoir thickness 14m - inter-stratified by impermeable beds
Permeability in the reservoir often exceeding 1000mD
Reservoir temperature up to 50°C
Thermal water mineralisation up to 85g/l (Na, CL, Cl)

Cambrian - thermal water complex
Position of depth ranging from 600 to 2100m dipping SW
Overall thickness 40 to 170m
Reservoir rocks are sandstones with schluff and argillites
Reservoir thickness 13 to 67m
Porosity 6.5 to 19 %
Reservoir temperature up to 90°C
Thermal water mineralisation up to 200g/l (Na, CL, Mg, Cl)

Electricity Generation

There is no electricity generated from geothermal resources.

Direct Uses

So far, direct uses are being developed:
Regional geological assessment
2 geothermal wells (1991/1993) were drilled for the installation of a geothermal loop (*Vidmantai*)
Preliminary investigations and feasibility studies into geothermal heat supply systems at different sites (*Vidmantai*, *Klaipeda*, *Palanga*, *Vilkaviškis*, *Šilute* etc.)
Investigations concerning the utilisation of the thermal water for balneological purposes (*Vilkaviškis*)
The construction of the *Klaipeda* geothermal heating station funded by the World Bank is in its initial stage (January 1997).

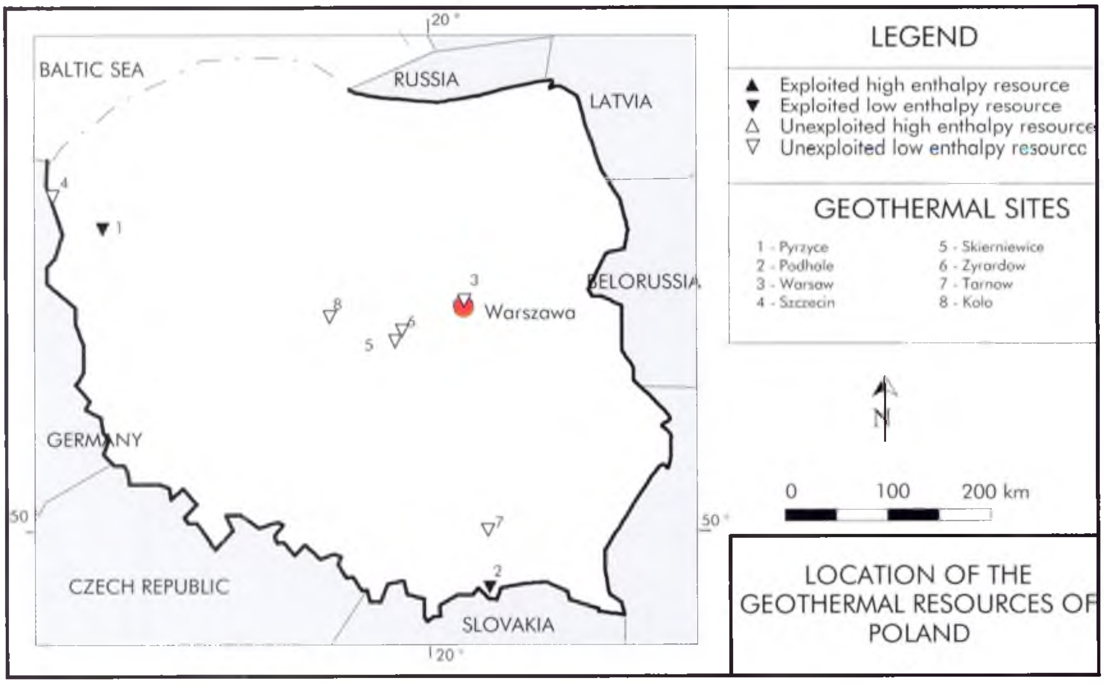
At present, funds are being raised for a balneological-geothermal project at the site of *Vilkaviškis*. Within the framework of a research project into the usability of dual-porosity reservoirs, the two existing geothermal wells shall be used in a circulation system at the site of *Vidmantai*.

Summary of Resources	
Exploited - plant in operation	n.a.
Unexploited - plant under construction or planned	$70MW_t$
Unexploited - proven resources	
Unexploited - probable and possible resources	[3]

[3] Resources unexploited (probable and possible) amount to $8.19 \cdot 10^{18}$ J

POLAND

Size	323,250	km^2
Population	38.388	millions
Annual population growth rate (1985-95)	0.4	%
GNP per capita (1995)	2,790	USD per year
Average annual growth rate of GNP (1985-1995)	-0.4	%
Average annual inflation (1985-1995)	91.8	%
Annual energy use per capita (1994)oil equivalent	2,401	kg
Average annual growth rate of energy use (1992)		%
Annual CO_2 emission per capita (1992)	8.9	tonnes
Production of electricity (1994)	132,940	GWh
Geothermal	0	GWh
Fossil fuels	131,207	GWh
Hydro	1,733	GWh
Nuclear	0	GWh
Wind		GWh



Geothermal waters for balneology purposes have been known and utilised since historical times. The interest in the geothermal water utilisation for heating purposes started in the 1980's. A series of investigations haven been carried out since that time. The estimation of resources and reserves shows that Poland has one of the largest potentials of geothermal energy in Central Europe.

It is estimated that the recoverable geothermal energy resources amount to over $30x10^9$ toe and water temperature is from 35 to 130°C at 1000-3000m depth.

On the basis of data obtained during oil and gas exploration, the following geothermal provinces in Polish territory were distinguished:

Carpathian Province with an area of 13,000km^2
Fore-Carpathian Province with an area of 16,000km^2
Lowland Province (Central European) with an area of 222,000km^2
Sudetic-Swietokrzyski Province with an area of 61,000km^2.

Data analyses from wells located in the geothermal regions allow the estimation of geothermal energy resources:

Carpathian Province
Geothermal water occurs in the Miocene and Cretaceous. Five sub-basins exist, the most important is the *Podhale* sub-basin. This sub-basin has an area of about $475km^2$ and contains geothermal waters with temperatures from 35 to 86°C, they have artesian pressure and a very low mineralisation. The 16 wells are in existence reaching the levels of geothermal waters. Most of these wells are located in the *Tatra* zone and only *Banska* IG-1, *Bialy Dunajec*, *Chocholow* are situated in the deeper zone of the sub-basin.
The experimental geothermal plant in Poland was built in *Banska-Bialy Dunajec* in 1987-1990. After a three-year trial exploitation period it was used in a geothermal heating network for *Banska Nizna* and *Bialy Dunajec*.

Fore-Carpathian Province
Geothermal waters can be found and used from specific tectonic units within the Carpathian Mts. The productivity of wells in the units of the Outer Carpathians ranges from several to tens of m^3/h. More favourable conditions have been found in the *Wisniowa* 1 well, where the self-flow of a brine with the mineralisation of about $10_{g}/dm^3$ and the productivity of $60m^3/h$ were received from the Polonica layer in the Skolska unit.
In the Carpathian Foreland, geothermal waters occur in the Palaeozoic and Mesozoic formations of the *Miechow* Basin which are covered by the Miocene formations. The rocks of this basin contain geothermal waters with mineralisation of several$_{g}/dm^3$ and with the temperatures from 35 to 100°C. The productivity reaches tens of m^3/h.

Lowland Province
Geothermal water resources occur mainly in *Grudziadz-Warsaw* and *Szczecin-Lodz* sub-basins.

Grudziadz-Warsaw sub-basin
The artesian and sub-artesian thermal waters occurred in Cretaceous and Jurassic reservoirs.
The following projects of geothermal water utilisation for heating purposes have been elaborated for the Central area of *Grudziadz-Warsaw* sub-basin:
Skierniewice where the project of drillings has been prepared and the *Skierniewice* GT-1 well was constructed in the vicinity of the greenhouse and the district heating network. In this well geothermal waters have been found in the Liassic formations. They have the temperatures of about 65°C and productivities from 70 to $170m^3/h$.
Zyrardow where geothermal water utilization for heating purposes has been designed. Geothermal waters under *Zyrardow* exist at about 2800m depth in the Liassic formations. Their temperature ranges from 65 to 70°C.
Mszczonow, this town is located about 25km to the east from *Zyrardow*. There exist two exploratory wells: *Mszczonow* 1 and *Mszczonow* 2. Geothermal waters were found in the Lower Cretaceous, Malmian, Dogger and Lias formation.
For the *Praga-Poludnie* district which is located in the south-east part of *Warsaw*, the preliminary project of the geothermal waters utilisation has been evalutated. Geothermal energy resources were found in the Lower Cretaceous, Jurassic, Triassic and Lower Palaeozoic formation.

Central area of Mogilno-Lodz sub-basin
The following projects of geothermal water utilisation for heating purposes were tested in the central and northern part of the *Mogilno-Lodz* sub-basin:

Kolo. In the wells of Kolo IG-3, *Przybylow* 1, *Ponetow* 1, geothermal waters were found in the Lower Cretaceous, Malmian and Dogger formations. Geothermal waters with a low mineralisation (6.5-9.1$_{g}$/dm^{3}) exist in the Albian Lower Cretaceous formations. They have a temperature of about 60°C. Waters with a temperature of 74°C and mineralisation of 113.5$_{g}$/dm^{3} exist in Malmian formations at a depth of 2250m.
Gnienzo. The preliminary project of geothermal water utilisation was prepared on the basis of the wells *Myslecin* 1, *Waliszewo* 1, *Trzemzal* 2. In the *Gniezno* region there is a very favourable geothermal gradient. It is possible to receive geothermal water with temperatures from 60 to 80°C from the rocks of Dogger and Liassic formations at a depth from 1500 to 2000m.
Uniejow. The Institute of Energetic resources of the Academy of Mining and Metallurgy and the National Geological Institute in *Warsaw* initiated a project which included drilling programme in the *Uniejow* region. However results from the research across the whole area of the Polish Lowland have not led to further development because of the lack of investors and financial funds.
Western part of Szczecin-Wagrowiec sub-basin
The following preliminary project of geothermal water utilization for energetic purposes were elaborated for the western part of the *Szczecin-Wagrowiec* sub-basin:
Pyrzyce. The construction of the geothermal heating plant in *Pyrzyce* was started in 1992. Two doublets of wells were drilled in 1993 (1700m depth). The two doublets supply about 360m^{3}/h of geothermal water with a temperature of about 65°C and a mineralisation of 120g/l. The peak capacity of the geothermal plant is about 55 Mw$_{t}$.
Stargard Szczecinski. It is planned to establish a geothermal heating plant on the basis of the high water temperatures in the Jurassic (Liassic) reservoirs which have good properties in a porous sandstone horizon (100°C at 2500m depth).
Szczecin. The Formation temperatures at a depth from 1600 to 2200 range from 65 to 85°C.

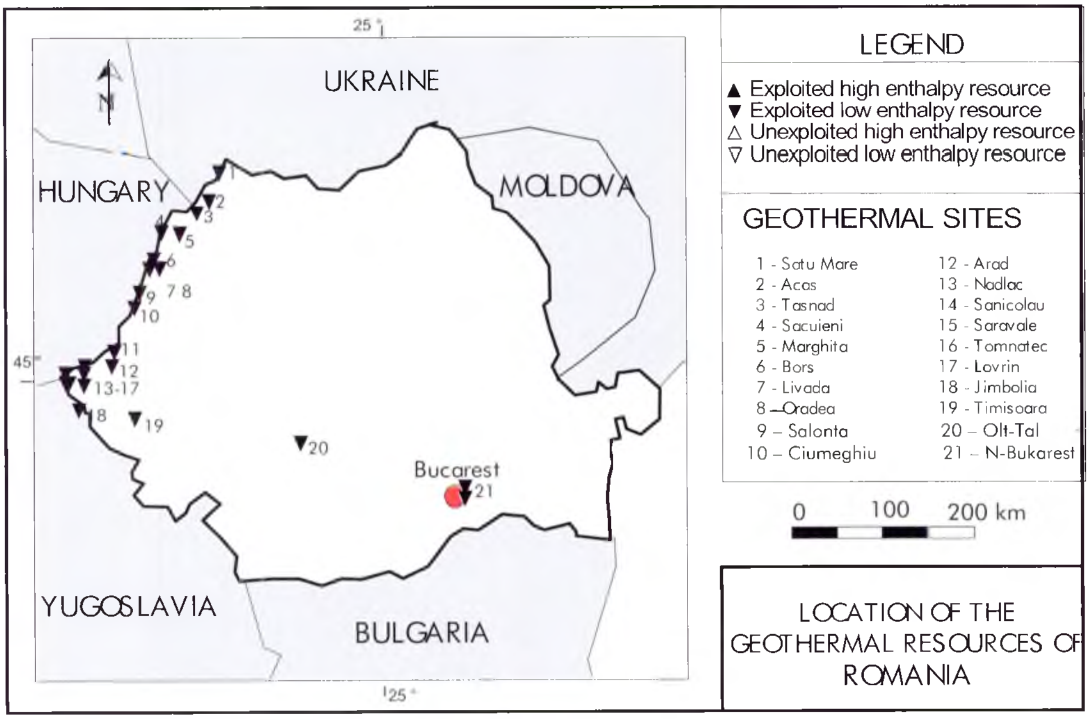
Sudetic-Swietokrzyski Province
In the Sudety Mountains geothermal waters have been exploited since the 10th century. At present, exploratory works to utilise geothermal waters for heating purposes in *Ladek Zdroj* and *Cieplice* regions have been performed. The Fore-Sudetes contains the North-Sudetes Basin, Zar Pericline, Fore-Sudets Monocline and the Fore-Sudetes Block. Geothermal waters with low and moderate temperatures occur in the Triassic formations in the North-Sudetes Basin, Zar Pericline, a southern part of the Fore-sudetes Monocline and the *Opole* region. No projects to utilise geothermal water have proceeded.

Summary of Resources	
Exploited - plant in operation	$44MW_t$
Unexploited - plant under construction or planned	
Unexploited - proven resources	
Unexploited - probable and possible resources	[4]

[4]Resources unexploited (probable and possible) amount to $30 \cdot 10^9$ toe

ROMANIA

Size	238,391	km^2
Population (1995)	22.835	millions
Annual population growth rate (1985-95)	0	%
GNP per capita (1995)	1,480	USD per year
Average annual growth rate of GNP (1985-1995)	-4.0	%
Average annual inflation (1985-1995)	69.1	%
Annual energy use per capita (1994)oil equivalent	1,733	kg
Average annual growth rate of energy use (1992)		%
Annual CO_2 emission per capita (1992)	5.4	tonnes
Production of electricity (1995)	55,136	GWh
Geothermal	0	GWh
Fossil fuels	42,090	GWh
Hydro	13,046	GWh
Nuclear	0	GWh
Wind		GWh



The exploration and research for geothermal resources began in Romania in 1962-1965. The first geothermal wells were drilled in the Western Plain (*Oradea*, *Felix*, *Calacea* and *Timisoara* areas). At present over 200 wells have been drilled which show the presence of geothermal resources. The drilling of most of these wells was funded by the Romanian government as part of the Geological Research Program. The completion and experimental exploitation of over 100 wells in the past 15 years had enabled exploitable heat resources from geothermal reservoirs to be evaluated. The proven reserves (with already drilled wells and exploited by downhole pumps) are about 200,000TJ for 20 years.

The total installed capacity of the existing wells for energetic uses is 320MW_t (for a reference temperature of 30°C). At present, only 137MW_t are used from 60 wells that produced hot water in the temperature range of 55 to 115°C. The annual energy utilisation from these wells was about 1,900TJ (45,000 toe), with a load factor of 63 % in 1994. More than 80 % of the wells are discharged in artesian flow and 18 wells require anti-scaling chemical inhibition.

Electricity Generation
There is no electricity generated from geothermal resources.

Direct Uses
The main energetic uses of geothermal energy are:
- space heating and hot water preparation for domestic use 53%
- greenhouse heating 34%
- industrial process heat (wood drying, milk pasteurisation, flax and hemp processing) 11%
- fish farming 2%.
- The total number of wells drilled is 122 but only 61 are active. Depth range between 0.8 and 3.2km (average 2.2km). Wellhead temperature is in the 50-115°C range.

About 30 wells are used for balneological and recreational purposes. The total flow rate from these wells is over 360l/s and the water temperatures are in the range of 35 to 65°C. In 1993, the average flow rate was 275l/s, with an annual utilisation of 870TJ. Geothermal water is currently used in 16 thermal spas that have a treatment capacity of over 550,000 people per year. Geothermal water is also used in 24 open pools and 7 indoor swimming pools. In 1993, the total energy savings in balneology was about 21,000toe.
The main geothermal systems discovered on the Romanian territory are found in porous permeable formations such as sandstones and Pannonian siltstones, interbedded with clays and shales specific for the Western Plain and Senonian specific for the Olt Valley or in carbonate formations of Triassic age in the basement of the Pannonian Basin and of Malm-Aptian age in the Moesian Platform.

The Pannonian geothermal aquifer is multilayered, confined and located in the sandstones at the basement of the Upper Pannonian on an area of approximately 2500km^2 along the western border of Romania from *Satu Mare* in the north to *Timisoara* and *Jimblia* in the south. The aquifer is situated at a depth of 800 to 2100m. The thermal gradient is 45-55 °C/km. The water temperature at surface varies between 50 to 85°C. The mineralisation of the geothermal waters is 4-5g/l (sodium-bicarbonate-chloride type) and most of the waters show carbonate scaling.

The *Oradea* geothermal reservoir is located in the Triassic limestone and dolomites at depths of 2200-3200m on an area of about 75km^2 and is exploited by 12 wells with a total flow rate of 140l/s geothermal water with temperatures at the well head of 70-105°C. There are no dissolved gases and the mineralisation is lower then 0.9-1.2g/l. Both aquifers, the Triassic aquifer *Oradea* and the Cretaceous aquifer *Felix* spa, are hydrodynamically connected and are part of the active natural circuit of water. Although there is a significant recharge of the geothermal system, the exploitation with a total flow rate of 300 l/s generates pressure draw down in the system, that is prevented by reinjection. Reinjection is the result of successful completion and beginning the operation with the first doublet in the *Nafural* district in *Oradea* city, in October 1992. At present, the total installed capacity is over 30MW$_t$ but by changing the exploitation, the downhole pumping and reinjection by operating 4 more doublets, the capacity could be doubled. The *Felix* spa reservoir is currently exploited by 6 wells, with depth between 50 and 450m. The total flow rate available from these wells is 210 l/s. The geothermal water has a well head temperature of 36-48°C and is potable.

The *Bors* geothermal reservoir is situated about 6km north-west of *Oradea*. The geological framework is completely different from the *Oradea* geothermal reservoir although the reservoir is in the same fissured carbonate formations. This is a tectonic closed aquifer with a small surface area of 12km^2. The thermal water has a mineralisation of 13g/l. The dissolved gasses are 70% CO_2 and 30% CH_4. The reservoir temperature is higher than 130°C at the average depth at 2500m. The artesian production of the wells can be maintained only by reinjecting the whole amount of extracted geothermal water. At present, 3 wells are exploited, with a total flow rate of 50l/s and 2 other wells are used for reinjection, at a pressure that does not exceed 6 bar. The geothermal water is used for the heating of 6 ha of greenhouses.

The *Ciumeghiu* geothermal reservoir is located in the Western Plain, south of *Oradea*. Geothermal water is produced by artesian flow with a well head temperature of 105°C and a mineralisation of 5-6g/l with strong carbonate scaling. The reservoir was investigated by 4 wells, but only one is currently in use, with a capacity of 5MW$_t$ (1MW$_t$ from gasses).

The *Otopeni* geothermal reservoir is located north to *Bucharest*. It is only partially delimited (about 300km^2). The 12 wells that were drilled show a huge aquifer located in fissured limestone and dolomites. The aquifer, situated at a depth of 1900-2600m. belongs to the Moesic Platform. The geothermal water has temperatures of 58-72°C and a mineralisation of 1.5-2.2g/l, with a high content of H_2S (over 25ppm). The production is carried out using downhole pumps, because the water level is at 80m below the surface. The total flow rate is 25-30l/s. At present, there are only 3 wells in production (5MW$_t$) for heating 1900 dwellings (annual savings 1900toe) and 2 wells are used for reinjection.

The *Cozia-Calimanesti* geothermal reservoir *(Olt* Valley*)* produces artesian geothermal water, with a flow rate of 20-25 l/s and well head pressure of 16-20 bar, from fissured siltstones of Senonian age. The reservoir depth is 1900-2200m, the well head temperature is 90-95°C, the water mineralisation is 14g/l. The gas water ratio (GWR) is 2Nm^3/m^3 (90% methane). Although the reservoir has been exploited for over 10 years, there is no interference between the wells and no pressure draw down. The thermal potential that is possible to be achieved from 3 wells is 18MW$_t$ (3.5MW$_t$ from gas), but at present, only 8MW$_t$ is used. The utilisation is mainly for space heating, but also for balneology and recreational purposes.

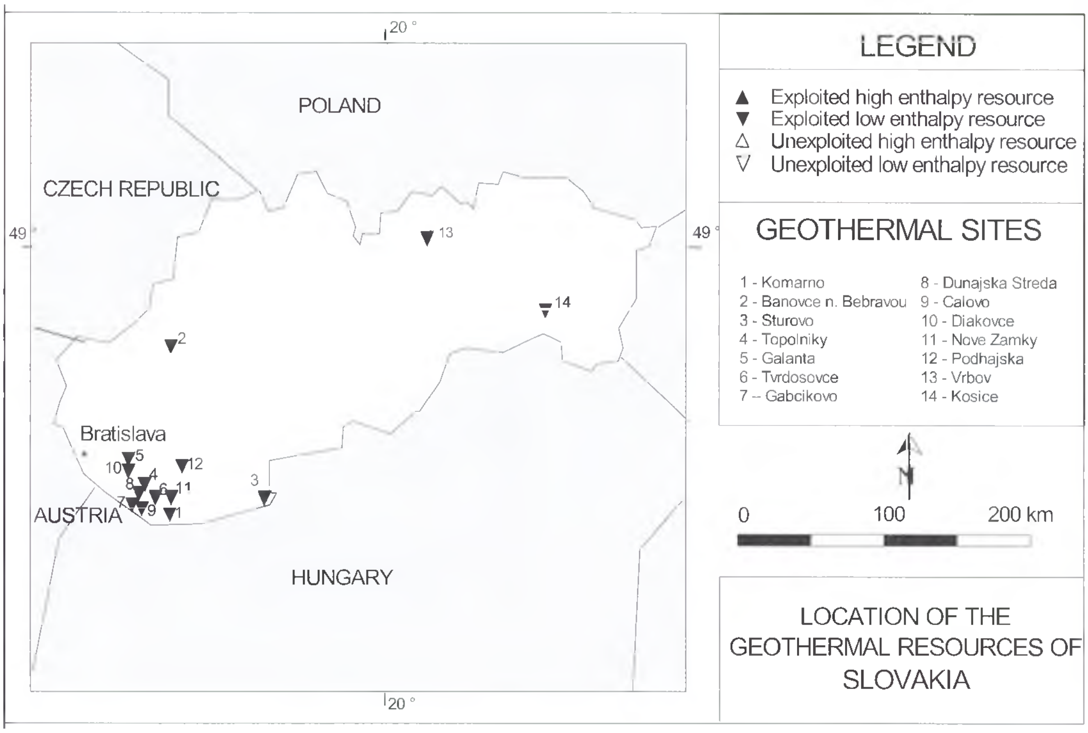
The main parameters of Romanian geothermal systems:

A number of new projects are underway. New wells are being drilled in the *Santandrei* area where it is hoped that the temperatures will be sufficiently high to supply fluid to ORC generators for electricity, at *Olanesti* it is expected that an artesian flow rate of 200m^3/h at a temperature of about 90-92°C will provide heating for a hotel complex, and north of Bucharest a doublet giving 80-85°C will provide heat to tourist dwellings. Investment in geothermal energy over the past two decades was US$ 259M with US$ 60M being spent in the last 10 years, all from public funds. Currently 27 professional person-years of effort have been allocated to these projects.

Summary of Resources	
Exploited - plant in operation	137MW$_t$
Unexploited - plant under construction or planned	
Unexploited - proven resources	320MW$_t$
Unexploited - probable and possible resources	

SLOVAKIA

Size:	49,012	km^2
Population (1995):	5.353	million
Annual population growth rate (1985-1995):	0.3	%
GNP per capita (1995):	2,950	USD
Average annual growth rate of GNP (1985-1995):	- 2.6	%
Average annual inflation (1985-1995):		
Annual energy use per capita (1994)oil equivalent	3,243	kg
Average annual growth rate of energy use (199)		
Annual $C0_2$ emissions per capita:	7.0	t
Production of electricity (1993)	24,740	GWh
Geothermal		
Fossil fuels	8,000	GWh
Hydro	4,601	GWh
Nuclear (1993)	12,139	GWh
Wind		



The geological structure of the West Carpathians in Slovakia and favourable geothermal conditions create a suitable setting for the occurrence of geothermal energy sources. The distribution of aquifers with geothermal waters and the thermal manifestation of geothermal fields in Slovakia have made it possible to define 26 prospective areas and structures with potentially exploitable geothermal energy sources. These include mainly Tertiary and intramontane depressions situated in the Inner West Carpathians (south of the Klippen Belt). The 26 defined prospective areas cover 27% of Slovakia´s territory.

The temperature and heat flow density of geothermal fields are highly variable. At a depth of 1000m, temperature range from 20°C (Komarno high block) to more than 70°C (Eastern Slovakian basin, in which the most important parts are the Kosice basin, the Humensky chrbat Mts. and the Besa-Cicarovce structure). The geothermal gradient in the Inner West Carpathians (0-1000m) averages 37°C/km (Eastern Slovakian basin 40-60°C/km), so the heat flow density varies from $50mW/m^2$ (Vienna basin) to $120mW/m^2$ (Eastern Slovakian basin). The highest temperatures, geothermal gradient and heat flow

density indicate that, with regard to the geothermal properties, the Eastern Slovakian basin is the most active region in Slovakia.
Geothermal energy is related to geothermal waters which largely occur in Triassic dolomites and limestones of Inner Carpathian nappes and, to a lesser extend, in Neogene sands, sandstones and conglomerates (Central depression, Horne Strhare - Trenc graben, Dubnik depression) or in Neogene andesites and related pyroclastics (Besa-Cicarovce). These aquifers lie at depths of 200-5000 m (except in spring areas) and the temperatures range from 20 to 240°C.

In 1971-1994 a total of 61 geothermal wells were drilled (only 4 of theme were unsuccessful) which verified 900 l/s of waters whose temperatures varies from 20 to 92°C. Thermal capacity of these thermal waters amounts to some 184MW$_t$ (water temperature will be reduced to 15°C during exploitation).

The most promising geothermal area is the Kosice basin, where medium- and high-temperature sources of geothermal energy suitable for electricity generation (25-30MW$_e$) can be captured. At a depth of 2500-3000m there are waters at 115-165°C.

Electricity Generation

At present, there is no electricity generated from geothermal resources, but it will be possible in the future.

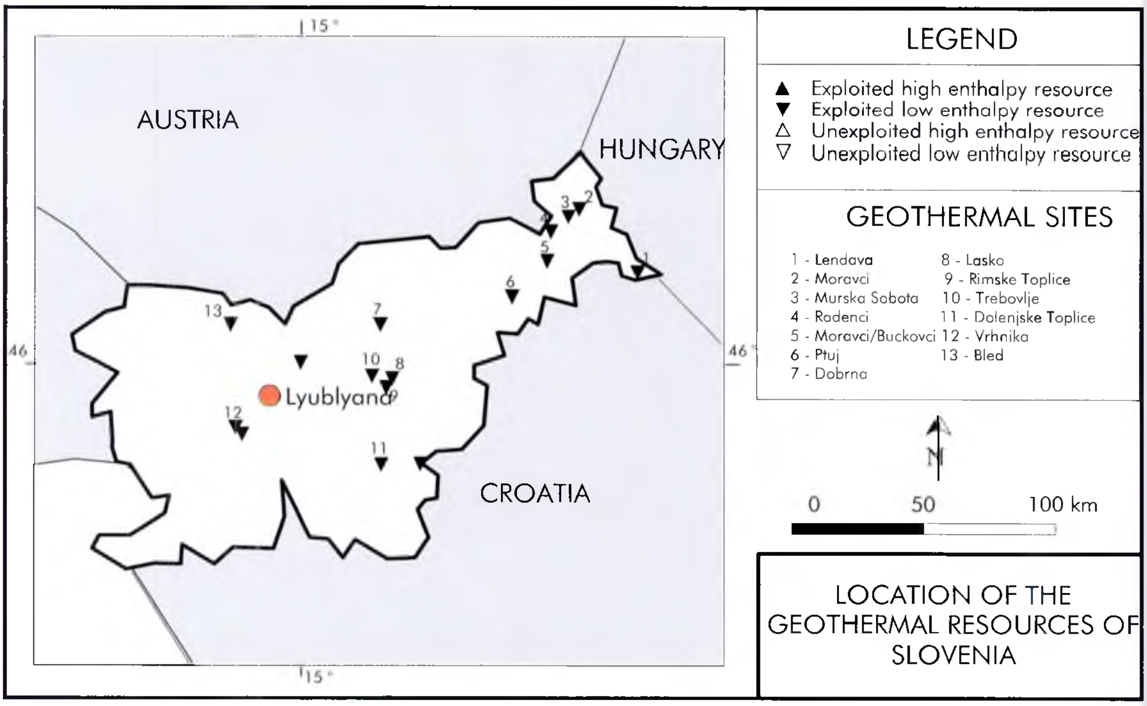
Direct Uses

Geothermal waters are used for space heating, recreation and swimming pools in 35 localities. Their combined discharge is 601l/s and recoverable thermal power 8MW$_t$. Buildings in three towns are partly heated in this way, and so are greenhouses covering 20 hectares in ten localities. About 80 thermal pools whose total area exceeds 50,000m^2 serve for swimming and recreation. Thermal spas and swimming pools can admit 75,000 visitors a day. The majority of exploited sources of geothermal energy are situated in southern Slovakia (Danube basin), primarily an the Danube basin central depression. At Vrbov in the Vysoke Tatry area, geothermal water is used not only for recreation but also for fish farming. In the Liptov basin, geothermal water is used for recreational swimming in one thermal spa (Besenova).
Essential conditions to the geothermal energy exploitation have already been created in Slovakia. A project to heat 1,300 flats, town hospital and pensionists` hostel in the town of Galanta in the Danube basin is in preparation. Another project is the construction of a reinjection station at Podhajska (to heat greenhouses, houses and swimming pools). Geothermal water will also be used to heat 500 flats and an indoor swimming pool in the town of Poprad (Vysoke Tatry area).

Summary of Resources	
Exploited - plant in operation	74.7 MW$_t$
Unexploited - plant under construction or planned	
Unexploited - proven resources	184 MW$_t$
Unexploited - probable and possible resources	5,700 MW$_t$

SLOVENIA

Size	20,256	km^2
Population	1.946,	millions
Annual population growth rate (1985-95)	0.1	%
GNP per capita (1995)	8,200	USD per year
Average annual growth rate of GNP (199 -9)		%
Average annual inflation (199 -9)		%
Annual energy use per capita (1994)oil equivalent	2,612	kg
Average annual growth rate of energy use (1992)		%
Annual CO_2 emission per capita (1992)	2.8	tonnes
Production of electricity (1994)	12,630	GWh
Geothermal	0	GWh
Fossil fuels	4, 622	GWh
Hydro	3,399	GWh
Nuclear	4,609	GWh
Wind		GWh



Systematic geothermal investigations started in 1982, aimed at the acquisition of fundamental geothermal parameters: virgin rock temperature and its gradients, thermal conductivity, and the concentration of radiogenic elements in the rocks.

Temperatures in Slovenia, up to a depth of 4000m, do not exceed 200°C, whereas the temperatures gradients change within the broad interval from less than 10mK/m to about 70mK/m. The geothermal energy potential is concentrated in the eastern part of the country.

ELECTRICITY GENERATION

At one locality (Ljutomer) electricity generation of the order of 1MW is expected, in addition to district heating.

Summary of Resources	
Exploited - plant in operation	
Unexploited - plant under construction or planned	1MWe
Unexploited - proven resources	
Unexploited - probable and possible resources	

Direct Uses

At present the total maximum possible flow rate of all thermal springs and boreholes with a temperature of at least 20°C is 1100kg/s with a thermal power of 64MW_t, considering 25°C as the outflow temperature, which is an ideal case. The installed thermal power at 21 locations amounted to 37MW_t for utilisation of geothermal energy for direct heat (December 1994). The total energy consumption at 21 locations reached, in 1995, about 781TJ, considering the annual flow rate of 327kg/s.

Thermal spas and recreation centres are the main consumers (50.3%). Hot water is also used for space heating (26.9%), the heating of greenhouses (9.4%) and thermal heat pumps (8.4%), but less for industrial processes (1.7%) and air conditioning (3.3%). Over 400 heat pumps of the water to water type are in use, contributing an additional 40TJ (940toe) of thermal energy.

Geothermal investigations since 1990 have resulted in 36 boreholes with a total depth of about 28.1km. Most of them were intended for the further exploration of already known centres and/or for increasing their capacities or for tapping new aquifers. The remaining boreholes were drilled for exploitation purposes.

Accumulations of geothermal fluids are clearly related to the tectonic and lithological setting of the country. The geothermal conditions in the W part of Slovenia are influenced by the large crustal thickness in the area of the Outer Dinarides and the Southern Alps (up to 40km). These tectonic units consist, in the upper few kilometres, of karstified carbonate rocks, where cold groundwater circulates. This is the cause for low geothermal gradients, and consequent low temperatures down to greater depths. In this area, the fractured type of geothermal reservoir prevails. The springs discharge mostly along the SW border area of the Pannonian basin. There, the carbonate rocks of the Southern Alps, the Outer Dinarides and partly also of Transition Zone, are overlain locally by young Tertiary sediments. The pre-Tertiary depression in this area were formed mainly along the fractured zones, where most thermal springs with temperatures of below 45°C are located.

In contrast, the NE part of Slovenia is affected by the large positive anomaly of the Pannonian basin, characterised by thin crust (up to 30km) and thick Tertiary and Quaternary sedimentary layers (up to 5km). Geothermal reservoirs of the intergranular type occur here. At depths greater than 2500m, thermal fluids reach temperatures within the range of 100 to 200°C.

All known geothermal resources are of the low enthalpy type. High enthalpy resources are still poorly known. The extraction of geothermal fluids has been limited to the use of exploitation boreholes only; doublet schemes are not in use yet.

In the past 10 years it is estimated that US$ 73.5million of public funds have been spent on geothermal development. In 1994, 13 professional person-years of effort were used in developing the geothermal programme.

SUMMARY OF RESOURCES	
Exploited - plant in operation	$37MW_t$
Unexploited - plant under construction or planned	
Unexploited - proven resources	$64MW_t$
Unexploited - probable and possible resources	[5]

[5]Resources unexploited (probable and possible) amount to $14.7 \cdot 10^{18}$ J

CYPRUS

Size		km^2
Population (1994)	0.73	millions
Annual population growth rate (1993-94)		%
GNP per capita (1993)	10,380	USD per year
Average annual growth rate of GNP (1990-93)		%
Average annual inflation (1995)		%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1994)	2,680	GWh
Geothermal	0	GWh
Fossil fuels		GWh
Hydro	0	GWh
Nuclear	0	GWh
Wind	0	GWh

Cyprus Island is subject to high tectonic stress due to the subduction of the African plate beneath Turkey. This causes uplift of the island with possible reactivation of existing faults. Although the tectonic setting appears favourable for geothermal energy, the outlet temperature of the known hot springs on the island (about 15) never exceeds 20°C. These springs are all related to the Troodos massif or the sedimentary cover.

No detailed geothermal assessment has been made. The existing springs are used for spas, but their discharges do not seem very high.

Other European Countries:

Albania
Armenia
Azerbadjan
Belarus
Bosnia & Herçegovina
Croatia
Georgia
Macedonia, FYR
Moldova
Ukraine
Yugoslavia, FR

ALBANIA

Size	28,748	km^2
Population	3.441	millions
Annual population growth rate (1985-95)	1.0	%
GNP per capita (1995)	670	USD per year
Average annual growth rate of GNP (199 -9)		%
Average annual inflation (1985-95)	29.7	%
Annual energy use per capita (1994)oil equivalent	720	kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (1992)	1.2	tonnes
Production of electricity (1995)	3,903	GWh
Geothermal	0	GWh
Fossil fuels	132	GWh
Hydro	3,771	GWh
Nuclear	0	GWh
Wind		GWh

LOCATION OF THE GEOTHERMAL RESOURCES OF ALBANIA

Thermal springs and wells in Albania are located in three areas:
Kruja geothermal area, *Ardenica* geothermal area and *Peshkopia* geothermal area.
In addition to them there are several separated springs in the east of the southern city of *Saranda*, near *Krane* village. Thermal springs have also been known in *Selenica* since the X century.

Kruja geothermal area is the zone which has the biggest geothermal resources in Albania, with a length of 180km and a width of 4-5km. It starts on the Adriatic coast, north of *Rodoni* Cape in *Ishmi* region, continues with *Tirana*, *Elbasani* up to south-eastern Albanian-Greek border and extends to the *Konica* district in Greece.

The *Ardenica* geothermal area is situated 40km north of *Vlora*. It comprises the molassic-neogenic brachyanticline *Ardenica* structure and the *Semani* anticline, the northern pericline of the *Patos-Verbas* carbonatic structure and the neogenic molasses covering it in the *Verbas* sector. The *Ardenica* geothermal area extends on that part of the peri-Adriatic Depression where the *Vlora-Elbasan-Diber* transverse passes.

The *Peshkopia* geothermal area is situated in the north-east of Albania, in the *Korabi* hydrogeologic zone. Two kilometers east of *Peshkopia* some thermal springs are situated very close to each other. These thermal springs flow out on the *Banja* river slope, which is composed of flysch deposits. These springs are linked with the disjunctive tectonic zone, in the *Ohri-Diber* deep fault, peripherically of the Permian-Triassic gypsum diapir, that has penetrated the Eocene flysch which surrounds it in a ring-like pattern.

Temperatures vary from a minimum of 12°C at 100m to 105.8°C at 6000m. In the central part of the Pre-Adriatic depression, where there are many boreholes, the temperature reaches 68°C at 3000m. The thermal springs, which are situated mainly in the regional tectonic fractures, have temperatures ranging from 21 to 58°C.

The geothermal resources of potential areas in Albania are between 0.39 and 39-63GJ/m^2.
The most important resources explored until now are located in the northern half of the *Kruja* geothermal area, from *Llixha-Elbasan* in the south to Ishmi north of *Tirana*. The values of specific reserves vary between 38.5 and 19.6GJ/m^2. The southern part of the *Kruja* area has resources of 20.63GJ/m^2, evaluated by data obtained in the *Galigati* section. According to the geological conditions in this zone, its hydrogeological and geothermal characteristics, and referring to the geothermal springs found in Greece as a direct continuation of that zone towards south, it is expected that even in this part of the *Kruja* geothermal area there are important geothermal resources, at least to an extent similar to those of the *Tirana-Elbasani* zone.
The *Ardenica* geothermal area is characterised by identified geothermal resources of $8.19 \cdot 10^9$GJ. The specific reserves amount to 0.39GJ/m^2 in the anticline structures. Between the anticline structures, sectors have been evaluated to have reserves below 0.25GJ/m^2.
Geothermal resources of *Pershkopia* area have been estimated similar to those of northern part of the *Kruja* geothermal area.

Albania represents a country with a real potential in low enthalpy geothermal energy, that can be used for economic purposes.
The springs at *Peshkopia*, *Llixha Elbasani* and *Langarica Permeti* and the Ishmi 1/b well have been used for medical purposes for several decades. In *Elbasani Llixha* is a medical centre with about 200 beds where rheumatism and skin diseases are treated. Thermal waters of the
springs have been used in their natural state as potable water for the treatment of diseases of the digestive system.
To date, geothermal energy has never been used in Albania as a source of energy.

The thermal water of the *Elbasani Llixha* and *Peshkopia* springs, the Ishmi 1/b and *Kozani* 8 wells are in good technical condition. These hot water springs represent energetic sources suitable for direct use in the future.
The important *Ishmi* 1/b and *Kozani* 8 wells, yielding 3.5 and 10.3 l/sec of hot water respectively, which can be used for the heating of greenhouses, industrial and scientific purposes once adequate equipment has been installed.
The utilisation of the thermal water of the *Ishmi* 1/b well (located in the plain near *Tirana*) is supported by a relatively good infrastructure (socially and economically

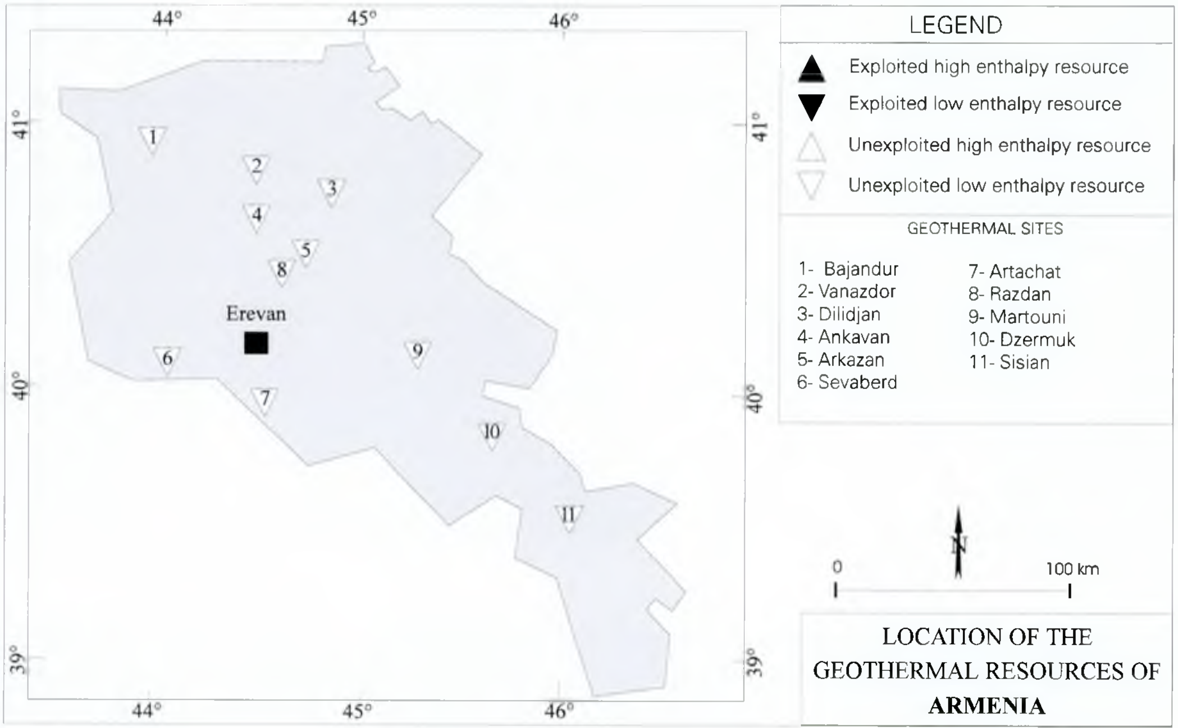
relatively developed area), a geographically favourable position (connected with the national road, close to the future route of an international highway which will link Yugoslavia, Albania and Greece).
Moreover, the advantage of the *Kozani* No. 8 well is the higher temperature of the thermal water and the relatively short distance from the West-East *Interbalkan* highway that will pass the town of *Elbasan*.

In the peri Adriatic Depression, there are areas with a geothermal gradient of 18-20°C/m where there are several abandoned oil and gas wells which may well be used for single or doublet ground-source heat pump installations. They are located in the plain area of the country, e.g. in *Divjaka* and *Kolonja* where greenhouses could be built to use the hot water for heating them.

More detailed and complex hydrogeological and geophysical investigations should focus on the exploration of new thermal springs in the *Kruja* and *Peshkopia* geothermal areas.
The same refers to the *Tirana* area which is situated in between the *Ishmi* 1/b and *Kozani* 8 wells, to *Elbasani Llixha* as well as to the *Galigati-Langarica-Sarandaporo* area close to the Albanian-Greek border, and to the *Peshkopia* area in north-east Albania.
Abandoned deep oil and gas wells, which are cased, could be used but the geological conditions need to be reviewed before the possible production of thermal water.

ARMENIA

Size	29,800	km^2
Population (1994)	3.5	millions
Annual population growth rate (1994)	0.15	%
GNP per capita (1994)	900	USD per year
Average annual growth rate of GNP (1993-94)	-2.0	%
Annual inflation (1994)	4,960	%
Average annual inflation		%
Annual energy use per capita (199)oil equivalent	525,000	kg
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity	5494	GWh
Geothermal		GWh
Fossil fuels	2015	GWh
Hydro	3479	GWh
Nuclear		GWh
Wind		GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF **ARMENIA**

Armenia is located within an area of intense tectonic activity and recent volcanism of the Minor Caucasus Chain. The occurrence of many surface hydrothermal manifestations highlights its large geothermal potential. A survey of geothermal resources has been completed and the main area of geothermal interest identified. The most promising area corresponds to a narrow zone extending over the central part of the country from NW to SE, with intra-mountain basins filled with thick alluvial deposits (*Sisian*, *Martouni*, *Sevan*). The geothermal gradient value is about 50°C/km. They contain shallow to deep aquifers with measured temperatures of 140°C, high permeability and high reservoir pressures. Fracture-controlled geothermal systems also develop within their granitic and metamorphic basements, and outside.

Most identified resources are related to low to intermediate temperature systems. They are listed below. Some evidences of high temperature systems also exist.

Direct Uses

Shirak Basin (Bajandur): a 2500m-deep well produces 100-110°C waters from the Upper Cretaceous reservoir.

Pamback Basin (Dilidjan and Vanadzor): a 2500m-deep reservoir in Upper Cretaceous Formations produces 110°C waters.

Ankavan: Is a fracture-controlled hydrothermal system developed within granites and schists of Precambrian to Palaeozoic Age. Water temperatures range between 32-41°C and salinity between 3-8g/l.

Arzakan: Is a fracture-controlled hydrothermal system developed within a recent graben structure filled with terrigenous deposits. Exploration wells produce 44-51°C waters with 5g/l salinity and 2-7l/s flow rate.

The Ararat Basin

Wells drilled for oil exploration evidenced 10-30°C/km gradient values and waters with high salinity (40-100g/l).

At *Sevaberd* (Kara *Kala*), a 3027m-deep well intersects a aquifer with highly saline waters (47g/l) at 83°C and a 25l/s flow rate. Reservoir formations are limestone, shales and clays.

At *Mkhtchyan* (*Artachat*), a 2634m-deep well intersects a aquifer with highly saline waters (43g/l) at 41°C and a low flow rate (1l/s). Reservoir formations are clays and sandstones of Palaeocene Age.

In *Gjumush* area, the 3000m-thick sedimentary sequence (Tertiary) contains 70-80°C aquifers.

At *Razdan*, Upper Cretaceous aquifers produce 100°C waters at 2600m depth; the temperature reaches 140°C at 3500m depth.

In *Chatma* Valley, 1700m-deep and 2500m-deep aquifers produce 60°C waters and 90°C waters, respectively.

Martouni: Is located within the large *Sevan* Basin filled with sedimentary and volcanic deposits. Exploration wells have been drilled down to 1200m depth. They encountered aquifers with low temperatures (32-40°C), low to high flow rates (4-50l/s), and low salinity (2-3g/l). Geothermal potential of thermal waters is estimated around 8MWt.

Dzermuk: Is a fracture-controlled hydrothermal system developed within granitic and metamorphic rocks. A well drilled in 1938 produced 5l/s of 45-56°C waters for balneological therapy. A deeper reservoir (1500-2000m) with higher temperature conditions (100°C) also exists within fractured limestone.

At *Dzermuk*, hot waters are used for bathing.

Sisian: It is a fracture-controlled hydrothermal system developed within the *Sisian* Basin filled with fluvial and lacustrine deposits intercalated with volcanic deposits of Tertiary to Quaternary Age. Exploration wells produced 36-43°C waters with high flow rates (20-100l/s) and low salinity (4-6l/s). Geothermal potential of thermal waters is estimated around 8MWt.

Summary of Resources	
Exploited - plant in operation	n.a.
Unexploited - plant under construction or planned	
Unexploited - proven resources	16MWt
Unexploited - probable and possible resources	

AZERBADJAN

Size	86,600	km^2
Population (1994)	7.46	millions
Annual population growth rate (1994)	1.2	%
GNP per capita (1994)	680	USD per year
Average annual growth rate of GNP (1993-94)	-22	%
Annual inflation (1994)	1780	%
Average annual inflation		%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity	16634	GWh
Geothermal		GWh
Fossil fuels	14852	GWh
Hydro	1782	GWh
Nuclear		GWh
Wind		GWh

LOCATION OF THE GEOTHERMAL RESOURCES OF **AZERBADJAN**

Azerbadjan has a similar geologic setting as neighbouring Georgia. It corresponds to a sedimentary trough surrounded by the Major and Minor Caucasus Chains. Oil exploration has provided much of the data about aquifers and geothermal gradient values. Low temperature (35-65°C) geothermal systems are evident within these sedimentary formations.

DIRECT USES

Exploitation of geothermal resources is mainly concerned with greenhouses.
In 1977, four regions of geothermal interest had been identified:

Istisu Region (Central Minor Caucasus) where hot springs occur;

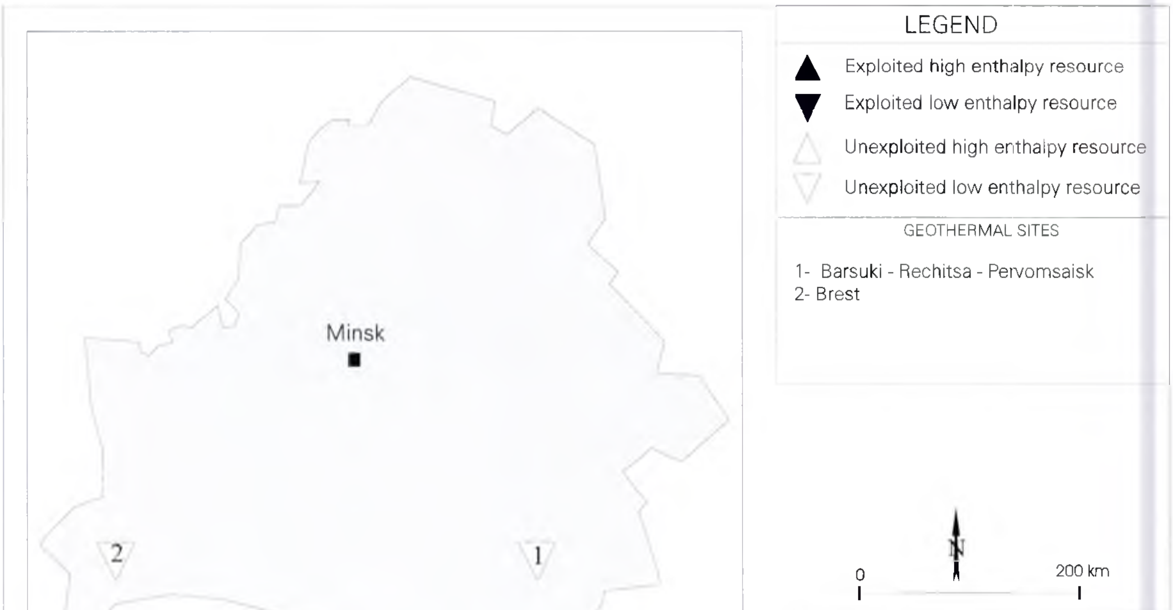
Ganca Region (Middle *Kura* Valley) where the use of 40-50°C waters is planned for space heating;

Lenkoran-Masally Region (South East Plain) where hot springs deliver 63°C waters; in *Lenkoran-Masally* Region, hot waters are used for greenhouses since 1978 (*Astara*).

Aspheron Peninsula (Caspian Coast) where extensive drilling for oil has provided detailed data. The Kirmakin Formation produces 10-60l/s of 58-60°C waters at *Surakhany*, and 5l/s of 35°C waters at *Bakou*. The Lower Cretaceous Formation produces 30l/s of 35°C waters at *Keschaj*.

BELARUS

Size	207,595	km^2
Population (1994)	10.2	millions
Annual population growth rate (1994)	0.6	%
GNP per capita (1994)	2,500	USD per year
Average annual growth rate of GNP (1993-94)	-20	%
Annual inflation (1994)	2,220	%
Average annual inflation		%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity	14,000	GWh
Geothermal		GWh
Fossil fuels	495,000	GWh
Hydro	19,000	GWh
Nuclear		GWh
Wind		GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF **BELARUS**

Belarus is located on the western part of the Russian Platform. Deep aquifers in sedimentary formations of Palaeozoic Age represent the main geothermal potential. They are especially developed in South Belarus (near Ukraine) within Middle Devonian.

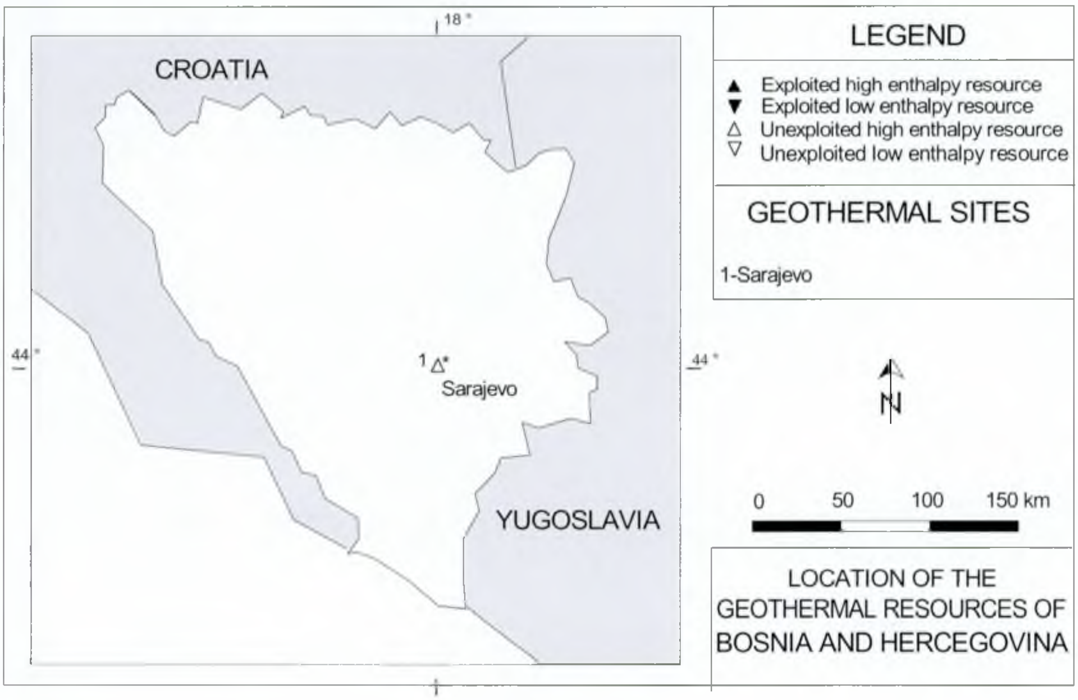
Direct Uses

Highly mineralised fluids (200-400g/l TDS) with temperature up to 100°C at 4,5km depth have been evidenced in the *Pripyat* Depression, SE Belarus (*Barsuki*, *Rechitsa*, *Pervomsaisk*). Aquifers with temperatures around 35°C at 2.5km also occur in the *Brest* Depression, SW Belarus.

No utilisation of geothermal resources are known to date.

BOSNIA AND HERÇEGOVINA

Size	51,129	km^2
Population (1995)	3.459	millions
Annual population growth rate (1985-95)	-4.39	%
GNP per capita (199)		USD per year
Average annual growth rate of GNP (199 -199)		%
Average annual inflation (199 -9)		%
Annual energy use per capita (1994)oil equivalent	348	kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (1992)	3.4	tonnes
Production of electricity (1994)	1,921	GWh
Geothermal	0	GWh
Fossil fuels	671	GWh
Hydro	1,250	GWh
Nuclear	0	GWh
Wind		GWh

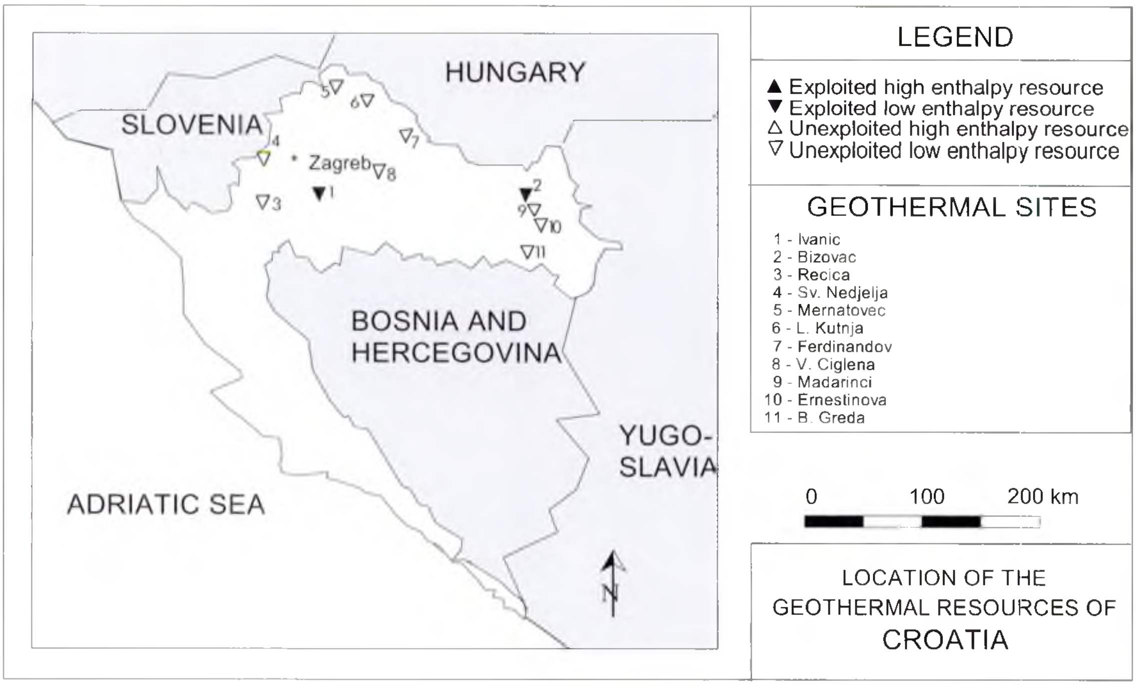


Before the recent civil war, the first 1MW pilot plant working on geothermal water was about to be built in Sarajevo. Due to lack of money the project has not been further developed. The flow rate is 240 l/s at a temperature of 58°C.

The country geothermal potential for space heating and balneological purposes, based on the existing wells is about 33 MWt.

CROATIA

Size	56,538	km^2
Population (1995)	4.495	millions
Annual population growth rate (1985-95)	0.2	%
GNP per capita (1995)	3,250	USD per year
Average annual growth rate of GNP (199 -9)		%
Average annual inflation (199 - 9)		%
Annual energy use per capita (1994)oil equivalent	1,395	kg
Average annual growth rate of energy use (199)		%
Annual CO_2 emission per capita (1992)	3.4	tonnes
Production of electricity (1994)	8,269	GWh
Geothermal	0	GWh
Fossil fuels	3,338	GWh
Hydro	4,930	GWh
Nuclear	0	GWh
Wind		GWh



In the Republic of Croatia, there are two regions possessing a geothermal energy potential. The southern area (the Dinarides) with an average geothermal gradient of 0.018°C/m has little geothermal energy potential. The northern part, which belongs to the *Pannonian* sedimentary basin, has an average geothermal gradient of 0.049°C/m. Several geothermal reservoirs, discovered during hydrocarbon exploration, have been extensively tested there.

Recorded flow rates reach 50-80kg/s, with well head temperatures of between 80 and 152°C. Geothermal energy (80-96°C) from three geothermal fields is utilised (with reinjection). The installed thermal capacity is 15MW$_t$, but the load factor is too low. It has been estimated that the total thermal capacity based on tested reservoirs could amount to 815MW$_t$ (outlet temperature 50°C).

ELECTRICITY GENERATION

There is no electricity generated from geothermal resources in Croatia.

DIRECT USES

At *Bizovac* the thermal water is used for balneology and some space heating with fluid extracted from two reservoirs at depths of 1800 and 1600m. Wellhead temperatures are 96 and 85°C with flowrates of 5 and 3kg/s (mineralisation 2g/l and 30g/l), respectively. Waste geothermal water has been discharged into surface water bodies. Separate treatment of waste water is planned.

At *Ivanic* the water (2kg/s with 10g/l of dissolved solids), at a wellhead temperature of 62°C, is used for balneology. The reservoir pressure (initially hydrostatic) declines slowly.

In Croatia's capital *Zagreb*, an aquifer has been discovered by an oil exploratory well. The geothermal water contains 2g/l of dissolved solids, 0.1m^3/m^3 of CO_2 and traces of H_2S. The reservoir temperature is 55 - 82°C at depths between 500 and 1000m. The very permeable section of the aquifer covers an area of 10km^2 in the south-western part of the town (sublocalities *Blato* and *Mladost*).
At the *Blato* site, the planned geothermal capacity is 7MW$_t$. In *Mladost*, there are several large buildings for sports activities (indoor and outdoor swimming pools and two other halls), which are entirely geothermally heated (6.3MW$_t$), including peak consumption.

At *Lunjkovec-Kutnjak*, carbonate breccia form the reservoir rock, is characterised by a porosity of ~7.5. The water contains 5g/l of dissolved solids and 3m^3 of gas (85% CO_2, about 15% hydrocarbon and traces of H_2S). The measured productivity index is 450m^3/(d·bar). In the reservoir evaluation study, an average flowrate of 80kg/s with WHP 3-5 bars and WHT 125-140°C has been predicted.

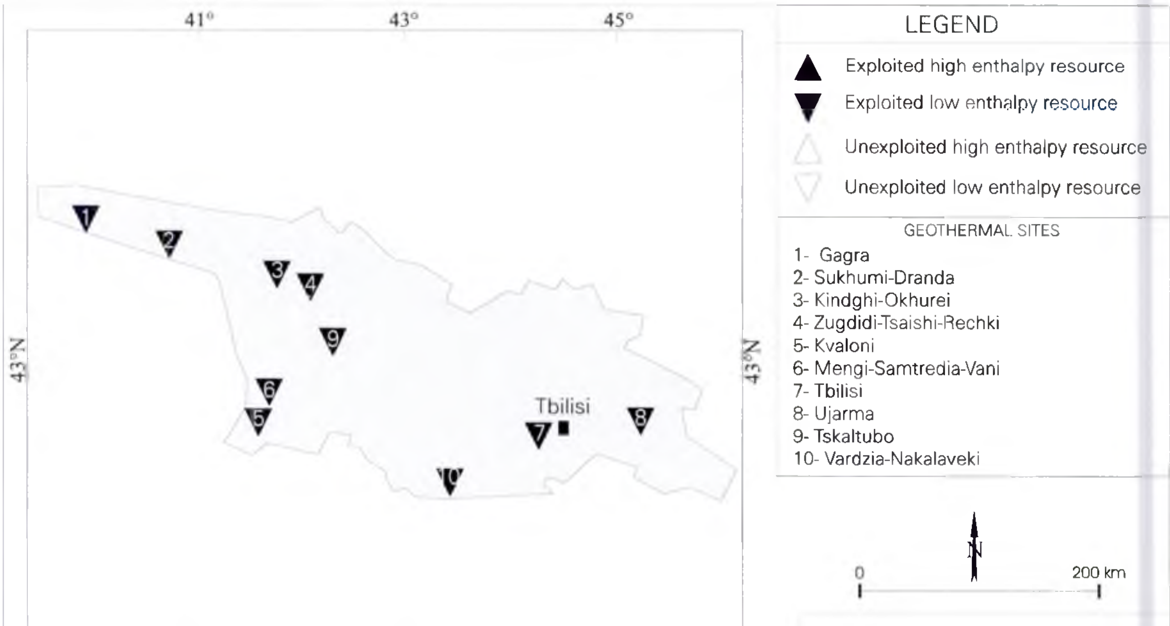
At *Velika Ciglena* the water from the dolomite reservoir (depth 3000m) contains 24g/l dissolved solid and 30m^3/m^3 CO_2 with 59 ppm H_2S. The predicted production well flowrate is 100kg/s with WHP 20-25 bars and WHT 165-170°C.

The northern cities are close to a natural gas pipe line, thus limiting the interest and development of these fields as in many other countries with financial and other constraints.

SUMMARY OF RESOURCES	
Exploited - plant in operation	10.5MW$_t$
Unexploited - plant under construction or planned	
Unexploited - proven resources	815MW$_t$
Unexploited - probable and possible resources	

GEORGIA

Size	70,000	km^2
Population (1994)	5.47	millions
Annual population growth rate (1994)	0.1	%
GNP per capita (1994)	500	USD per year
Average annual growth rate of GNP (1993-94)	-10	%
Annual inflation (1994)	21,000	%
Average annual inflation		%
Annual energy use per capita (199) oil equivalent		kg
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity	14.168	GWh
Geothermal		GWh
Fossil fuels	6.643	GWh
Hydro	7.525	GWh
Nuclear		GWh
Wind		GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF **GEORGIA**

Georgia corresponds to a collapsed sedimentary trough surrounded by the Major Caucasus and Minor Caucasus Chains. Wells drilled for oil have provided much of the data on aquifers and geothermal gradient values. Georgia has a large geothermal potential, with 15-20 low temperature geothermal fields identified mainly in Western Georgia.

DIRECT USES

Geothermal resources are widely exploited for direct uses such as space heating, greenhouses, agricultural drying, bathing and swimming, etc. Total installed power is $245MW_t$, producing 7,689TJ/y.

The total flow rate exceeds 8000l/s with water temperatures ranging from 33° to 108°C, and low salinity (1-3g/l). Production wells are usually deeper than 2000 m, and maximum depth is 3728m. Reservoir formations are fractured, karstic limestones of

Upper Cretaceous in the sedimentary trough (West Georgia), and volcanics/sandstones of Paleocene-Middle Eocene in the folded systems (East Georgia).

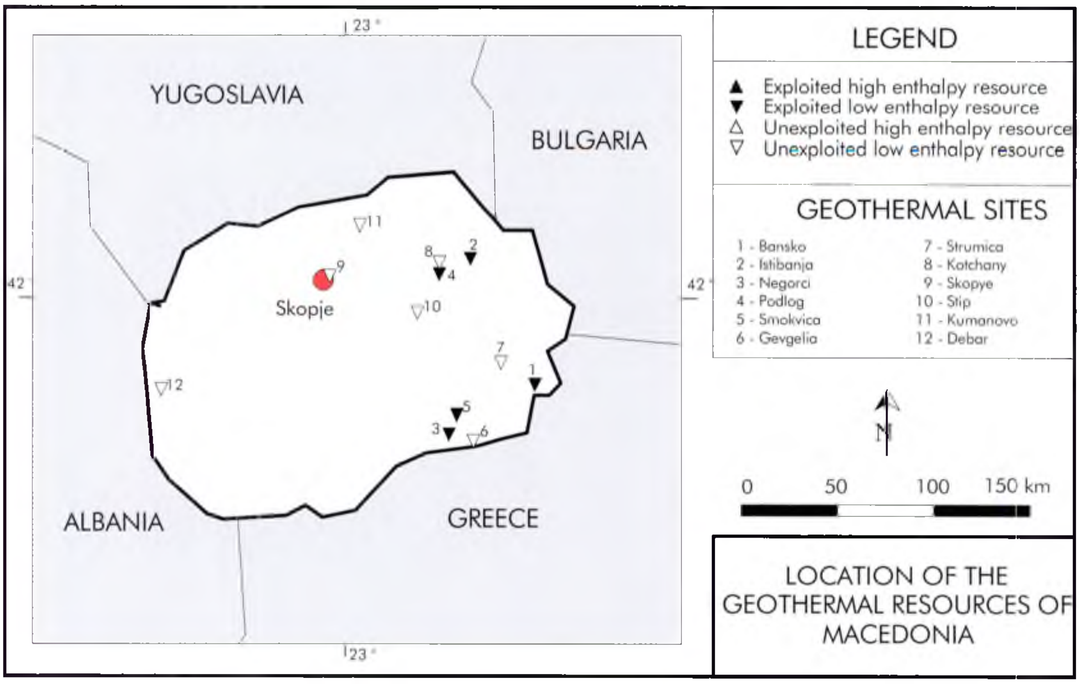
The main areas of geothermal exploitations are
Gagra 47°C; 30 l/s; balneology.
Sukhumi-Dranda 90°C; 25 l/s; bathing, greenhouses, airport heating;
Kindghi-Okhurei 105°C; 360 l/s; greenhouses, space heating;
Zugdidi-Tsaishi-Rechki 92°C; 375 l/s; industrial process heat, space heating;
Kvaloni 97°C; 87 l/s;
Mengi-Samtredia-Vani 65°C; 150 l/s; bathing, greenhouses;
Tbilisi 65°C; 60 l/s; space heating;
Ujarma 59°C; 6 l/s;
Tskaltubo 33°C; 250 l/s; bathing;
Vardzia-Nakalaveki 46°C; 20 l/s;

Since 1991, no development has taken place.

Summary of Resources	
Exploited - plant in operation	245MW$_t$
Unexploited - plant under construction or planned	
Unexploited - proven resources	
Unexploited - probable and possible resources	

F.Y.R. of MACEDONIA

Size	25,713	km^2
Population (1995)	2.163	millions
Annual population growth rate (1985-95)	0.7	%
GNP per capita (1995)	860	USD per year
Average annual growth rate of GNP (199 -9)		%
Average annual inflation (199 -9)		%
Annual energy use per capita (1994)oil equivalent	1,279	kg
Average annual growth rate of energy use (1992)		%
Annual CO_2 emission per capita (1992)	2.0	tonnes
Production of electricity (1994)	5,511	GWh
Geothermal	0	GWh
Fossil fuels	4,816	GWh
Hydro	695	GWh
Nuclear	0	GWh
Wind		GWh



The Republic of Macedonia is situated in the central part of the Balkan Peninsula, along the very favourable geothermal zone that starts in Hungary in the north and Italy in the west and stretches through Greece down to Turkey and beyond to the east. However, existing natural springs and results of exploratory investigation have revealed that Macedonia is one of the countries with the richest low-enthalpy geothermal energy resources. Known geothermal fields are grouped according to geotectonic divisions in Macedonia. The east and Northeast, which form part of the Macedonian-Serbian massif characterised by crystalline basement rocks, is much richer than the west and Southwest (Bosnian-Serbian-Macedonian geothermal area) which is characterised by limestone. The extreme aggressiveness of the waters of this limestone area makes them unsuitable for practical use as heat sources at this stage of the development of geothermal energy use.

Out of the seven geothermal fields identified in the east and Northeast of the country, some have been found to be very promising: *Strumica*, *Kotchany* and *Skopye*.
Three of them have been investigated to the stage where practical use is possible: *Stip*, *Kumanovo*, *Debar*.

The *Gevgelia* valley is located in the river *Vardar* zone, in the southern part of the country. Three geothermal sites, all near active faults in an area of high seismic activity, have been identified so far.
The *Smokvica* geothermal site was determined after the drilling of 22 boreholes down to 30-850m. The largest aquifer was found at 350-500m. The maximum total yield from 4 production wells is about 180 l/s with an average temperature of 65°C. The flow of 80l/s has been found as a realistic maximum for the field, without causing a negative influence on the water temperature.
In *Negorska banja* several shallow boreholes, between 20 and 130m deep, were drilled in 1983. During 1984-1985, two boreholes of 600m each were drilled, resulting in a total thermal water flow by pumping of 80l/s at 51°C.
Gornitchet has not yet been sufficiently explored. There are two springs yielding 5l/s thermal water at 24°C. Geothermometers indicate that the water has a temperature of 150°C.

The geothermal field *Kotchany* is situated in the southernmost part of the Bosnian-Serbian-Macedonian geothermal area. Three main geothermal localities have been defined in the *Kotchany* valley.
Podlog is located in the middle of the valley. The first well was drilled in 1967 down to a depth of 70m, giving 5l/s free water flow at 60°C. In 1980 a deeper well was drilled nearby. At 307m an aquifer was intersected yielding over 150l/s free flowing water at 79°C. In the period 1980-1986, 18 exploratory and production wells were drilled in the area, resulting in a totally possible yield of 600 l/s and water temperatures between 57°C an 79°C.
Banja is located about 5km north of *Podlog*. One successful well yields about 50l/s of thermal water at 65°C, but the latest borehole (450m) was unsuccessful.
Vinica (or *Istibanja*) is also north of *Podlog*. The water temperature in drilled shallow boreholes (up to 30m deep) is between 30 and 40°C. In addition, a 180m deep borehole was drilled and yielded 2l/s of 60°C thermal water and another at 190m well yielded 6l/s at 60°C. The latest production wells have been drilled down to 200-350m and resulted in a total flow of around 60l/s at 60°C.

Electricity Generation

There is no electricity generated from geothermal resources.

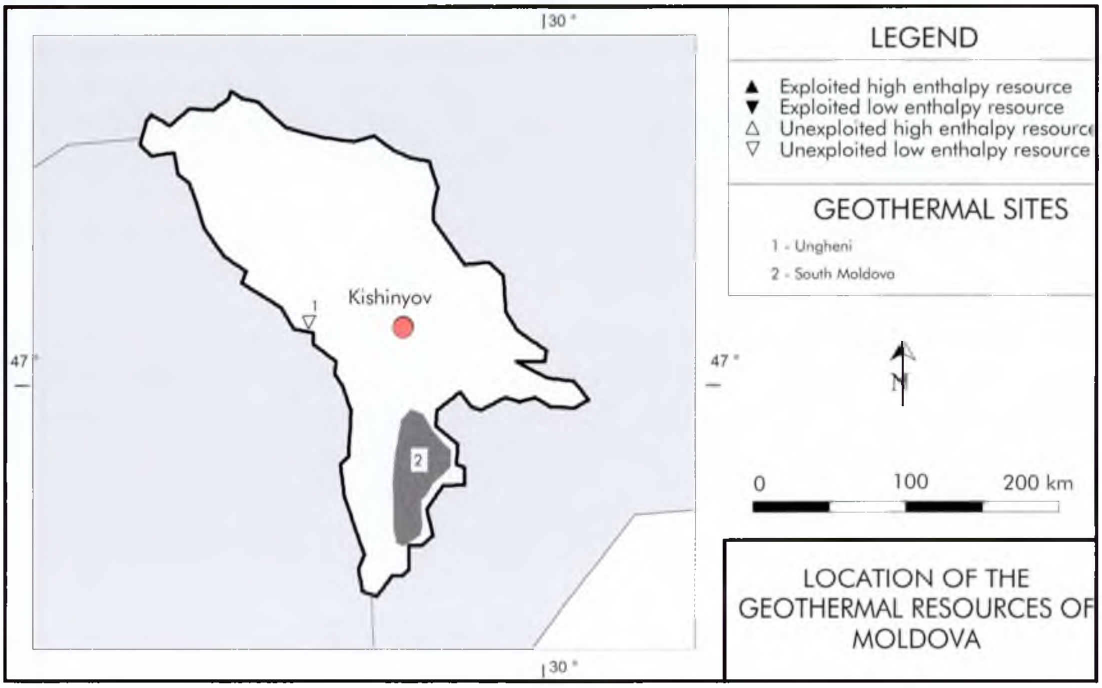
Direct Uses

15 geothermal projects are in operation or under development in 5main areas. The total flow is 1000l/s, and the total installed thermal capacity is estimated to exceed 70MW_t with an energy use of 510TJ/yr, of which 80 % is exploited in greenhouse heating at load factors of about 33%.

Summary of Resources	
Exploited - plant in operation	74.5MW_t
Unexploited - plant under construction or planned	
Unexploited - proven resources	220MW_t
Unexploited - probable and possible resources	

MOLDOVA

Size	33,700	km^2
Population (1995)	4.347	millions
Annual population growth rate (1985-95)	0.4	%
GNP per capita (1995)	920	USD per year
Average annual growth rate of GNP (1985-1995)	-8.2	%
Average annual inflation (199 -9)		%
Annual energy use per capita (1994)oil equivalent	1,095	kg
Average annual growth rate of energy use (1992)	3.3	%
Annual CO_2 emission per capita (1992)		tonnes
Production of electricity (1994)	8,228	GWh
Geothermal	0	GWh
Fossil fuels	7,950	GWh
Hydro	278	GWh
Nuclear	0	GWh
Wind	0	GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF MOLDOVA

The geothermal conditions of Moldova have been well investigated regionally. The data currently available provide a good characterisation of Mesozoic-Cenozoic formations in the country. Temperature measurements have been carried out over different periods of time (between 1950 and 1990) by means of hydrogen thermometers and electrometric units (laboratory AEKS-1500, thermometer ETMP-55) in coasting ditches and wells drilled of oil, gas and water exploration.

Based on the evaluation of the geological-hydrogeological and geothermal documentation, two zones may be distinguished on the territory of Moldova which are characterised by temperature anomalies:
1) the southern zone covering the territory of Moldova below 46 °40’00“,
2) the western zone around the town of *Ungheni*.

The southern zone is characterised by the following characteristics: The temperature of the rocks and the underground waters increases towards the direction of submergence of the crystalline basement and increasing thickness of the sedimentary rocks from north and northwest to south and southwest. The highest temperatures were measured around the villages of *Baimakliya*, *Valen*, *Kongaz* and the town of *Kagula*. The analysis of the stratigraphic sections at depths of 250, 500, 750 and 1,000m shows that the temperature increase with depth from 25°C to 50°C on average. In the same direction, the chemical composition of the underground waters changes from H_2CO_3-Mg_2SO_4-type with a mineralisation ranging from 1.0-3.0g/l to the Cl-type with the mineralisation exceeding 30.0g/l. As a rule, the temperature anomalies are linear, bound to tectonic fractures and accompanied by high contents of He (more than 1.0 percent by volume).

The western zone covers an area of about 1,600km² and is a part of the foreland of the Carpathians. Wells were drilled down to the crystalline basement and water with temperatures between 37.0 to 46.0°C was encountered in the Proterozoic formations. Temperature anomalies can be followed from the Neogenic to the Proterozoic sediments. The mineralisation of the water changes from 1.0-5.0g/l up to 56.0g/l.

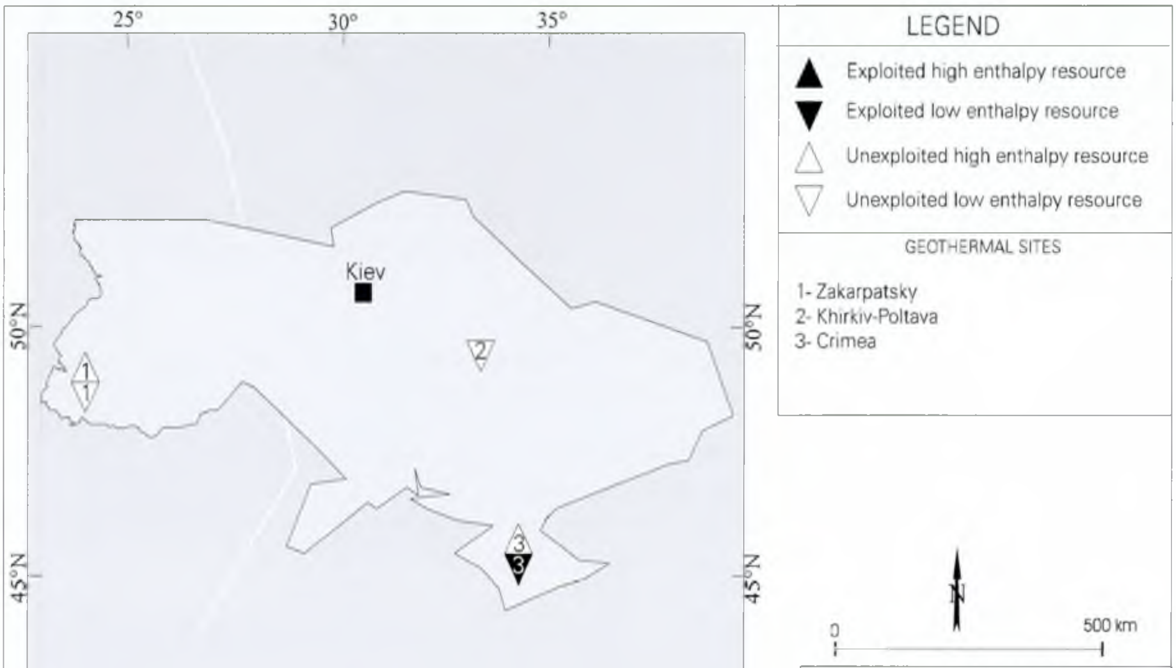
Apart from the two identified geothermal zones, several authors (N.M. Frolov, 1963, K.E. Moraru, 1990) consider the Prut river region and the areas of intersection of major tectonic fractures as prospective for geothermal waters which is based on the geophysical and geochemical (He content) data obtained so far.

It has to be stated, that the majority of the wells are either artesian or the water table adjusts at 10.0-200.0m below ground level.

The large amount of data on the geothermal resources of Moldova collected so far (maps, well documentations, flowrates, chemical composition and other) forms the basis for the discussion of the possibilities of future heat recovery in Moldova in terms of economic profitability.

UKRAINE

Size	603,700	km^2
Population (1994)	52.3	millions
Annual population growth rate (1994)	0.3	%
GNP per capita (1994)	1,570	USD per year
Average annual growth rate of GNP (1993-94)	-19	%
Annual inflation (1994)	876	%
Average annual inflation		%
Consumption of energy (1994) oil equivalent	180	million t
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity (1995)		GWh
Geothermal		GWh
Fossil fuels		GWh
Hydro		GWh
Nuclear	68.4	GWh
Wind		GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF **UKRAINE**

In Ukraine, low to medium temperature aquifers are evident within sedimentary basins running along the Carpathians and the Caucasus Chains (South and West Ukraine). The *Dnepr-Donec* coal Basin (Central Ukraine) also show elevated thermal gradient values at the top of the basement and contain geothermal reservoirs. High temperature aquifers are found in the deepest part of these basins with measured temperature up to 210°C.

ELECTRICITY GENERATION

There is no exploitation of high temperature waters for electricity generation. Some pilot geothermal power stations with a capacity of 1.5MW each based on a two-circuit scheme with a low-boiling secondary fluid are planned for construction by 2005.

DIRECT USES

The areas with expected geothermal potential are:

The *Zakarpatsky* Basin in the *Trans-Carpatian* Trough. Artesian wells produce 60-90°C thermal waters from reservoirs located between 1000-2500m.depth (*Beregove*, *Uzhgorod*, *Kosyno*, *Tereblju*). A deep well (Zaluzska-3, 4050m.depth) produces 210°C hot waters.
The *Kharkiv-Poltava* Region in the *Dnepr-Donec* Basin. More than 100 wells with depth between 3000 to 4500m. have been drilled. Measured water temperatures range from 125 to 168°C.
The *Crimea* Region. Maximum temperatures of 158°C have been measured in wells up to a depth of 2400m.

Thermal waters (60-90°C) are used in the Autonomous Republic of *Crimea* mainly for space heating. Five geothermal systems are operating with a total installed capacity of $12MW_t$.(see below). In addition, there are single wells connected with boiler houses in many places, which are not considered as geothermal exploitation, and not recorded here.

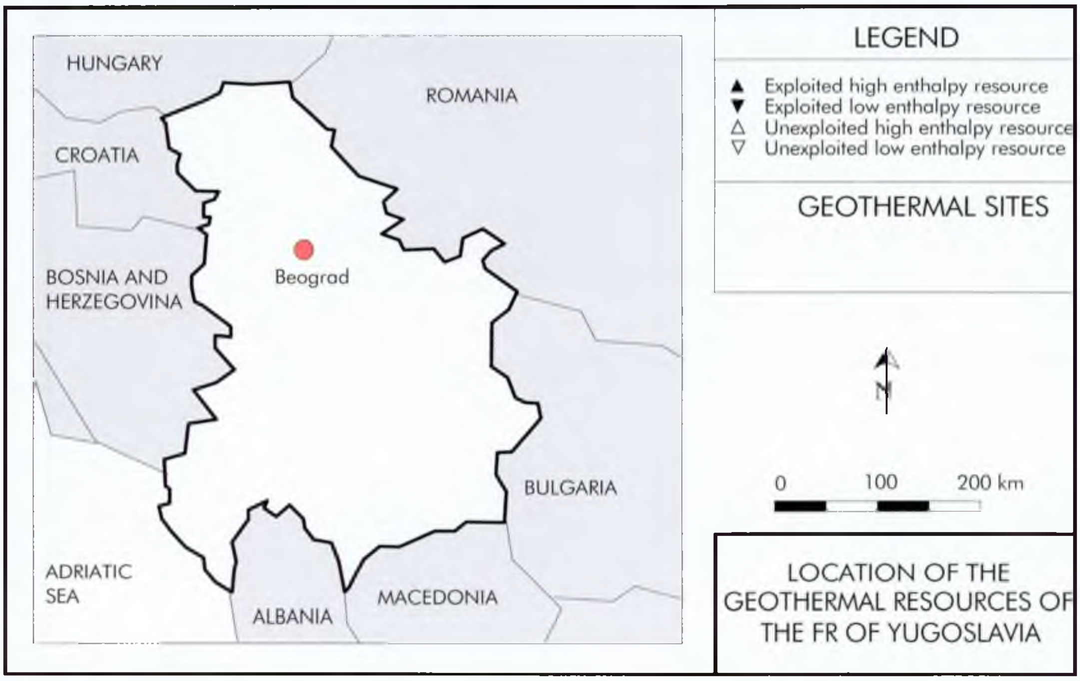
Iljinka ($1MW_t$ installed capacity) for residential building heating; *Sizovka* ($1MW_t$) for residential building heating; *Kotelnikovo* ($2MW_t$) for residential building heating; *Novo-Alekseevka* (3MWT) for dairy farming; *Yantarne* (5MWT) for residential building heating.

Development of direct uses of thermal waters is planned and installed capacity could be $154MW_t$ in 2000, $200MW_t$ in 2005 and $250MW_t$ in 2010.

SUMMARY OF RESOURCES	
Exploited - plant in operation	$12MW_t$
Unexploited - plant under construction or planned	$238MW_t$
Unexploited - proven resources	
Unexploited - probable and possible resources	

FEDERAL REPUBLIC OF YUGOSLAVIA

Size	102,173	km^2
Population (1995)	10.849	millions
Annual population growth rate (1985-95)	0.5	%
GNP per capita (199)		USD per year
Average annual growth rate of GNP (199 -9)		%
Average annual inflation (199 -9)		%
Annual energy use per capita (1994)oil equivalent	1,110	kg
Average annual growth rate of energy use (1992)		%
Annual CO_2 emission per capita (1992)	3.6	tonnes
Production of electricity (1994)	33,171	GWh
Geothermal	0	GWh
Fossil fuels	23,171	GWh
Hydro	10,000	GWh
Nuclear	0	GWh
Wind		GWh



Geothermal investigations began in 1974, and an assessment of the resources has identified four geothermal provinces of which the most promising are the Pannonian and Neogene magmatic provinces. More than 80 low enthalpy systems have been identified, the most important of which are located at the southern edge of the Pannonian Basin. The heat flow density values are higher than the average for continental Europe, with the highest in the Pannonian Basin (>100mW/m^2). A total of 159 natural thermal springs have been identified, with temperatures in excess of 15°C and a total flow of about 4000kg/s. Between 1977 and 1988, 58 were drilled in the Pannonian Basin, with an overall yield of 550kg/s and a heat capacity above 25°C of 48MW$_t$, but since 1988 only four exploration wells have been drilled. In the other provinces 45 boreholes were drilled up to 1992, with a yield of 500kg/s and a total capacity of 108MW$_t$.

Electricity Generation

There is no electricity generated from geothermal resources.

Direct Uses

The most common use of the geothermal fluid is the traditional one of balneology; there are today 59 thermal spas in this country and thermal waters are also bottled in nine mineral water bottling companies. The direct use for space heating is in its initial stage and very modest in relation to the potential. The total installed thermal capacity is $80MW_t$ and $6MW_t$ of heat pumps and a total energy use of 2375TJ/yr. 48% (1150TJ/yr) of the total is used for bathing and swimming, 24 % for space heating and nearly 11 % for greenhouse heating. The geothermal activity is currently manned by a total of four professional person-years of effort, three from the universities. The resource base data suggest that geothermal energy in Serbia could make a significant contribution to the national energy mix in future; in addition, the intensive use of thermal water in agro- and aquacultures and in district heating systems, particularly west of Belgrade, could be of value to the Serbian energy situation.

Summary of Resources	
Exploited - plant in operation	$86MW_t$
Unexploited - plant under construction or planned	
Unexploited - proven resources	$156MW_t$
Unexploited - probable and possible resources	

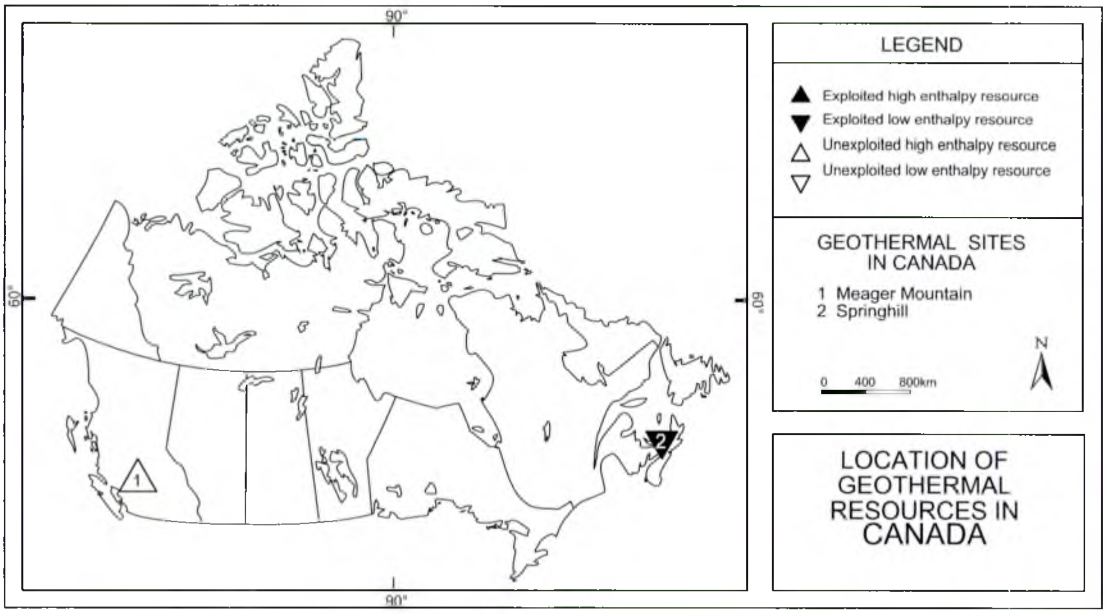
Annex 1.1

North America

Canada
Mexico
USA

CANADA

Size:	9,976,000 km^2
Population:	29.2 millions
Annual population growth rate (1994):	1.3 %
GNP per capita (1994):	19,510 USD
Average annual growth rate of GNP (1990-1994):	0.3 %
Average annual inflation (1984-1994):	3.1 %
Annual energy use per capita (oil equivalent):	7,795 kg
Average annual growth rate of energy use:	2.2 %
Annual CO_2 emission per capita:	14.36 metric tons
Production of electricity (1995):	535,167 GWh
Geothermal:	0 GWh
Fossil fuels:	112,186 GWh
Hydro:	330,676 GWh
Nuclear	92,650 GWh
Wind:	-



GEOTHERMAL POTENTIAL

The largest geothermal resources are expected to be found in the western part of the country. The Corddillera of Western Canada are host to about 25 young volcanic centers and to about 100 hot springs. Available data is insufficient for a thorough evaluation of potential geothermal resources. The geological environment and the number of young volcanic centers in the area indicate that the geothermal potential might be some thousands of megawatts for electricity generation. Three wells have been drilled in the Meager Mountain region and a high-temperature (270 °C) resource demonstrated.

GEOTHERMAL UTILISATION

The only geothermal utilisation in Canada at present is the use of 18 ĶC water from the old coal mine of Springhill, Nova Scotia. Heat exchangers are used to extract the energy from the fluid and it is returned back to the mine at 12 ĶC. The system is designed both for heating in the winter as well for cooling in the summer.

Carleton University in Ottawa has been using 9.5 °C from sedimentary formations for heating and cooling of large buildings.

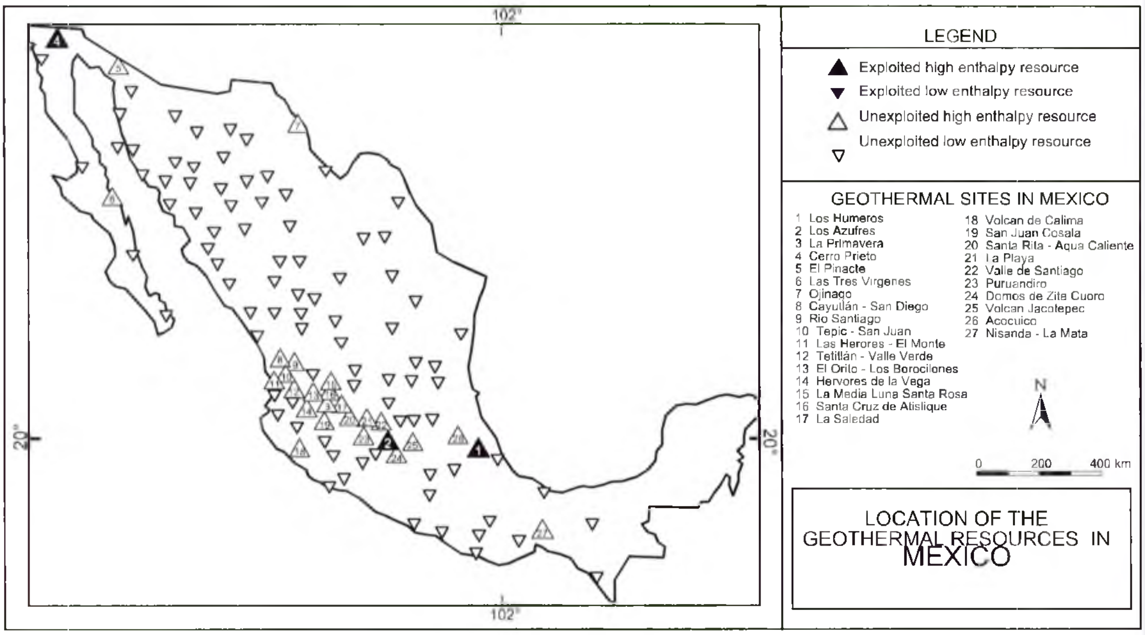
Geothermal wells have been drilled at Moose Jaw (Saskatchewan), Summerland (British Columbia) and Meager Mountain (British Columbia) but commercial utilisation has not started so far.

SUMMARY OF GEOTHERMAL RESOURCES

	Electricity		Direct use	
	MW_e	GWh/y	MW_{th}	GWh/y
In operation	0	0	3	13
Planned or under construction	70	570		
Estimated potential	20 000	180 000	410 000	3 600 000

MEXICO

Size:	1,958,000 km^2
Population (1994)	88.5 millions
Annual population growth rate (1994)	2.0 %
GNP per capita (1994)	4,180 USD per year
Average annual growth rate of GNP (1990-1994)	2.5 %
Average annual inflation (1984-1994)	40 %
Annual energy use per capita (oil equivalent)	1,577 kg
Average annual growth rate of energy use	2.0 %
Annual CO_2 emission per capita	3.92 metric tons
Production of electricity (1995)	142,350 GWh
Geothermal	5,682 GWh
Fossil fuels	100,691 GWh
Hydro	27,528 GWh
Nuclear	8,443 GWh
Wind	6 Gwh



GEOTHERMAL POTENTIAL

The estimate of the geothermal potential of Mexico is as follows:

High enthalpy resources (170-350 ĶC) 6,000 MW_e
Medium enthalpy resources (110-170 ĶC) 48,000 MW_e

Here, it is assumed that the potential for electricity generation is 36,000 MW_e.
An estimate of low enthalpy resources (80-110 ĶC) is not available, but 1380 individual thermal locations are listed in different locations in Mexico. By 1990, geothermal investigations had been carried out in 42 geothermal fields across the country. The geothermal potential of the country is therefore very large.

GEOTHERMAL UTILIZATION

In 1995, four high-temperature geothermal fields were utilised for electricity generation and two additional fields were under development. The table shows the installed capacity and energy output from these fields.

	Installed capacity MW_e	Annual energy production GWh/year	Average load %	Under construction MW_e
Cerro Prieto	620	4743	87.3	150
Los Azufres	98	654	76.2	140
Los Humeros	35	286	93.3	50
La Primavera				70
Las Tres Virgenes				25
TOTAL	753	5682	86.1	435

The installed capacity of geothermal power plants for electricity generation was 753 MW_e in 1995. This is 2.3% of the total 32,167 MW_e installed in the Mexico. Electricity generated by geothermal plants (5,682 GWh/y) represents the 4% of the electricity generated in the country.

Many of the 1380 thermal springs in Mexico are used for bathing and recreation. A review of the direct use of geothermal energy in Mexico has not been carried out.

Summary of geothermal resources				
	Electricity		Direct use	
	MW_e	GWh/y	MW_t	GWh/y
In operation	753	5,682	n.a.	n.a.
Planned or under construction	435	3,000		
Estimated potential	36,000	315,000	700,000	6,300,000

UNITED STATES OF AMERICA

Size:	9 364 000 km2
Population:	260.6 million
Annual population growth rate (1994):	1.03%
GNP per capita (1994):	25 880 USD per year
Average annual growth rate of GNP (1990-1994):	2.5%
Average annual inflation (1984-1994):	3.3%
Annual energy use per capita (oil equivalent):	7 905 kg
Average annual growth rate of energy use (1990-1994):	1.5%
Annual CO2 emission per capita:	19.11 metric tons
Production of electricity (1995):	3 084 300 GWh
Geothermal:	14 660 GWh
Fossil fuels:	2 057 000 GWh
Hydro:	309 800 GWh
Nuclear:	673 000 GWh
Wind:	-

GEOTHERMAL POTENTIAL

The United States of America has large geothermal resources, and more electricity (15 TWh) is generated in geothermal power plants in the USA, than in any other country in the world. Identified resources for electricity production corresponds to 23,000 MW_e for 30 years and identified resources for direct use are estimated to be 400×10^{18} Joule (110,000 TWh). The geothermal potential of the USA for electricity production is estimated to be 130,000 MW_e for 30 years, and recoverable heat energy is estimated $2{,}400 \times 10^{18}$ J (670,000 TWh).

GEOTHERMAL UTILIZATION

Electricity generation has been the main utilization mode of geothermal energy in the USA. In recent years, rapid installment of heat pumps has resulted in the direct use of geothermal energy which is now approaching comparable levels of energy consumption to electricity generation. Table 1 shows a summary of the power plants for electricity generation in the USA, and Table 2 gives a summary of geothermal direct heat uses.

Table 1. Geothermal power plants in the USA					
	Number of power plants	Installed capacity [MW_e]	Capacity in use [MW_e]	Annual production [GWh/a]	Average load %
The Geysers	32 (6 retired)	2,100	1,896	7,449	45
Imperial Valley	17 (1 retiered)	406.3	406		
Casa Diablo	3	27	27		
Honey Lake	3	8.3	8		
Coso	9	236	236	1,860	91
Hawaii	1	25	25		
Nevada	15	219.5	219		
Utah	4	31	31		
TOTAL	84	3,053	2,848	14,660	59

Total electricity generation from the geothermal power plants (where information was available) was 14,660 GWh in the year 1995. The average load factor for these geothermal power plants is 0.59.

Table 2. Summary of geothermal direct heat use

	Installed	Energy use		Load factor
	MW_t	TJ/year	GWh/year	
Space heating	169	1,388	386	0.26
Bathing and swimming	71	1,606	446	0.72
Agricultural drying	20	299	83	0.47
Greenhouses	81	709	197	0.28
Fish and animal farming	77	1,468	408	0.60
Industrial process heat	43	629	175	0.46
Snow melting	0.7	3	1	0.14
Air conditioning	0.7	5	1	0.23
SUBTOTAL	461	6,107	1,696	0.42
Heat pumps	1,444	8,188	2,274	0.18
TOTAL	1,905	14,295	3,971	0.24

SUMMARY OF GEOTHERMAL RESOURCES

	Electricity		Direct use	
	MW_e	GWh/y	MW_{th}	GWh/y
In operation	2,848	14660	1,905	3,971
Planned or under construction	130	3 000		
Estimated potential	130,000	1,100,000	2,500,000	22,000,000

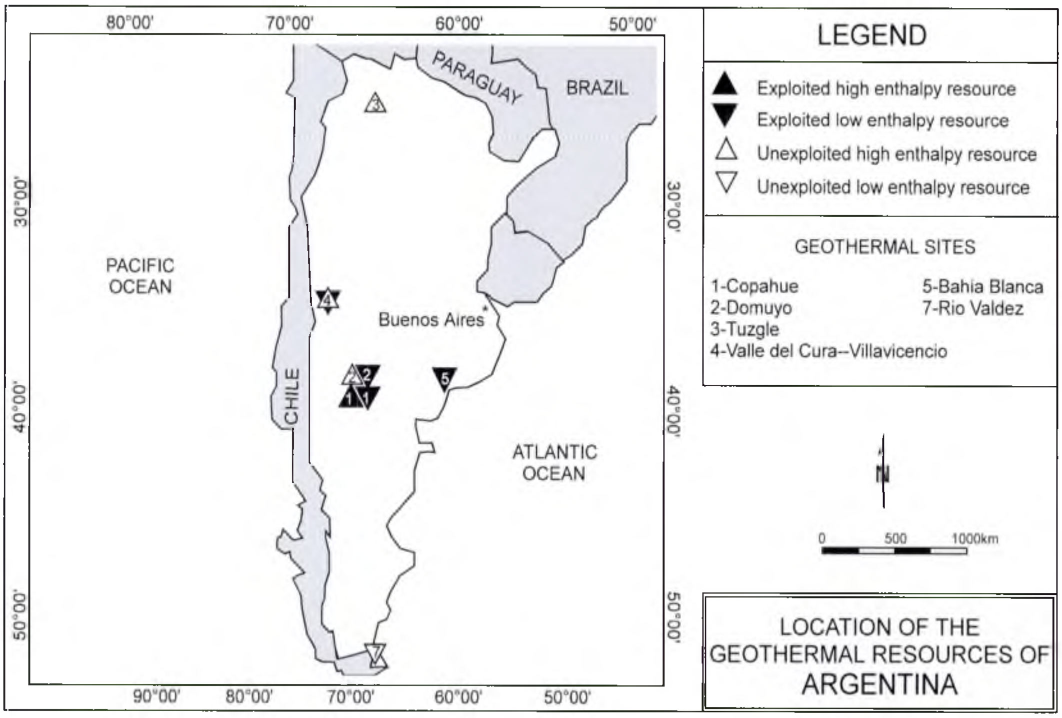
Annex 1.1

Central & South America

Argentina
Bolivia
Brazil
Chile
Colombia
Costa Rica
Ecuador
El Salvador
Guatemala
Honduras
Nicaragua
Panama
Peru
Venezuela

ARGENTINA

Size	2,766,890	km^2
Population (1995)	34.2	millions
Annual population growth rate (1993-94)	1.2	%
GNP per capita (1993)	7220	USD per year
Average annual growth rate of GNP (1990-93)	31.0	%
Average annual inflation (1995)	3.7	%
Annual energy use per capita (1993)oil equivalent	1367.5	kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (1993)	3.2	tonnes
Production of electricity (1995)	62811.7	GWh
Geothermal	3.5	GWh
Fossil fuels	28,826	GWh
Hydro	26,911	GWh
Nuclear	7,066	GWh
Wind	5.2	GWh



The geothermal programme in Argentina includes several projects.

ELECTRICITY GENERATION

There are four high enthalpy geothermal fields in the country, only one is producing electricity, and all of them are associated with Quaternary calc-alkalic to shoshonitic volcanism.

Neuquén Province:

-The project at *Copahue* is probably the most important of all schemes in South America; in April 1988, a 670kW binary cycle power plant, using an isopentane working fluid was built. The plant runs on 6.7tons/h of 171°C saturated steam and contains 8% non-condensable gas. The reservoir depth is between 850-1000m.

A feasibility study has been carried out for a new commercial-size station with a power-generating capacity up to 30MW.

- Reconnaissance surveys at the *Domuyo* field site suggest the existence of a vapour-dominated zone at 218-226°C overlying a liquid-dominated reservoir at 186-190°C. Pre-feasibility studies have been completed.

Jujuy and Salta Provinces:

- Geochemistry at *Tuzgle* suggests the presence of resources having temperature ranges of between 132-142°C. This project is in the pre-feasibility stage.

San Juan Province:

- *Valle del Cura* field hosts a boiling reservoir. The geochemistry suggests temperatures above 200°C and possibly a secondary shallow aquifer. This project has reached the pre-feasibility stage by 1995.

SUMMARY OF RESOURCES	
Exploited - plant in operation	0.67MWe
Unexploited - plant under construction or planned	-
Unexploited - proven resources	~30MWe
Unexploited - probable and possible resources	-

DIRECT USES

Several proposals for the direct and indirect use of the resources were made but only a few of them are underway to date: 45 projects are under regional assessment, 4 are under feasibility studies (*Tuzgle*, *Focomar*, *Antuco* and *Copahue*) and only *Bahia Blanca* (space heating, greenhouses) and *Copahue*, *Domuyo*, *Villavicencio* (space heating, hot water heating as well as recreation) are under commercial utilisation.

With the exception of *Domuyo* and *Tuzgle* where wells were drilled for thermal gradient measurements and *Copahue* where exploration wells are working in flash condition, production artesian wells represent the most common utilisation of geothermal waters in this country.

At *Copahue* wells have been drilled for electrical and combined uses (two exploratory and one production). They were drilled between 1981 and 19991 and reached a max. depth of around 1400m and a maximum temperature of 250°C for the productive well.

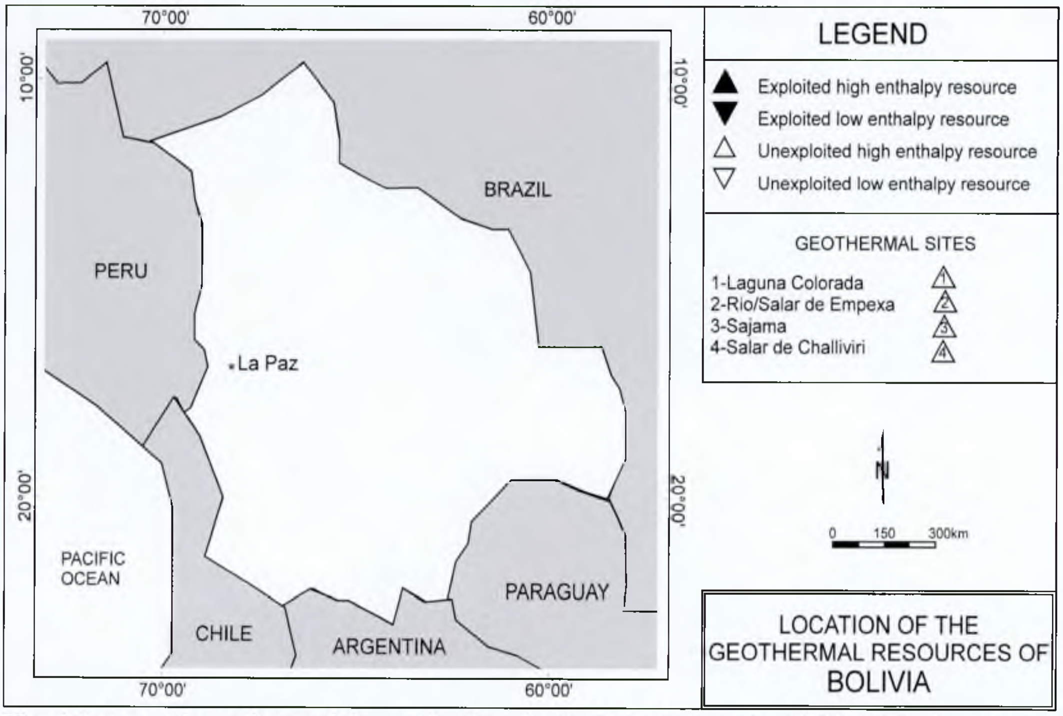
At *Rio Valdez* (Tierra del Fuego Province) and *Bahia Blanca-Pedro Luro* sedimentary basin (Buenos Aires Province) there are real possibilities of geothermal development for low temperature utilization at least.

For direct heat utilisation 50 artesian wells have been drilled from 1914 to 1991. Most wells were drilled in between 1954-1958 (13 wells), 10 were drilled between 1949-1953, 8 in between 1984-1988, 4 in between 1959-1963 and 3 in the following five years; two wells were drilled during each of the following five year periods: 1914-1918, 1969-1973, 1979-1983, and in 1924-1928, 1939-1943, 1944-1948, 1974-1978, 1989-1993 only 1 well was drilled per period, while no drillings were carried out during the 5 years periods 1919-1923, 1929-1933, 1934-1938, 1944-1948. Depths range from around

500 to around 1700m and temperatures are low (50-70°C) except for *Copahue* where is about 235-250°C. Flow rates vary widely from well to well from less than 1 to at least 61kg/sec.

BOLIVIA

Size	1,098,580	km^2
Population (1995)	7.9	millions
Annual population growth rate (1993-94)	-6.2	%
GNP per capita (1993)	760	USD per year
Average annual growth rate of GNP (1990-93)	2.8	%
Average annual inflation (1995)	12.5	%
Annual energy use per capita (1993)oil equivalent	317.5	kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (1993)	2.68	tonnes
Production of electricity (1995)	2,900	GWh
Geothermal	0	GWh
Fossil fuels	1,500	GWh
Hydro	1,400	GWh
Nuclear	0	GWh
Wind	0	GWh



The history of geothermal investigation in Bolivia began in 1971 with the inventory of the resources and the first prospecting. A certain amount of effort was put in the following years but a few results have been obtained. The pre-feasibility and feasibility studies were carried out aimed at the electricity generation by geothermal.

No low enthalpy project is known to date.

ELECTRICITY GENERATION

At *Laguna Colorada* area (*Apacheta* and *El Sol de Mañana* fields) in 1986 six deep wells of 1500m average depth were drilled (five of which are producers and one is considered an injector). Production tests were also performed. The following year reservoir evaluation and feasibility studies were fulfilled. Operating wells with an additional well will be sufficient to install up to 30MW using a condensing power plant. In 1993 a feasibility study was carried out for the pilot plant (6-10MW) and currently funding is being sort to install it. At this field the fluid is double phase and runs at 300-

360tons/h, the geothermal gradient is 300°C/km. Total capacity has been estimated at 350MW.

At *Rio / Salar de Empexa* a feasibility study was completed and some shallow wells drilled.

Most pre-feasibility studies, including at *Sajama* and *Salar de Challiviri* fields, were carried out between 1978-1979.

Summary of Resources	
Exploited - plant in operation	-
Unexploited - plant under construction or planned	-
Unexploited - proven resources	36-40MWe
Unexploited - probable and possible resources	350MWe

BRAZIL

Size	8,547,404	km^2
Population (1994)	155,8	millions
Annual population growth rate (1993-94)		%
GNP per capita (1993)		USD per year
Average annual growth rate of GNP (1990-93)		%
Average annual inflation (1995)		%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1994)	260,682	GWh
Geothermal		GWh
Fossil fuels		GWh
Hydro		GWh
Nuclear		GWh
Wind		GWh

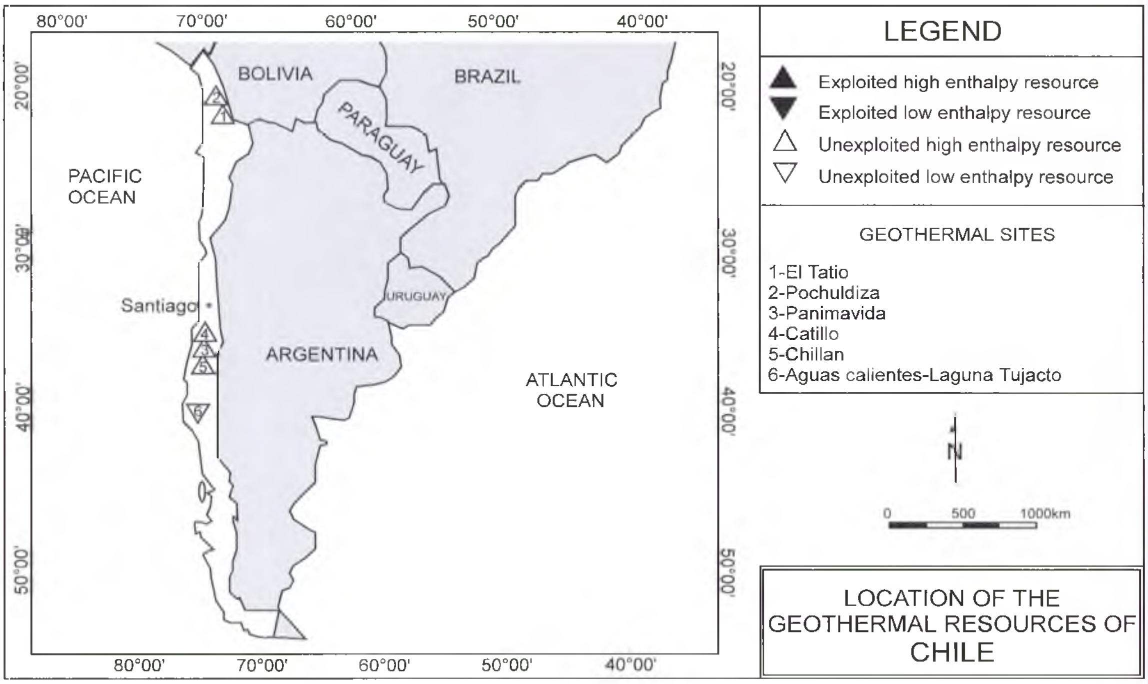
The occurrence of low temperature water is quite widespread in the Brazilian highlands, and more than 400 thermal mineral springs are known. Geochemical studies point to the possibility that at least a portion of the fluids originates from deep reservoirs, but there is no conclusive evidence for the existence of high enthalpy resources. Most of the springs are located in the metamorphic fold belts in central and eastern Brazil, and their occurrence seems to be intimately related to local fault and fracture systems. Nevertheless, the flow rates of some of these spring systems are quite impressive. Their temperature ranges from about 20° to about 80°C.

At present, geothermal waters are being used almost exclusively for balneological purposes. Industrial uses of thermal water have been attempted in the 1970s-1980s in two localities for wood processing (pre-cooking prior to peeling) and pre-heated feed water for boilers in the production of instant coffee.

The potential for large scale exploitation of low temperature waters for industrial use and space heating may be significant in the southern and south-eastern parts of the country, where relatively cold winters prevail.

CHILE

Size	756,950	km^2
Population (1994)	13.9	millions
Annual population growth rate (1993-94)	2.2	%
GNP per capita (1993)	3170	USD per year
Average annual growth rate of GNP (1990-93)	13.4	%
Average annual inflation (1996)	7.4	%
Annual energy use per capita (1995)oil equivalent	1225	kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (1995)	3.2	tonnes
Production of electricity (1995)	28,027	GWh
Geothermal	0	GWh
Fossil fuels	9,619	GWh
Hydro	18,408	GWh
Nuclear	0	GWh
Wind	0	GWh



Geothermal investigation started almost 30 years ago, and after a long period of inactivity, interest in geothermal resources of Chile reawakened due to new legislation that will allow private sector investment in those resources.

ELECTRICITY GENERATION

No power plant has been installed in the country up to the date.

Chilean high-enthalpy geothermal production is concentrated along the Cordillera mainly at the well known *El Tatio* field.

At *El Tatio*, 6 exploration wells revealed temperatures between 180-253°C into the pyroclastics at a depth of 600m. 7 production wells found three discrete reservoirs with temperatures up to 260°C. Only three out of the seven wells produce an average of 14.7kg/s (adequate for 6MW each) and two produce less but are capable of producing 5MW. A through estimate of the field indicate that a potential 100 MW could be realised.

Puchuldiza field is the second important field of the country but studies there are still at the beginning.

Three sites have been chosen for the pre-feasibility studies undertaken in 1993 and a significant geothermal potential has been revealed: *Panimávida* hot springs, *Catillo* hot springs and *Chillán* hot springs.

Prospective fields are likely to exist at the already mentioned field of *Pochuldiza* and *Chillán,* and moreover at *Suriri*, *Vegas del Flaco*, *Cajón de Calabozos*, *Tolguaca*, *Rio Blanco* (all these sites have geothermometric temperature between 150-280°C), *Polloquere* (superheated steam at the fumaroles with surface T=110°C), *Jurase*, *Chanchocó-Copahue* (possibly related with the already operating *Copahue* field in Argentina, *Petrohué*, *Alitar*, *Pampa de Lirima* and several other sites in the rest of the country.

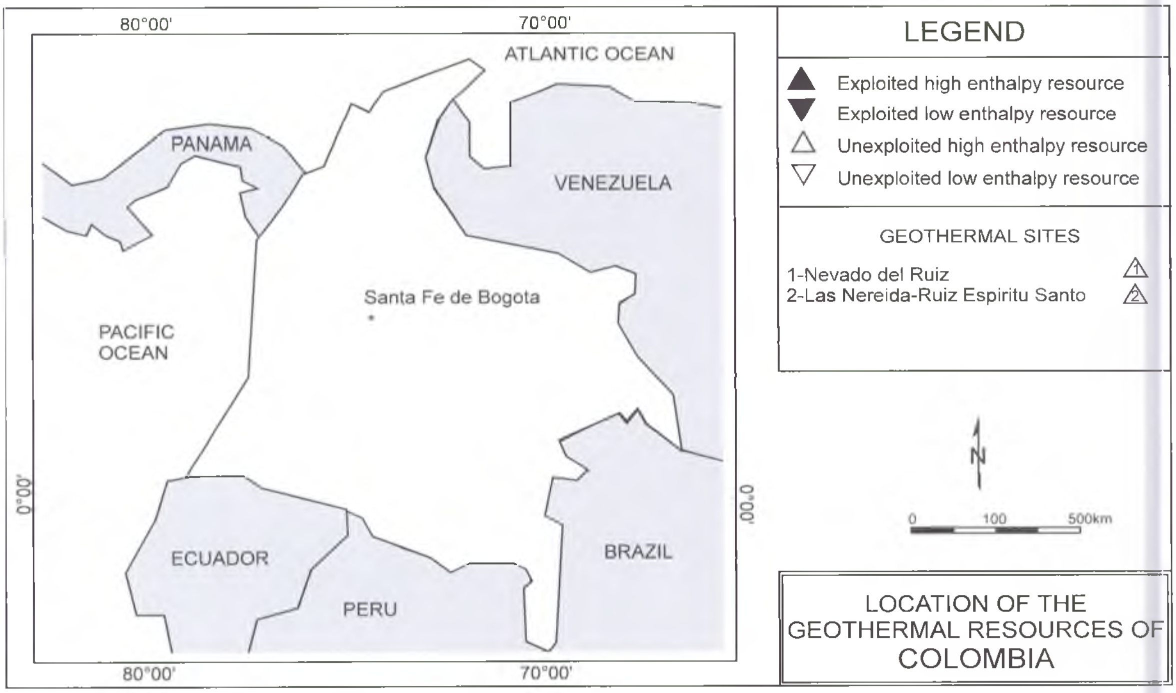
SUMMARY OF RESOURCES	
Exploited - plant in operation	-
Unexploited - plant under construction or planned	28MWe
Unexploited - proven resources	72MWe
Unexploited - probable and possible resources	-

DIRECT USES

Resources with temperature less than 100°C are abundant along the eastern edge of the Central Valley. Salt lakes (*salares*) like *Aguas Calientes Sur* and *Laguna Tujacto* are considered interesting thermal areas due to their water chemistry and the proximity to *El Taco* iron mine. The *Santiago* basin should be mentioned with geothermometric temperatures between 69-94 °C.

COLOMBIA

Size	1,138,910	km^2
Population (1994)	35.5	millions
Annual population growth rate (1993-94)	1.7	%
GNP per capita (1993)	1400	USD per year
Average annual growth rate of GNP (1990-93)	3.4	%
Average annual inflation (1996)	20.8	%
Annual energy use per capita (1995) oil equivalent	883	kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (1995)	1.6	tonnes
Production of electricity (1995)	47,000	GWh
Geothermal	0	GWh
Fossil fuels	10,000	GWh
Hydro	37,000	GWh
Nuclear	0	GWh
Wind	0	GWh



In 1968 the country began to devote some attention to geothermal energy.
The first reconnaissance study, completed in the early 1980s, was made through a regional survey which 20,000km^2 were identified for geothermal exploration suitable for electric power generation.

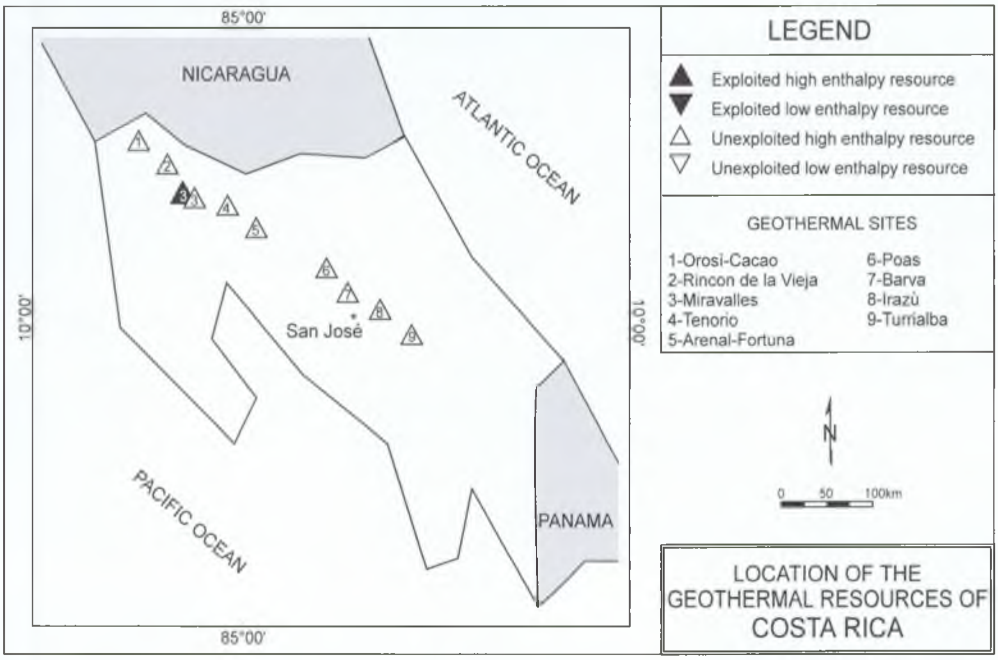
No low enthalpy project is known to date.

Electricity Generation

As a result of reconnaissance studies the area of *Nevado del Ruiz* volcano was identified as a prospect and a pre-feasibility study was carried out. In light of the catastrophic volcanic eruption of 1985 studies were discontinued and only started again in 1992. Feasibility is still in progress at *Las Nereida-Ruiz Espíritu Santo* geothermal field (*Villamaría* village) and the first 2000m deep exploration slim well is now underway.

COSTA RICA

Size	51,100	km^2
Population (1994)	3.34	millions
Annual population growth rate (1993-94)	2.5	%
GNP per capita (1993)	2150	USD per year
Average annual growth rate of GNP (1990-1993)	6.3	%
Average annual inflation (1994)	13.5	%
Annual energy use per capita (199) oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1995)	4,828	GWh
Geothermal	401	GWh
Fossil fuels	752	GWh
Hydro	3,675	GWh
Nuclear	0	GWh
Wind	0	GWh



Costa Rica is located in special geological setting, at the triple junction of three oceanic plates. Along the Cordilleran arc volcanic activity is intense and geothermal potentiality high.
Estimates indicate that 75% of the total heat resource is medium to low temperature (<150°C) while the remaining 25% heat is over 150°C. All these resources represent 0.3% of the resource base of the country.

No low enthalpy project is known to date except for bathing and swimming.

ELECTRICITY GENERATION

The estimated installaed capacity using a conventional cycle plant is 1,947MW for high temperature resources, and decreases to 865MW for high temperature reserves. If binary cycle plants were used the installed capacity would increase to 2,535MW for the resources and 1107MW for the reserves.
The most promising geothermal site is *Miravalles* geothermal field, at the base of *Miravalles* volcano.

Miravalles volcano area has been exploited between March-November 1994 and shows a reservoir temperature of around 255°C. At present a total of 60MW of power comes from Miravalles I which represents about the 5.6% of the total installed electrical capacity of the country. 55MW are generated by a single flash condensing plant while 5MW are generated using a non-condensing backpressure facility.

The Miravalles II project, which is already underway will see the installation of another 55MW single flash power plant and will start full operation in 1998. Part of the excess steam is already sent to 2×5MW back pressure plants installed and operated by the Mexican utility (CFE), and their use will continue until the steam is required for Miravalles II.

A third phase, the Miravalles III project for the installation of 27.5MW, is scheduled and drilling of 3 exploration wells (two of which have combined capacity of 14MW) has been completed. This would add 27.5MW.

Feasibility for another 27.5MW power plant, the Miravalles IV, is also underway.
The local utility is considering the utilisation of part of the heat contained in waste fluids to run small ancillary power plants with the purpose of optimising the use of geothermal resources and increasing the capacity of the field.

In the areas of *Tenorio* and *Rincòn de la Vieja* volcanoes two other large geothermal fields have been investigated in detail, including preliminary drilling. As a consequence of these pre-feasibility studies the former is estimated to have 120-160MW potential and the latter around 140-190MW. Feasibility studies started in 1996.

Geothermal areas in the vicinity of volcanoes *Irazù*, *Turrialba*, *Platanar*, *Poás* and *Barva* are estimated to have a geothermal potential of 100-115MW each.
Finally the *Fortuna* and the *Orosì-Cacao* volcanoes areas have a lesser potential with 70MW and 35MW geothermal potential respectively.

In Costa Rica a total of 39 wells have been drilled for electrical and combined use (14 production, 14 injection and 11 thermal gradient wells) in the *Miravalles*, *Tenorio* and *Rincòn de la Vieja* areas, totalling 5,1476m.

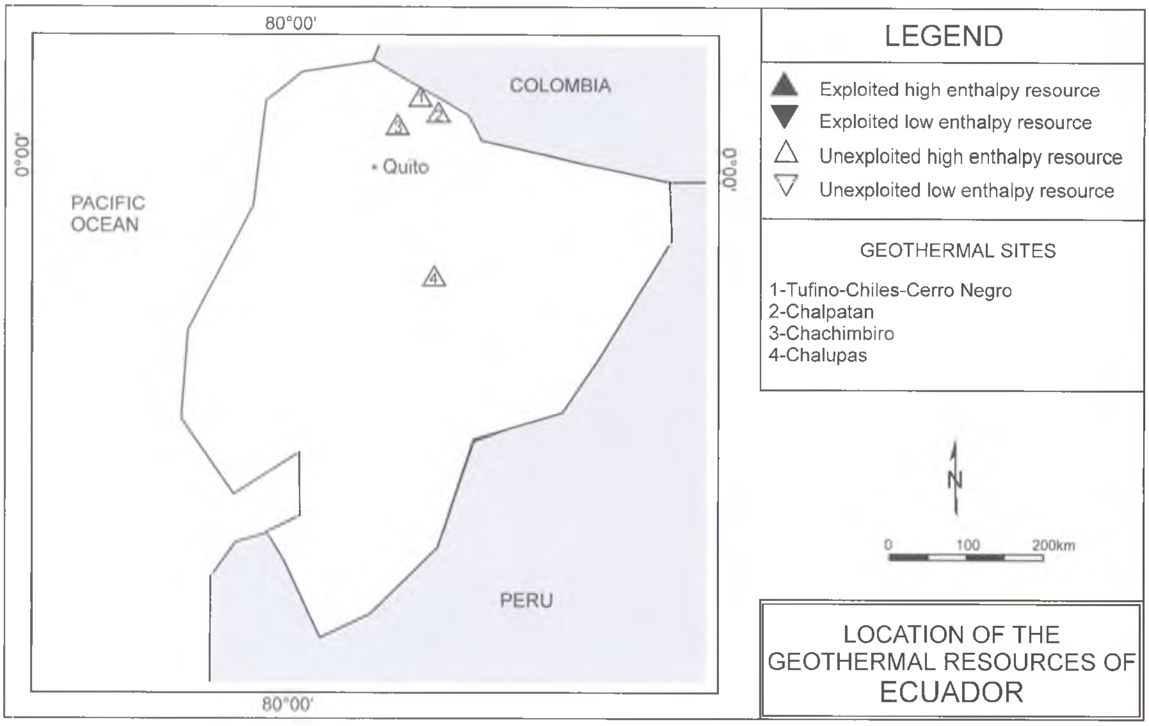
In 1995 the geothermal generation capacity of Costa Rica was 60MW (gross production: 447GWh/yr). At *Miravalles* another 55MW (gross production: 409.5GWh/yr) power plant is underway (Miravalles II) and power will be put on line on April 1998, while a 27.5MW capacity unit is expected for the year 1999 (Miravalles III).

By the year 2000, a total of about 152.5MW (gross production: 1200GWh/yr) will be provided by domestic geothermal resources representing 15% of the country's electricity supply.
By the year 2005 geothermal power supply will reach 207.5MW (gross production 1,565GWh/yr) which will be 8% of the company's total installed generation capacity of the country. No further geothermal development is scheduled until 2010.

Summary of Resources	
Exploited - plant in operation	60MWe(+10MWe)
Unexploited - plant under construction or planned	137.5MWe
Unexploited - proven resources	780-950MWe
Unexploited - probable and possible resources	1700-1800MWe

ECUADOR

Size	283,560	km^2
Population (1994)	11.2	millions
Annual population growth rate (1993-94)	1.8	%
GNP per capita (1993)	1200	USD per year
Average annual growth rate of GNP (1990-93)	7.0	%
Average annual inflation (1995)	23	%
Annual energy use per capita (1993) oil equivalent	705	kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (1993)	18	tonnes
Production of electricity (1996)	9,400	GWh
Geothermal	0	GWh
Fossil fuels	3,400	GWh
Hydro	6,000	GWh
Nuclear	0	GWh
Wind	0	GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF ECUADOR

In 1978 exploration began in Ecuador over the whole territory, and covered regional assessment, geological and geochemical stable isotopes studies, surface pre-feasibility studies including geophysics.

A theoretical evaluation of the geothermal potential based on volume estimates and heat flow measurements yielded the following results: at *Tufiño-Chiles-Cerro Negro* the base resources are 5.62×10^{19}J, resources 2.90×10^{18}J, reserves 4.93×10^{17}J this corresponds to a total installed capacity of 201MW; at *Chalupas* the base resources are 2.32×10^{19}J, resources 9.04×10^{17}J, reserves 3.79×10^{16}J which corresponds to a total installed power of 156MW; at *Chachimbiro* the base resources are 6.72×10^{19}J, resources 3.27×10^{18}J, reserves 4.56×10^{17}J which corresponds to a total installed capacity of 411MW.

No low enthalpy project is known to date except for bathing and swimming.

ELECTRICITY GENERATION

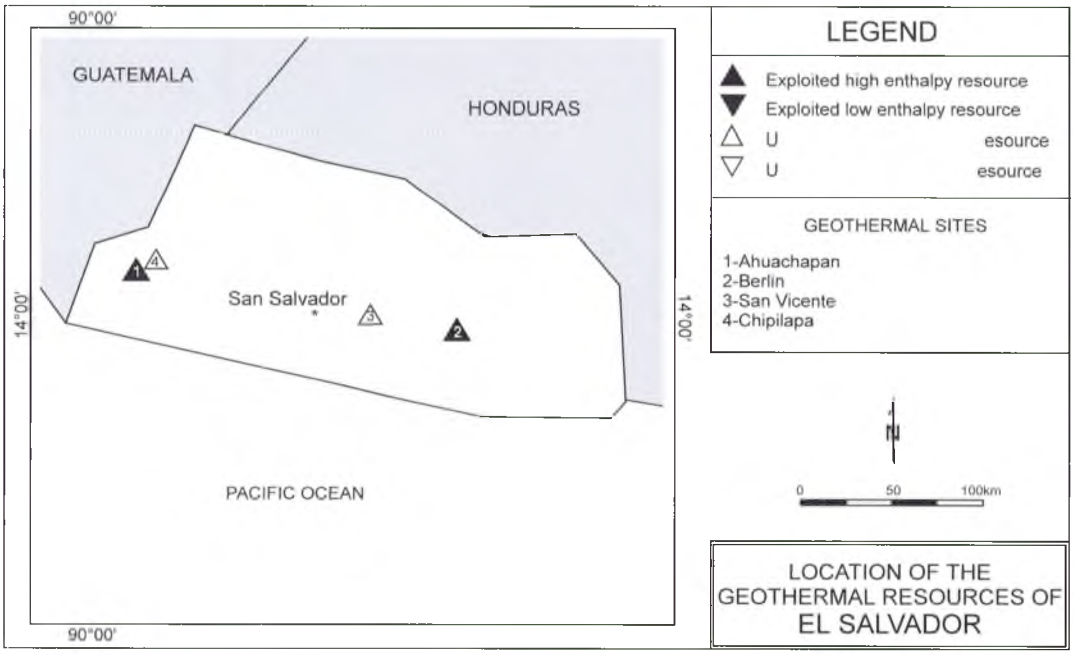
A prefeasibility study was carried out at *Tufiño-Chiles-Cerro* Negro where an only one shallow well was drilled (1987) to support geophysical data interpretation and at *Chalupas*, *Chachimbiro* and *Chalpatan* where surface surveys were carried out.

Only a fraction of the total geothermal potential corresponding to the economic reserves with temperatures >200°C, is considered as high enthalpy resources, and evaluation results indicate: *Tufiño-Chiles-Cerro Negro* 139MW, *Chalupas* 282MW and *Chachimbiro* 113MW.

SUMMARY OF RESOURCES	
Exploited - plant in operation	-
Unexploited - plant under construction or planned	-
Unexploited - proven resources	534MWe
Unexploited - probable and possible resources	768MWe

EL SALVADOR

Size	21,040	km^2
Population (1994)	5.67	millions
Annual population growth rate (1993-94)	2.0	%
GNP per capita (1993)	1320	USD per year
Average annual growth rate of GNP (1990-93)	8.6	%
Average annual inflation (1994)	10.5	%
Annual energy use per capita (199) oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1995)	3,585	GWh
Geothermal	485	GWh
Fossil fuels	800	GWh
Hydro	2,300	GWh
Nuclear	0	GWh
Wind	0	GWh



Several geothermal sites occur mainly in alignment with the young volcanic Cordillera and are well-known in the country. Some of them have already been exploited.
Since 1985, El Salvador has spent about US$ 22M on R&D, including the drilling of 6 wells plus US$ 34M on field development and equipment and about US$ 56M on electrical utilisation.
El Salvador is planning projects to turn geothermics into one of the main energy resources of the country. To date geothermally generated electricity produces around 15% of the whole electricity production.

No low enthalpy projects are known to date.

ELECTRICITY GENERATION

At the moment, *Ahuachapan* is the most important geothermal area of the country. In 1975 the first 30MW single flash power plant was put on line and in 1976 capacity doubled with an additional 30MW unit. In 1980 a third plant, 35MW double flash, brought the field into a total capacity of 95MW. 32 production wells were drilled for this project 14 of them are producers but unfortunately because the field has been overexploited, the reservoir performance has been affected, and because of the lack of reinjection capability, power output declined to 48MW.
The drilling of 10 new production and 4 injection wells brought an increase in pressure to the existing field. The field expansion should help to reach the maximum production for the installed 95MW of plant by 1997.

In the 1960s the *Berlin* geothermal area was explored with 6 wells down to 1400-2300m, where temperature of 230°C were encountered, but the project failed because of the low permeabilities. In 1980-1982 two wells with commercial characteristics were drilled and in 1992 2×5MW non condensing wellhead back pressure units were installed. Later, in 1993-1994, two new wells were drilled and encountered better permeabilities and temperatures of up to 275°C. A third 5MW non condensing wellhead unit has been on line since 1995. At present the plants are generating only 13MW. The drilling of an additional 16 deep wells, construction of a fluid transport device and assemblage of two generator units, totalling 28MW (two modular condensing units), is scheduled for 1998-1999.
Preliminary studies indicate that the potential capacity of this field could reach 150MW.

San Vicente area has been investigated intensively: good permeabilities and high temperatures have been recorded (a 1300m deep exploration well intercepted a 230°C aquifer). Pre-feasibility has been completed, four deep wells are planned to be drilled by 1998. Feasibility studies are underway. An estimated geothermal potential of 50-100MW.
Power could be available by the year 2010.

Chipilapa field which is hydrologically connected to Ahuachapán has recently installed two 5MW power plants.

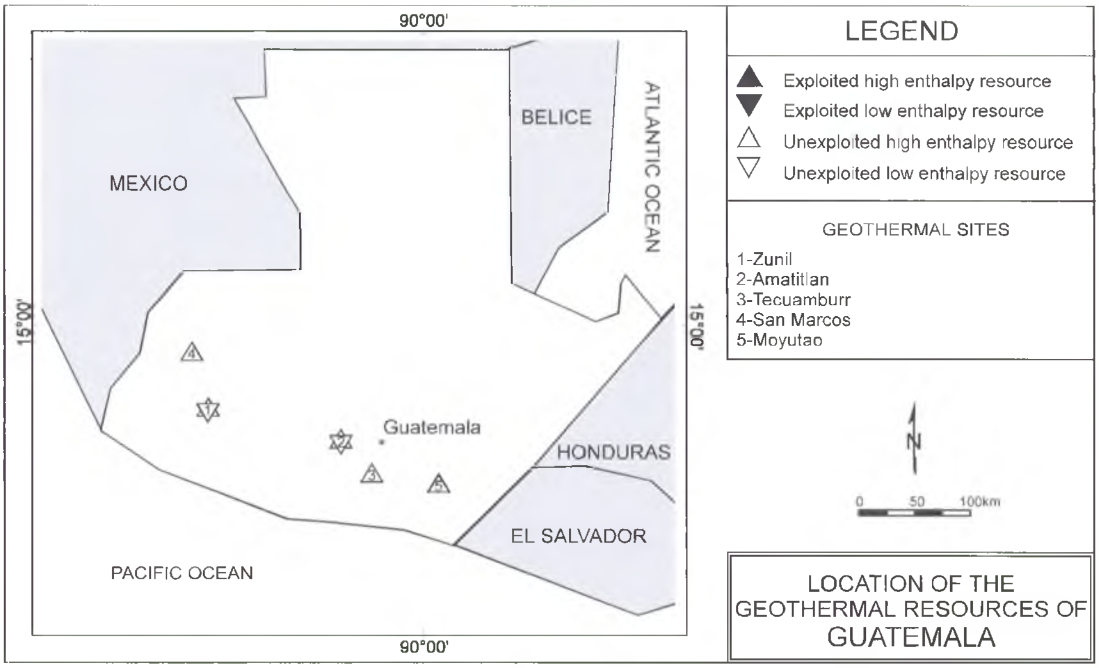
Studies are in progress in *Chinameca* (pre-feasibility), *Coatepeque* (pre-feasibility), *Chongagua*, *Santa Rosa Lima*, *Parras Lempa* (one exploratory well: 940m), and *Obrajuelo Lempa*.

The installed capacity at 1995 was 118 MWe the updated electricity generation at 1997 is about 105 MWe an expansion plan has started for an additional 150MW by the year 2010.

SUMMARY OF RESOURCES	
Exploited - plant in operation	105MWe
Unexploited - plant under construction or planned	28MWe
Unexploited - proven resources	150MWe
Unexploited - probable and possible resources	~200MWe

GUATEMALA

Size	108,890	km^2
Population (1994)	10.32	millions
Annual population growth rate (1993-94)	2.9	%
GNP per capita (1993)	1100	USD per year
Average annual growth rate of GNP (1990-93)	6.2	%
Average annual inflation (1994)	11.6	%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1995)	3,810	GWh
Geothermal	0	GWh
Fossil fuels	1,544	GWh
Hydro	2,266	GWh
Nuclear	0	GWh
Wind	0	GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF GUATEMALA

The arc-trench tectonic setting of Guatemala is marked by the plates junction and by several regional faults. Volcanism and the connected geothermal activity is concentrated along the Cordillera.

Up to date, no geothermal plants have been constructed but 54MWe are planned by the year 2000.

ELECTRICITY GENERATION

In the South-western most part of the Guatemalan volcanic belt 14 significant geothermal areas have been identified for steam power generation.

To date at *Zunil* I (*Quetzaltenango* area), 7 wells have encountered temperatures around 297°C at depths of 1500-2330m and a 24MW plant is under construction.

At *Zunil* II, a second field has been developed 3 slim-holes were drilled from 370-757m and the measured reservoir temperature was 245°C. One of the wells encountered commercial quality resources at 690m, producing 35t/h of dry steam. It is believed that this field may have the potential for fuelling 40-50MW.

At the *Amatitlán* field 4 exploratory wells were drilled in 1992-1993, ranging from 1500-2058m deep and have encountered temperatures from 230-300°C (production zone in the four wells is located 1110m deep). Two of these wells can produce a total of 24MW (one flow test was performed).

At *Tecuamburro* field regional assessment is underway. One slim-hole was drilled to 806m depth and found a bottomhole temperature of 235°C (with geothermometry indicating equilibrium at 300°C).

At *San Marcos* field geothermometry indicated a temperature of 250°C. Pre-feasibility assessment with exploratory drilling and detailed geophysical survey is underway.

In addition, at the *Moyuta* field studies have begun at a pre-feasibility level and the *Ipala* field is under regional assessment..

16 wells from 120-2230m were drilled between 1990-1994 and funds are committed for the installation of a total of 70MW. A total of 94MW of installed capacity is projected by the year 2000.

Summary of Resources	
Exploited - plant in operation	-
Unexploited - plant under construction or planned	94MWe
Unexploited - proven resources	~70MWe
Unexploited - probable and possible resources	-

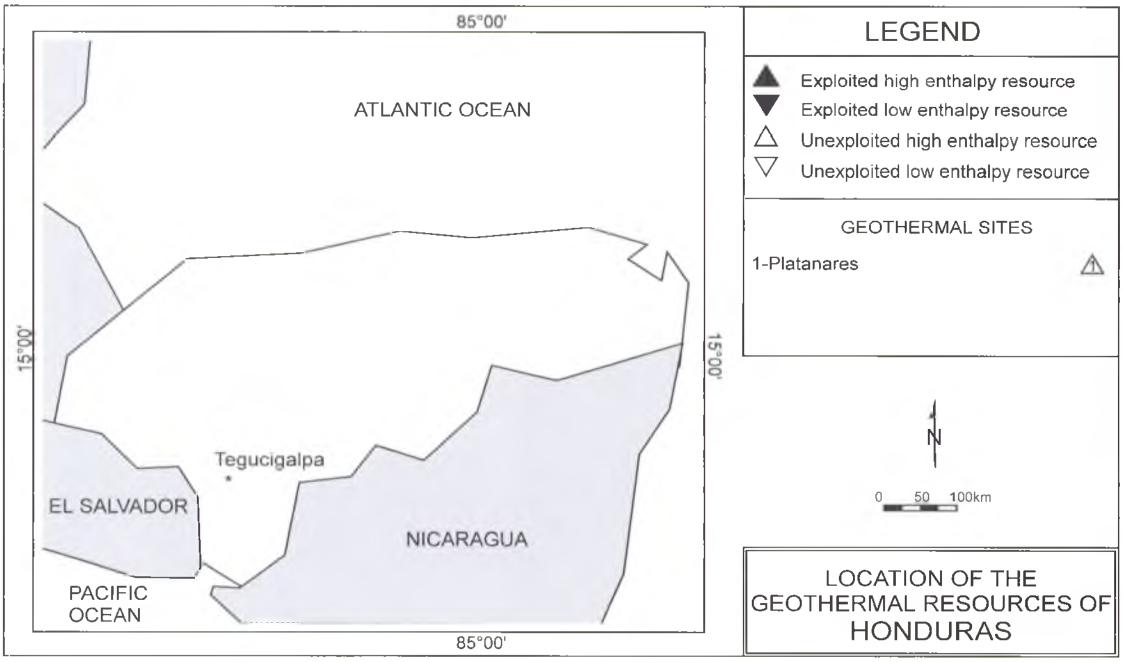
Direct Uses

In the area of *Zunil* I a farm-produce dryer plant uses steam from one of the slim holes to dry fruits and vegetables. Heat is also used for bathing/swimming. Energy use is 18.47TJ/yr and 5.28TJ/yr respectively.

At *Amatitlán* heat is used for industrial processes (brick drying for building) and for bathing/swimming. Energy use for the latter is 59.36TJ/yr.

HONDURAS

Size	112,090	km^2
Population (1994)	945.77	millions
Annual population growth rate (1993-94)	3.2	%
GNP per capita (1993)	600	USD per year
Average annual growth rate of GNP (1990-93)	-4.8	%
Average annual inflation (1994)	21.7	%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1995)	2,800	GWh
Geothermal	0	GWh
Fossil fuels	200	GWh
Hydro	2,600	GWh
Nuclear	0	GWh
Wind	0	GWh



The country was first studied in 1977. A geothermal interest scale was prepared for the area surveyed that includes *Platanares*, *Azacualpa*, *San Ignacio* and *Sula valley*, in the order, of the highest priority sites.

No low enthalpy project is known to date.

ELECTRICITY GENERATION

A feasibility study was carried out at the *Platanares* geothermal field between 1986 and 1988. Geophysics and exploratory drilling indicated high potential for electrical development.

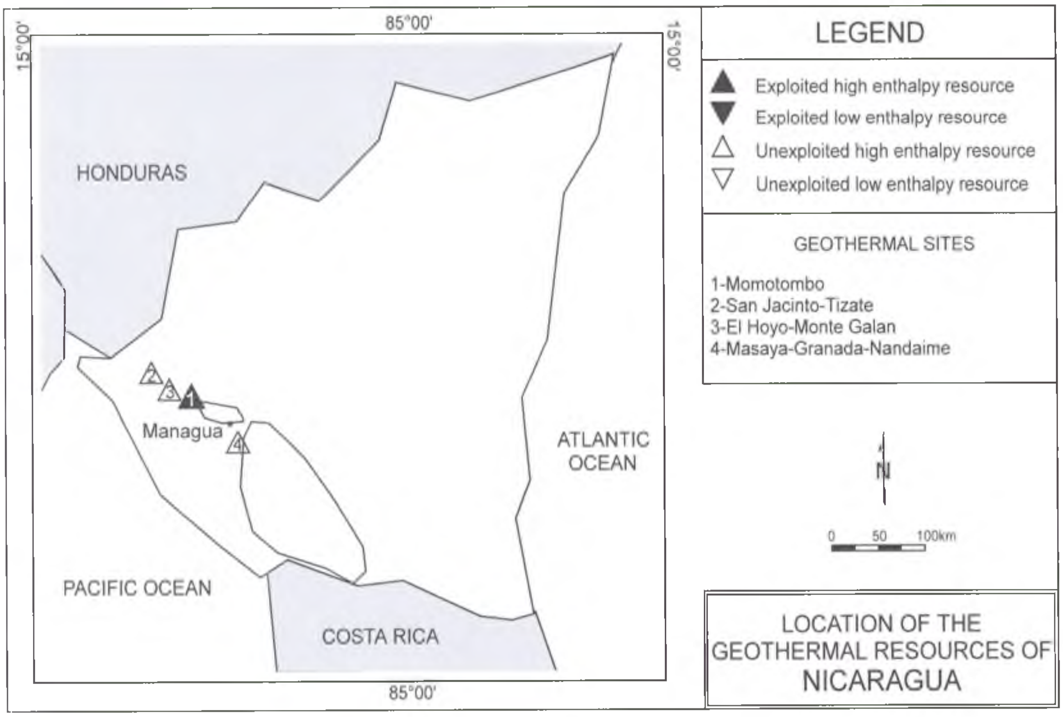
The *Platanares* field so far explored is capable of supporting 7MW.

Additional drilling to depths greater than 1,000m and, in due course, the placement of a generating plant at the wellhead has been considered.

Summary of Resources	
Exploited - plant in operation	-
Unexploited - plant under construction or planned	-
Unexploited - proven resources	7MWe
Unexploited - probable and possible resources	-

NICARAGUA

Size	129,494	km^2
Population (1994)	4.4	millions
Annual population growth rate (1993-94)	3.0	%
GNP per capita (1993)	340	USD per year
Average annual growth rate of GNP (1990-93)	0.3	%
Average annual inflation (1994)	7.8	%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1995)	1625	GWh
Geothermal	310	GWh
Fossil fuels	900	GWh
Hydro	415	GWh
Nuclear	0	GWh
Wind		GWh



Geothermal investigation began in the late 1960s along the Cordillera de *Los Marrabios*, in the graben of Nicaragua. Priority was given to the *Momotombo* and *San Jacinto Tizate* fields, but several other geothermal sites are significant.

No low enthalpy project is known to date.

ELECTRICITY GENERATION

Momotombo field, at the base of the homonym volcano, was exploited in 1983 with the first 35MW power plant and in 1989 a second equal power plant was operating. At present, power is reduced to 40MW but further drilling is planned for the beginning of 1997 which will recover the lost capacity. In 1997 feasibility and eventual installation of a third unit (20MW) is planned.

At *San Jacinto-Tizate* drilling started in 1992. Seven production wells have been completed to depths from 728m to 2,339m of which three can generate 23-30MW where the potential for exploitation has been proven. The objective is the installation of 5×24MW units (estimated potential is 120MW). This project has reached a hiatus but the installation of the first 24MW power plant is scheduled to start operating in 1998 and four equal power plants will be operating by 1999, 2000, 2001, 2002.

Studies up to a pre-feasibility level have been carried out at *El Hoyo-Monte Galán*, *Masaya-Granada-Nandaime*.

At *El Hoyo* there are two projects; *El Hoyo* I in which feasibility is planned in 1997 and the installation of three power units is expected in 1998 (35MW), 2000 (35MW), 2001 (35MW), and *El Hoyo* II that includes a feasibility study by the year 2000, and possible installation of three units in 2002 (35MW), 2004 (35MW), 2005 (35MW).

At *Masaya-Granada-Nandaime* feasibility is planned in 2004 and installation of three power units in 2005 (35MW), 2008 (35MW), 2009 (35MW).

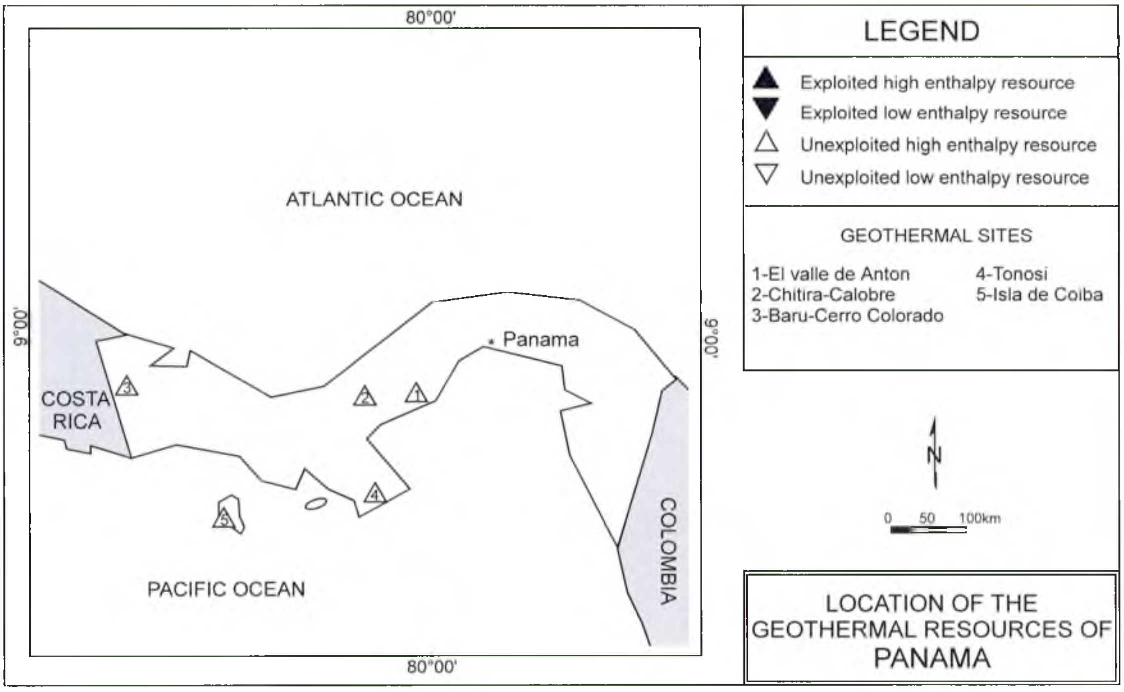
Reconnaissance studies are taking place at *Cosigüina*, *Casita* and *Telica-El Ñajo* volcanoes, *Managua-Chiltepe*, *Masaya-Tipitapa*, *Isla de Ometepe*.

All the above geothermal anomalies give an estimated potential of 3000MW.

Summary of Resources	
Exploited - plant in operation	40MWe
Unexploited - plant under construction or planned	465MWe
Unexploited - proven resources	-
Unexploited - probable and possible resources	~2,500MWe

PANAMÁ

Size	78,200	km^2
Population (1994)	2.6	millions
Annual population growth rate (1993-94)	0	%
GNP per capita (1993)	2600	USD per year
Average annual growth rate of GNP (1990-1993)	8.4	%
Average annual inflation (1994)	1.3	%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1995)	3,600	GWh
Geothermal	0	GWh
Fossil fuels	1,100	GWh
Hydro	2,500	GWh
Nuclear	0	GWh
Wind	0	GWh



Due to extensive investigation and evaluation of the country four geothermally attractive areas have been recognized: *El Valle de Antón* (Panamá-Coclé province), *Chitira-Calobre* and *Tonosí* (Veraguas-Coclé province), (Veraguas province). Reconnaissance studies carried out in those areas revealed *El Valle de Antón* field as the most interesting for the occurrence of a big caldera collapse structure and optimal hydrological and sealing conditions.

No low enthalpy project is known to date.

ELECTRICITY GENERATION

In 1971 geothermal exploration began in the country. A first reconnaissance study characterised *Cerro Pando/Barù-Colorado* as an high priority area. Pre-feasibility studies, including drilling, revealed that exploration risk was too high to proceed investigating further.

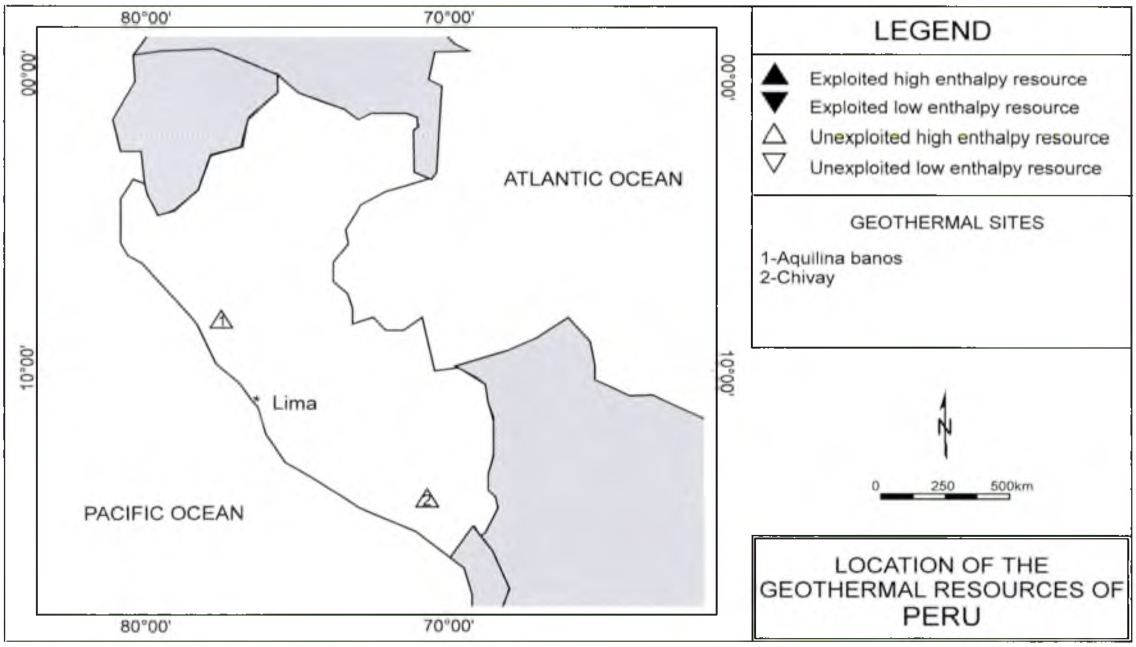
Later, two other projects aimed at the generation of electricity, at *El Valle de Antón* and *Chitira-Calobre* fields, were brought to an advanced pre-feasibility stage. However, because of the financial and political situation of the country activities were interrupted in 1988.

New funds were made available from 1995 and reactivation of the *El Valle de Antón* project is impending. The next step will be the determination of the geothermal potential. *Chitira-Calobre* is considered a high risk project because of the low thermal anomaly.

Isla de Coiba and *Tonosí* do not offer an interesting prospect for high enthalpy resources at an economic depth.

PERU

Size	1,285,220	km^2
Population (1994)	23.4	millions
Annual population growth rate (1993-94)	2.2	%
GNP per capita (1993)	2600	USD per year
Average annual growth rate of GNP (1990-93)	8.4	%
Average annual inflation (1995)	11	%
Annual energy use per capita (1994)oil equivalent	475	kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (1994)	1.08	tonnes
Production of electricity (1995)	15,600	GWh
Geothermal	0	GWh
Fossil fuels	3,900	GWh
Hydro	11,700	GWh
Nuclear	0	GWh
Wind	0	GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF PERU

As well as other countries embraced in the 'Pacific ring of fire' Peru is characterised by high heat flow and over 2,000 hydrothermal sites which have been identified along the volcanic chain.
More than 300 areas have surface temperatures of 40-89°C.

ELECTRICITY GENERATION

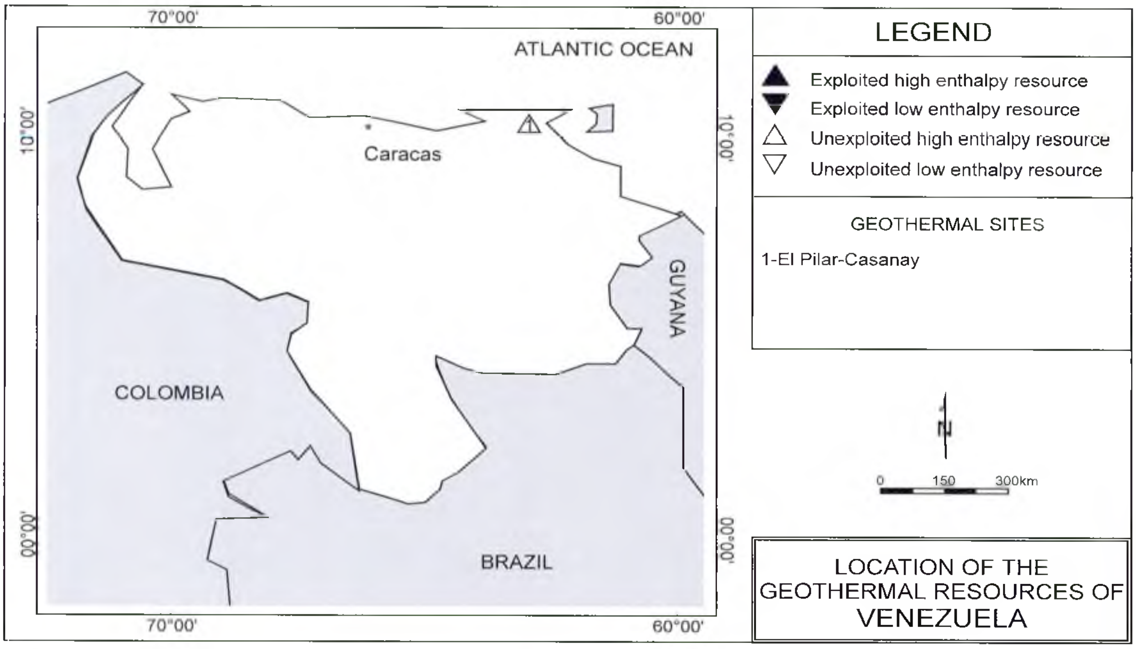
Pre-feasibility studies carried out in the 1980s for electricity generation identified two priority geothermal areas:
Aquilina Baños - department of Huaráz - in the north and *Chivay* - department of *Arequipa* - in the south, the latter being more interesting.
Both areas seem to have the potential users (including for direct uses) and the possibility for the installation small geothermal power plants.
Pre-feasibility studies carried out in *Callerón de Huaylas* (*norte*, *centro*, *sur*), *Otuzco* and *La Grama*, *Aguas Calientes*, *Cajamarca*, included geochemical prospections, thermal gradient measurements and resistivity surveys. Some recent geochemical and

isotopic analyses suggest reservoir temperatures in the 180-210°C range, at a site 1,200km southeast of *Lima*.

The country wishes to reduce its dependence on fossil fuels and hydro power but there has been no geothermal development in Peru.

VENEZUELA

Size	912,050	km^2
Population (1994)	21.1	millions
Annual population growth rate (1993-94)	2.4	%
GNP per capita (1993)	2840	USD per year
Average annual growth rate of GNP (1990-93)	2.4	%
Average annual inflation (1996)	109	%
Annual energy use per capita (1994)oil equivalent	112.7	kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (1994)	6	tonnes
Production of electricity (1995)	74,000	GWh
Geothermal	0	GWh
Fossil fuels	19,000	GWh
Hydro	55,000	GWh
Nuclear	0	GWh
Wind	0	GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF VENEZUELA

The only geothermal development in Venezuela is balneology in many of the 361 geothermal localities. Interest in electricity generation has come from the high temperature systems of *El Pilar-Casanay* (State of Sucre) which has been previously evaluated but never developed further.

ELECTRICITY GENERATION

Since the early 1980s regional exploration has led to a detailed geochemical and pre-feasibility study of *El Pilar-Casanay* field. A water-steam shallow reservoir with temperatures of 200-220°C and a deep liquid dominated reservoir at 250-300°C has been inferred. Fluids are composed of a medium salinity neutral brine with high CO_2 partial presure. A partial self-sealing system with a meteoric water recharge exists. The possible users, for both electricity and direct applications, have also been identified.

Geothermal systems with temperatures in the range of 100-150°C are not sufficiently documented except for *El Pinto* in Monagas and *Ño Carlos* and *Cariaco* in Sucre.

Direct Uses

Low temperature resources between 60 °C and 100°C occur in several localities around the Eastern Mountain Massif and *San Diego*, *Naricual* and *Clarines* in Anzoátegui, and *Qda. Seca*, *Pantoño*, *Cariaco* and *Los Impures* in Sucre.

These resources are used for bathing spas but could also be useful in direct applications for food-related industries; geothermal energy must be able to compete with the low cost of Venezuelan electricity and oil.

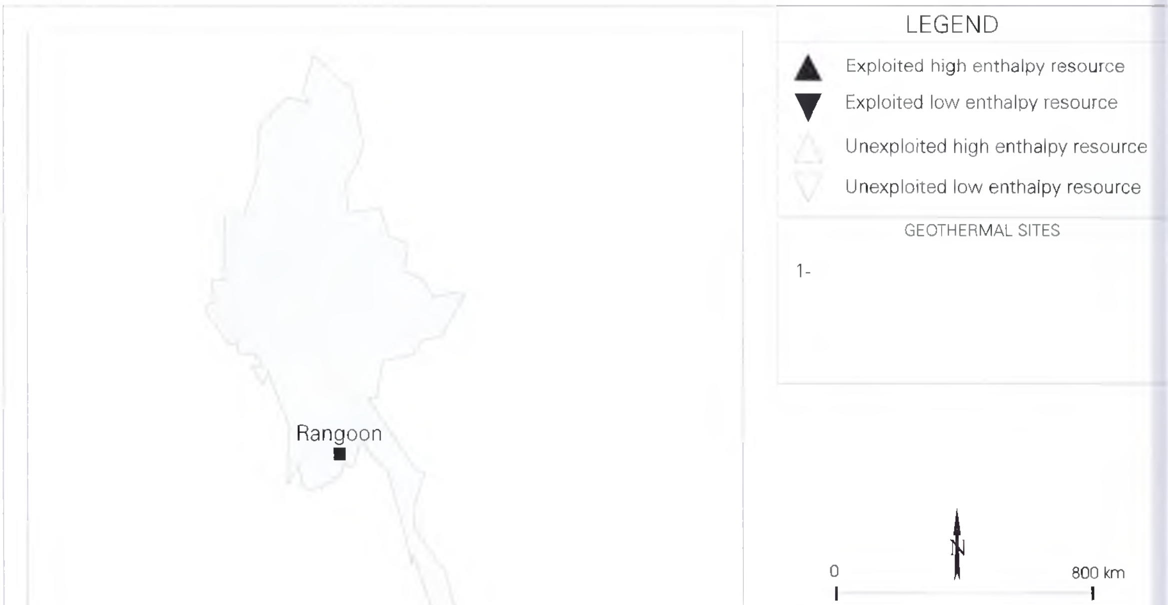
Annex 1.1

Asia

Burma
China
India
Indonesia
Iran
Israel
Japan
Jordan
Laos
Lebanon
Nepal
Kazakhstan
Korea
Kyrgyzstan
Pakistan
Philippines
Sri Lanka
Taiwan
Thailand
Turkmenistan
Uzbekistan
Vietnam

BURMA

Size	678,528	km^2
Population (1994)	45.5	millions
Annual population growth rate (1994)	2.2	%
GNP per capita (1994)	900	USD per year
Average annual growth rate of GNP (1993-94)	+6.0	%
Annual inflation (1994)	22.2	%
Average annual inflation		%
Consumption of energy (1994) oil equivalent	1.85	millions t
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity (1993)	3,369	GWh
Geothermal		GWh
Fossil fuels	1,802	GWh
Hydro (1992)	1,567	GWh
Nuclear (1994)		GWh
Wind		GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF **BURMA**

Burma is located on the eastern edge of the Himalaya Chain where intense deformation and faulting has taken place. It consists of a low-lying central belt comprised of Tertiary marine deposits bordered by two igneous belts running North-South. The lands of the coastal area are filled with deltaic deposits which extend out into from the Bay of Bengal and overly a Tertiary rock basement. Tertiary to Quaternary volcanism occurred in the central belt (Mount Popa) and the coastal area.

A total of 97 hot springs are known in areas of recent volcanism and along the main faulted zones in the central belt and Southern Burma. A preliminary survey has been made on 43 hot springs in 1986. Water temperatures range from 25 °C to 65°C. Estimated deep temperatures using Na-K-Ca or Na/k geothermometers vary from 150 to 350°C.
No geothermal exploitation is known to date.

CHINA

Size	9,596,961	km^2
Population (1994)	1.2	billions
Annual population growth rate (1994)	1.49	%
GNP per capita (1994)	425	USD per year
Average annual growth rate of GNP (1993-94)	+11.8	%
Annual inflation (1994)	21.7	%
Average annual inflation		%
Consumption of energy (1992) oil equivalent	700	millions t
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity		GWh
Geothermal	980	GWh
Fossil fuels		GWh
Hydro	132,500	GWh
Nuclear	1,800	GWh
Wind		GWh

LOCATION OF THE GEOTHERMAL RESOURCES OF **CHINA**

China has large geothermal resources, including low-to-intermediate and high temperature geothermal systems, disseminated throughout the country. Around 3,000 geothermal systems have been mapped, including less than 200 sites suitable for electricity generation.

ELECTRICITY GENERATION

High temperature geothermal systems are mainly concentrated in zones of recent volcanism and tectonic activity, i.e. the Himalayan Belt and Taiwan. Along the Himalayan Belt, they are disseminated in an area of 2000km long and 200-400km wide in Southern Tibet, Western *Yunnan* and Western *Sichuan* Regions. A 112 geothermal localities are known in Tibet, 47 in Yunnan and 12 in *Sichuan*. Most of these fields are remote areas where conventional energy is limited, and the population density is low.
Seven geothermal power plants have been installed in China, with a total capacity of

32.2MWe. These are: *Yangbaijian*, *Shiquanhe*, *Naqu*, *Tuchang*, *Dengwu*, *Huitang*, *Quingshui*.

In Tibet, the following geothermal plants occur:
- *Yangbaijian:* It is the largest power plant in China. 18 production wells (200m deep) have been drilled and produce 140-160°C waters. The total installed capacity is 25.2MWe, generated by nine single flash, double flash and hybrid cycle power units. Resources are estimated to be important and the capacity could increase (50-80MWe by the year 2000; 100-150MWe by the year 2010). A new well drilled in 1993 in northern part of the field produced 330°C waters at 2000m depth and its potential is estimated to be 10MWe. Waste thermal waters are used for heating greenhouses (50,000m^2).

Shiquanhe (or Langjiu): A 180°C reservoir has been identified and a 2MWe plant was built in 1987. It does not run continuously due to cold water invasion of the reservoir.
Naqu: A 1MWe binary cycle power plant uses 110-113°C waters (well head temperature) from a 170°C reservoir.

In SE China (*Guangdong* Province), two single flash power plants are using 90°C waters: *Dengwu* (0.686MWe) and *Huitang* (0.30MWe). They operate intermittently.

Others geothermal fields are under investigation:
Yangyi in Tibet: an estimated 30MWe potential for electricity generation is related to the occurrence of a shallow reservoir (300m) with 207°C waters.

In *Yunnan*, the high temperature geothermal fields are:
Rehai-Tenchong: Abundant surface manifestations are known in the *Rehai* area and used for bathing. Deep reservoir temperature is estimated about 276°C and its potential to be more than 200MWe.
Reshuitang-Lanpu: Surface-boiling hot springs are known and reservoir temperatures are estimated to be between 160-220°C. The potential installed capacity could be 100MWe.
Redian: Reservoir temperature and extent are estimated to about 190°C and 3.2km^2, respectively. It corresponds to a potential capacity of 47MWe.
Reli: The estimated potential capacity of the 215-227°C reservoir is 20MWe.

In Western Sichuan, there are small fields near *Litang* and *Chaluo*, with temperature up to 220°C and a 10MWe potential.

Further development of electric generation in China would be focused on Tibet and *Yunnan* Regions. Installed capacity of existing plants will be increased and new plants will be installed (*Xietongnen* in Tibet; *Rehai*, *Reli* and *Pannazhang* in *Yunnan*; *Yangyi* and *Litang* in *Sichuan*). Estimations of the geothermal potential are 1,000MWe in South Tibet, 570MWe in West *Yunnan* and 170MWe in West Sichuan.
The article 48 of the Electricity Law, which was taken effect in China on April 1, 1996, stipulates the encouraging and supporting policies of China government for developing geothermal energy and other new energies, through favourable policies on price of electricity and taxes.

Summary of Resources	
Exploited - plant in operation	32.2MWe
Unexploited - plant under construction or planned	
Unexploited - proven resources	
Unexploited - probable and possible resources	1,840MWe

Direct Uses

Low to intermediate temperature geothermal resources are widespread in China. They are developed in large-scale sedimentary basins covering 36% total area of China. The main basins are: *Sanglio*, North China, *Eerduos*, *Erlian*, *Jianghan*, *Sichuan*, *Talimu*, *Chaidamu*, *Zhungeer*. Among them, North China and *Jiangsu* Basins seem to be the most promising areas for geothermal resources.

Low to intermediate temperature geothermal resources are also developed in regions of high heat flow. These are:

SE China (*Fujian*, *Guangdong*, E *Jiangxi*, S *Hunnan* Provinces). More than 600 hot springs have been mapped with temperatures ranging between 40-95°C. Exploration has been carried out on several hydrothermal systems and reservoir temperatures estimated : *Zhangzhou* (140°C), *Yangjiang* (140°C), *Fuzhou*, *Dengwu* (135°C), *Baoting* (120°C), *Huitang*;

Shangdong-Liaoning area, along the *Tancheng-Lujiang* Fault Zone;

Fen-Wei Graben, West of *Pekin*;

W *Sichuan*-N *Yunnan* to NE *Tengchong* zone, corresponding to a north-south, trending tectonic and seismic zone.

Highest reservoir temperatures are observed along the coastal area of SE China.

Low to intermediate temperature waters are widely used in China. In 1995, total flow rate of thermal waters for direct uses was 5996 kg/s. Annual energy use was 16 981 TJ from an installed capacity of 1,914MWt with an average load factor of 28%. The main direct uses are:

Space heating, mainly in North China (1,313,000m^2 of heating area in total). In *Tianjin* area (*Tanggu*, *Hangu*, *Dagan*), about 50 wells produce 83l/s thermal waters with temperature up to 97°C to heat 805,000m^2 (334GWh);

Greenhouses (1,159,156m^2 in total; 100,000m^2 at *Xiaotangshan*, near Beijing);

Fish farming (1,600,000m^2 in total; 650,000m^2 at *Xiaotangshan*; 60,000m^2 at *Tangshan*);

Bathing (594 baths, 23 swimming pools, 179 sanatoriums);

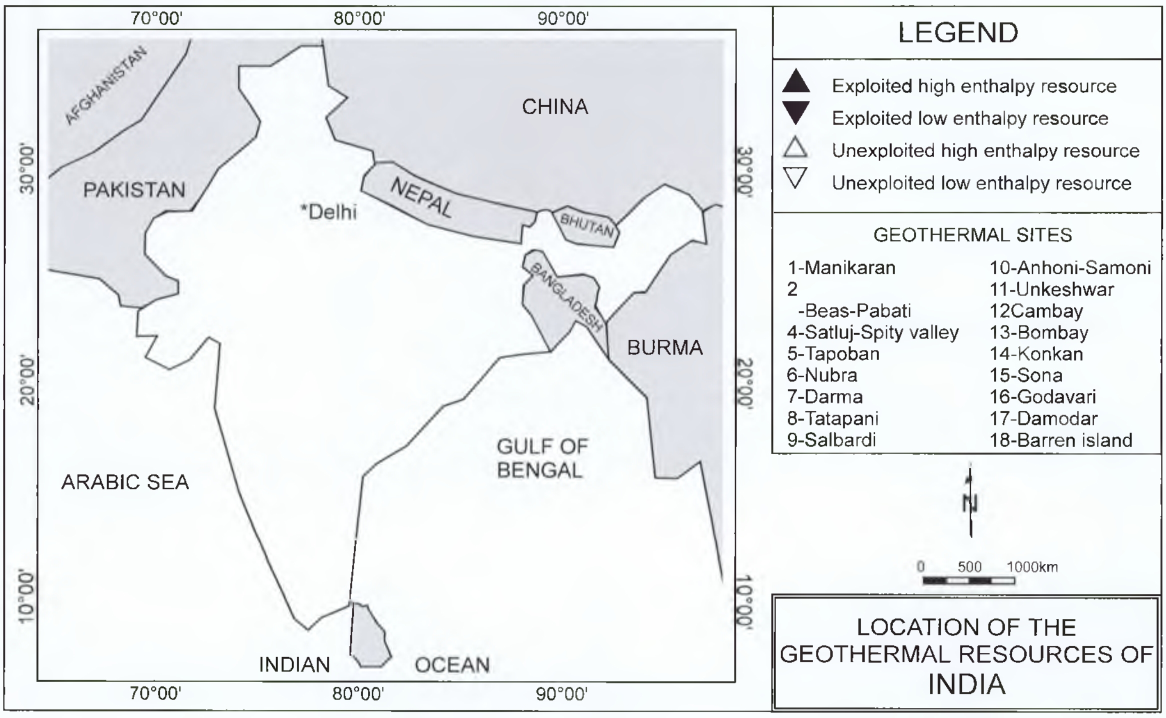
Industrial heat process; 49 known projects using thermal waters for dyeing, drying fruits and vegetables, paper and hide processing, air conditioning and pre-heating boiler feed water,...).

There are good prospects for future geothermal exploitation as environmental and economic constraints favour the development of the geothermal resources for district heating particularly close to the load centres.

Summary of Resources	
Exploited - plant in operation	1,914MWt
Unexploited - plant under construction or planned	
Unexploited - proven resources	
Unexploited - probable and possible resources	

INDIA

Size	3,287,590	km^2
Population (1994)	920	millions
Annual population growth rate (1993-94)	2	%
GNP per capita (1993)	300	USD per year
Average annual growth rate of GNP (1990-93)	-6.6	%
Average annual inflation (1995)	8.3	%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1995)	398,280	GWh
Geothermal	0	GWh
Fossil fuels	320,000	GWh
Hydro	71,000	GWh
Nuclear	7,225	GWh
Wind	55	GWh



Due to its tectonic context, India is not particularly well placed for geothermal energy, however there is geothermal development potential on the *Andaman Nicobar* island and at several places across the sub-continent were the astenosphere is thinner and heat flow anomlaies occur.
Geothermal exploration has comprised detailed reconnaissance and evaluation which has been limited to North Western Himalaya and parts of central and western India.
Preliminary total geothermal power potential is estimated to be 2,000-10,000MW. Most resources are of intermediate temperature type.

Himalayan Province:

-*Puga-Chhumathang area*: there are several thermal springs with temperature up to 87°C. At *Puga* geophysic surveys indicate a reservoir at 1-3km, drilling (34 wells with maximum depth 385m) and other studies indicate reservoir temperatures of 180-260°C.

At *Chhumathang* 6 wells to a depth of 221m discharged water-steam mixture of 109°C. Reservoir temperature is being estimated 160-200°C.

-*Beas and Parbati Valleys*: at *Beas Valley* eight thermal springs have temperatures of 30-57°C. 18 wells 50-500m deep have been drilled. Reservoir temperatures are estimated to be 120-160°C. At *Parbati* Valley six springs are around 21-90°C. 19 wells 57-707m deep have been drilled with maximum temperatures reaching 101°C. Reservoir temperatures are estimated to be 186-202°C at the most promising site (*Manikaran*) while other reservoir temperatures are 170°C (Jan), 100°C (*Kasol*), 150°C (*Khirganga*).

-*Satluj and Spity Valley*: in 12 thermal localities temperatures are 23-73°C. 5 exploratory holes were drilled to a maximum depth of 183m. The reservoir temperature is estimated to 110-212°C.

-*Tapoban area*: there are 12 springs with temperatures of up to 65°C. 5 shallow (50-52m) and 4 medium depth (291-728m) wells were drilled during 1975-1990. The estimated reservoir temperature is 160-200°C.

-*Other localities*: the most promising site, in *Nubra Valley*, have springs up to 76°C. Reservoir temperature is estimated to be 110-180°C.
In *Darma Valley* springs have 80°C and reservoir temperature is expected to be less than 140°C.

Son-Narmada-Tapti Province:

-*Tatapani area*: is considered a possible future geothermal field.
Springs have temperatures between 58-98°C. A number of wells have been drilled here. A reservoir is likely to occur at a depth 1-3km with temperatures from 112±30°C (1km) to 230±40°C (3km).

-*Salbardi area*: thermal springs have temperatures around 38-42°C and the reservoir temperature is estimated to be 110°C.

-*Anhoni-Samoni area*: at *Anhoni* springs temperature is 30-42°C. A few wells were drilled to a depth of 635m where temperatures were around 50°C.

-*Unkeshwar area*: springs have temperatures between 30-42°C. The estimated reservoir temperature is about 100°C.

West coast Province:
-*Cambay graben*: hot water with steam was encountered during oil drillings.
Temperatures at 3km depth are estimated to be 150-200°C.
-*Northern and Eastern Bombay offshore*: from temperature gradients, 125-225°C are expected at 3km depth.
-*Konkan area*: 60 thermal springs have temperatures of between 34-71°C. 10 wells were drilled and in *Ganeshpuri* reservoir temperature could be 90-130°C.

Sona Province:

Thermal springs have temperature of 24-46°C. Several wells were drilled to a depth of 547m. Thermal gradients indicate a large variation. The reservoir base temperature is 100 °C.

Eastern and North Eastern Province:

51 thermal springs have temperatures of 35-88°C. The estimated base temperature range is from 90-150°C. Very little exploration has been done at this location.

Southern India Province:

-*Godavari Graben*: the area has been extensively studied in connection with oil exploration. Springs have recorded temperature from 30-62°C. Estimated reservoir temperature is 100-150°C.

Damodar Valley Basins Province:

Springs have recorded temperature up to 80°C, while reservoir temperatures are estimated to be 80-120°C.

Andaman-Nicobar Province:

-*Barren island* has a geotectonic similarity to the Taupo zone, of New Zealand. If so it could turn into the most promising exploitable thermal field in India. Unfortunately exploration has not started yet.

ELECTRICITY GENERATION

Presently, attempts are being made to install geothermal power plant but none a currently operating. In 1992 a 5MW binary cycle pilot power plant was successfully tested its optimum operating capacity in the *Manikaran* field (Himalayan province). Another binary cycle power plant for the generation 20MW is planned for the *Tatapani* field (*Son-Narmada-Tapti* province) and a 1MW plant in *Puga Valley* (Himalayan province).

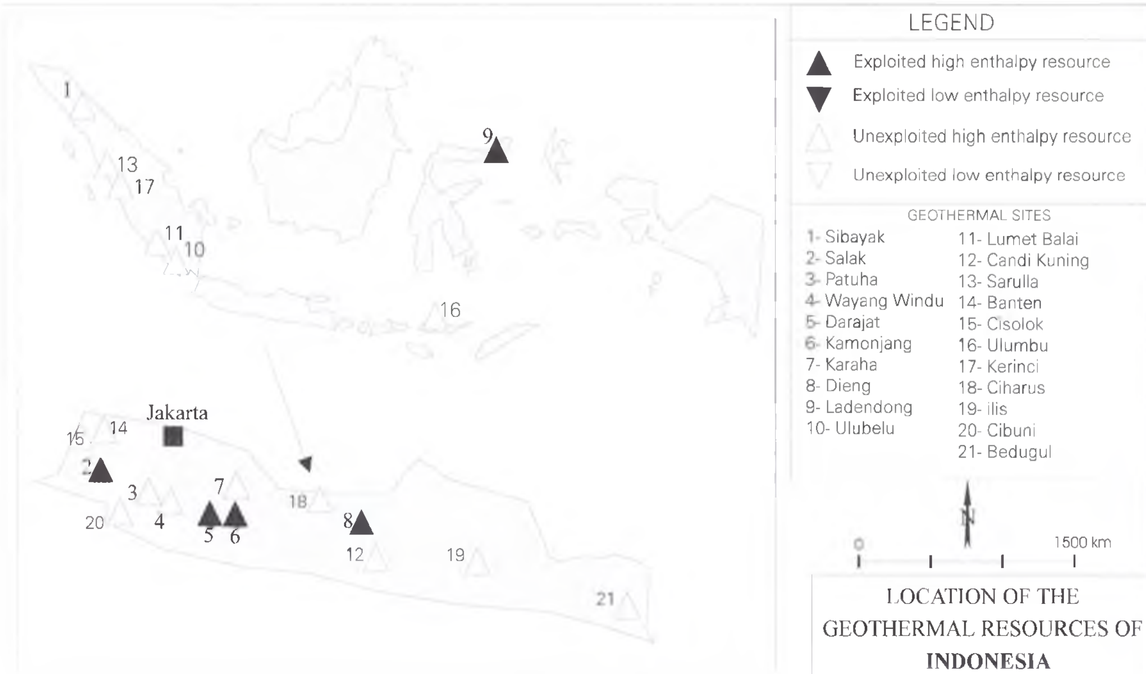
SUMMARY OF RESOURCES	
Exploited - plant in operation	-
Unexploited - plant under construction or planned	21MW
Unexploited - proven resources	-
Unexploited - probable and possible resources	2,000-10,000MW

DIRECT USES

Recently it has been decided to utilise thermal discharge from a well in *Tapoban* (Himalayan province) for greenhouse farming.

INDONESIA

Size	2,027,087	km^2
Population (1994)	191.8	millions
Annual population growth rate (1994)	1.7	%
GNP per capita (1994)	780	USD per year
Average annual growth rate of GNP (1993-94)	+6.7	%
Annual inflation (1994)	8.5	%
Average annual inflation		%
Annual energy use per capita (1994) oil equivalent		kg
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity (1995)		GWh
Geothermal	0.31	GWh
Fossil fuels	10.435	GWh
Hydro	2.134	GWh
Nuclear		GWh
Wind		GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF **INDONESIA**

The Indonesian Archipelago is located in an area of three major plate margins (Indo-Australian, Eurasian, Pacific plates). Interaction between them has led to the generation of island-arc volcanism and major faulting. More than 130 active or recent volcanoes have been recorded. The combination between shallow crustal magmatic heat sources and faulting creates highly suitable conditions for the development of large geothermal resources in the Indonesia Archipelago.
The Indonesian Geological Survey has identified 217 geothermal localities with low to intermediate (<150°C) and high (>150°C) reservoir temperatures. Most of them are characterised by vigorous surface manifestations.

At the end of 1994, Indonesia had 309.5MW$_e$ of electricity generating capacity from geothermal plant at five sites. In October 1996, President Suharto issued a decree that provided for the creation of a new agency to approve and supervise new geothermal projects. This agency will eliminate redundancy in the approval process, which previously required both PLN and Pertamina approval of all projects. It is also aimed at lowering the cost of geothermal power so that it is competitive with coal-fired power generation.

ELECTRICITY GENERATION

70 prospects in Indonesia are classified as high temperature (>200°C) geothermal systems. Their estimated resource potential is estimated to be about 19,000MW_e, distributed between *Sumatra* (4900), *Java* (7800), *Bali* (325), *Nusa Tengarra* (350), N *Sulawesi* (1500), *Maluka* and *Irian Jaya* (1200).

Exploration and/or development wells have been drilled on 11 prospects *Kamojang* (54 wells), *Ciharus* (1 well), *Darajat* (7 wells), *Salak* (17 wells), *Wayung Windu* (1 well), *Cisolok* (1 well), *Banten* (1 well), *Dieng* (26 wells), *Lahendong* (12 wells), *Sibayak* (3 wells), Kerini (2 wells). About 1057MW_e resource potential has been proved.
Exploration drilling has been started in *Sarulla* (N *Sumatra*), *Wilis* (E *Java*) and *Ulumbu* (*Flores*).

Detailed scientific survey results have been used to identify other prospects which are under consideration as part of 20-25 years development plans in Java-Bali (6 prospects), Sumatra (8 prospects), *Sulawesi* (2 prospects). Their potential is estimated to be more than 1,400MW_e.

Major projects for development are planned between 1995 and 2000 the total installed capacity would be 1,079MW_e by the end of 1999, from *Salak* (220MW_e), *Darajat* (70MW_e), *Dieng* (95MW_e), *Ulubelu* (40MW_e), *Lumut Balai* (40MW_e), *Sibayak* (22MW_e), *Lahendong* (20MW_e), *Kamojang* (80MW_e), *Patuha* (55MW_e), *Karaha* (55MW_e), *Wayang Windu* (40MW_e), *Candi Kuning* (60MW_e), *Cibuni* (10MW_e), *Bedugul* (110MW_e).

In July and October 1994, Unocal brought 2×55MW plants online at the *Gunung Salak* field near *Jakarta*. The company plans to construct four additional \$380-million, 55MW plants at the *Gunung Salak* field, with the next to come online by mid-1997. Also, the company is conducting geothermal exploration in North Sumatra's Sarulla block.

On the *Darajat* concession south of Jakarta, *Amoseas* supplies geothermal steam to fuel PLN's 55MW plant nearby. In January 1996, *Amoseas* announced that it had signed a PPA that will allow for construction of 70MW plant on the *Darajat* block. Construction of the \$125 million plant started in 1996 and is scheduled for completion by the end of 1998.
Also smaller scale developments will take place on more than 15 off-grid sites throughout the country, mostly in East Indonesia (Flores, *Lombok*, Ambon, *Sumbawa*). Installation of micro geo binary cycle plants of 100-1000kW would added 74MW_e of capacity.

At the end of 1997 six power plants sites were operating and total installed capacity is 589.5 MW_e.
Salak six 55MW_e units,
Sibayak 2 MW_e,
Lahendong one 2,5MW_e binary plant,
Dieng one 60MW_e unit,
Darajat one 55 MW_e unit.
Kamojang one 30MW_e and two 55MW_e double flash plants,
In Kamojang there are power reserves for about 250 MW_e.

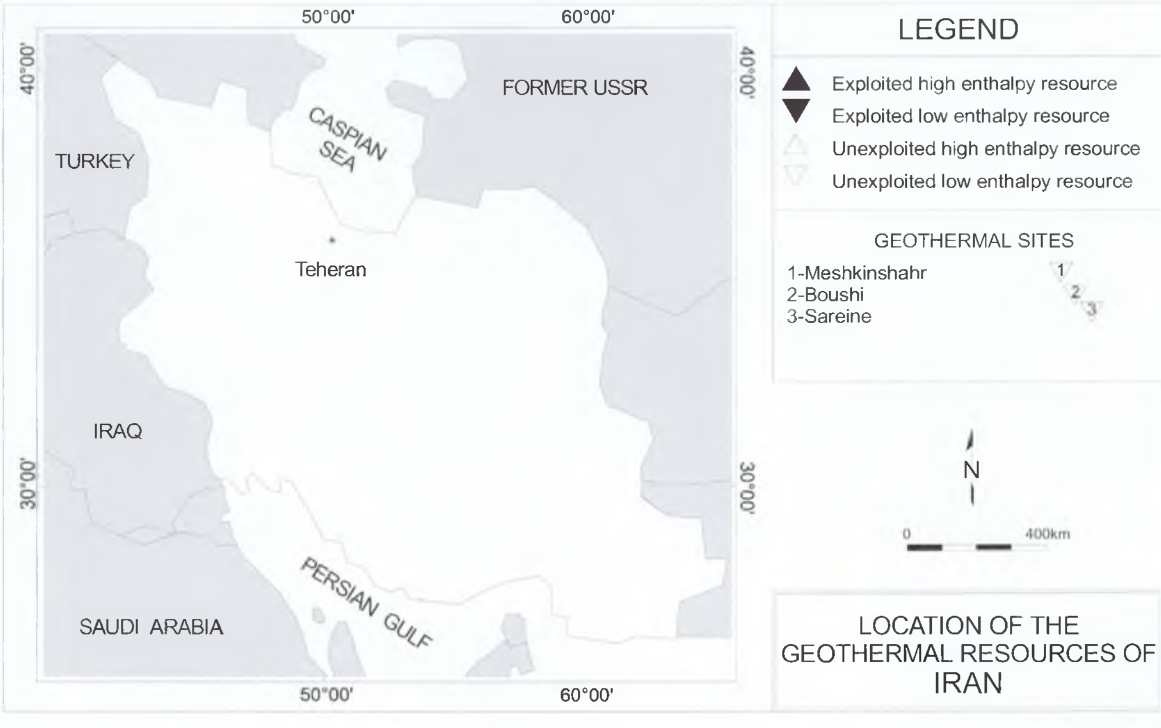
Summary of Resources	
Exploited - plant in operation	589.5MWe
Unexploited - plant under construction or planned	712MWe
Unexploited - proven resources	1,057MWe
Unexploited - probable and possible resources	8,000MWe

Direct Uses

No direct uses are mentioned in Indonesia.

IRAN

Size	1,648,000	km^2
Population (1994)	65.76	millions
Annual population growth rate (1993-94)		%
GNP per capita (1993)		USD per year
Average annual growth rate of GNP (1990-93)		%
Average annual inflation (1995)		%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1995)	79,130	GWh
Geothermal	0	GWh
Fossil fuels	71,683	GWh
Hydro	7	GWh
Nuclear	0	GWh
Wind		GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF IRAN

Exploration began in 1975 and as a result, the main targets were identified in the northern provinces. In 1993, feasibility studies started and as a result the *Sabalan* region appeared the most prospective as potential for electricity generation; results from *Khoy-Maku* and *Sahand* regions have also appeared interesting.

ELECTRICITY GENERATION

In Sabalan region there are reported to be at least 17 thermal springs with an average temperature of 40°C and maximum temperature of 85°C at *Meshkinshahr*, *Boushli* and *Sareine* where geothermometers estimate reservoir temperatures of 140-251°C. After extensive surface explorations the potential for this region is estimated to be 48×10^{18}Joule.

Meshkinshahr has been selected for the first deep drilling site.

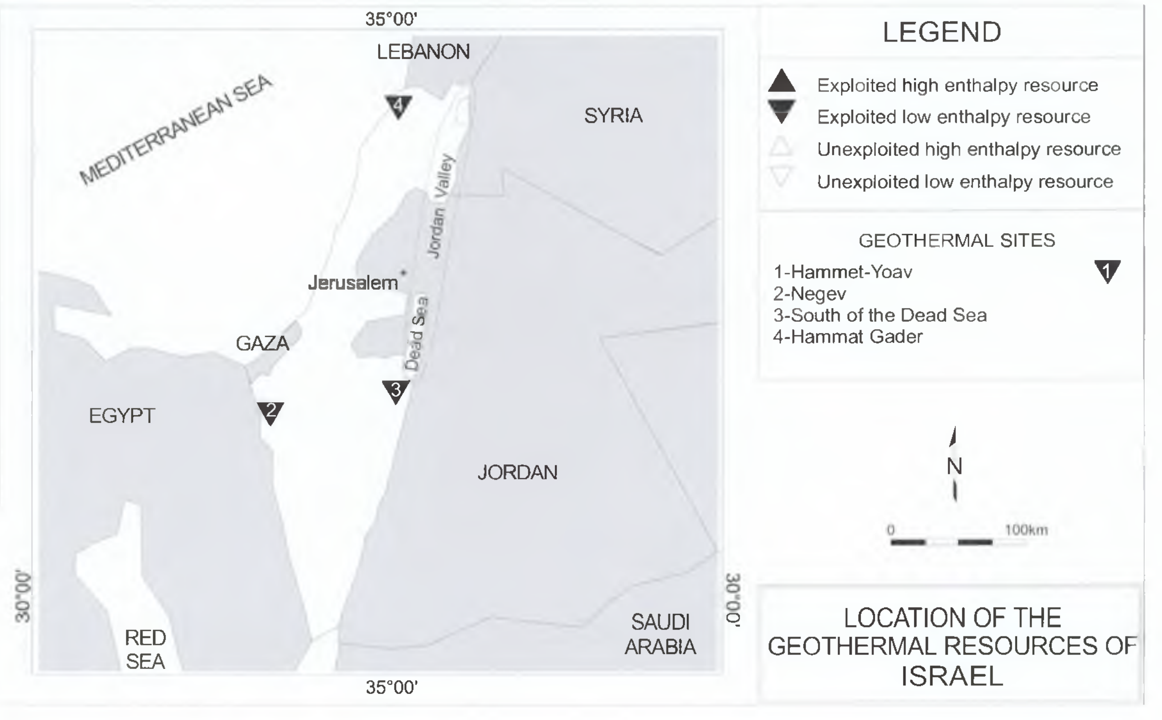
In *Damavand* region the potential is estimated to be 5×10^{18}Joule.

Summary of Resources	
Exploited - plant in operation	
Unexploited - plant under construction or planned	
Unexploited - proven resources	
Unexploited - probable and possible resources	[1]

[1]The estimated potential of the most promising areas totals 53×10^{18}Joule.

ISRAEL

Size	20,320	km^2
Population (1994)	5.42	millions
Annual population growth rate (1993-94)		%
GNP per capita (1993)		USD per year
Average annual growth rate of GNP (1990-93)		%
Average annual inflation (1995)		%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1995)	32,780	GWh
Geothermal	1.196	TJ
Fossil fuels	27,610	GWh
Hydro	0.032	GWh
Nuclear	0	GWh
Wind	0	GWh



The extensive geothermal investigation made in the country during the 1970's and '80s revealed several surface anomalies with temperatures between 26-62°C. Deep well data (about 340 deep drill holes spread all over the country) and other geothermal and geological data, have led to the identification of ten anomalous zones where temperature gradients were subsequently calculated.
The most promising zones are the *Jordan Valley*, and *Sea of Galilee*.
The value of the heat resources has not been calculated.

All thermal springs in Israel are located in the *Jordan-Dead Sea rift*, which is a segment of the Syrian-African fault system. Temperature observed at these springs range between 26°C and 62°C.

There is no electricity generation from geothermal resources in the country.

DIRECT USES

Presently, due to the relatively low temperature, geothermal water is used mainly for health and recreation (44%) and agriculture: greenhouses (13%) and fish farming (43%).

Thermal waters at 42°C from an 1,857m deep drill hole are utilised in a spa at *Hammei Yoav*, along the western part of Israel between the foothills and the Mediterranean Sea. Water is from a dolomite/limestone aquifer of the *Yarkon-Tainin* basin.

In the northern *Negev* area, as a demonstration plant for growing vegetables has been established. Hot brackish water at 35°-42°C from the same aquifer at 550-650m is used; the chloride content ranges from 1000ppm to 1400ppm, with a flow rate ranging from 150-220m^3/hour.

South of the *Dead Sea*, water at 60°C comes from a 1536m deep water well, and is used for heating greenhouses and as a frost prevention measure.

Geothermal water for fish farming is used in northern Israel close to the Jordan Valley at *Hammat Gader* springs and along the Mediterranean coast about 70km north of Tel-Aviv. The spring temperature is 27°C.

The uses of geothermal resources in Israel are quite limited and currently the geothermal fluids utilised give about 42MWt of installed thermal power and a total annual energy of 1,196TJ.

SUMMARY OF RESOURCES	
Exploited - plant in operation	42MWt
Unexploited - plant under construction or planned	
Unexploited - proven resources	
Unexploited - probable and possible resources	

JAPAN

Size	372,313	km^2
Population (1994)	124.9	millions
Annual population growth rate (1994)	0.37	%
GNP per capita (1994)	37,300	USD per year
Average annual growth rate of GNP (1993-94)	-0.9	%
Annual inflation (1994)	0.1	%
Average annual inflation		%
Consumption of energy (oil equivalent) (1994)	477.0	million t
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity (1995)	906.909	GWh
Geothermal	1.722	GWh
Fossil fuels	550.257	GWh
Hydro	105.674	GWh
Nuclear	249.256	GWh
Wind		GWh

About 200 recent volcanoes including 83 active ones are recorded in Japan. In addition, sedimentary basins with aquifers are abundant. Its geologic framework is very favourable to the development of geothermal systems which are possible sources for both electricity generation and direct uses of thermal waters.

Japan is today amongst the world's largest producers of geothermally generated electricity, and thermal waters are widely and traditionally used for bathing.

Electricity Generation

Geothermal power plants are concentrated in two areas, Tohoku and Kyushu. The first geothermal plant took place at Matsukawa in 1966. At 1997 there are 18 plant sites with a total installed capacity of 300MW$_e$ and other 230MW$_e$ been completed at the end of 1997. However, this represents less than 1% of the overall Japanese power demand. An increase to 600MW$_e$ in 2000 and 2800MW$_e$ by 2010 is planned.

The geothermal plant sites are:

Hokkaido *Mori* (50MW$_e$)
Tohoku *Matsukawa* (23,5MW$_e$), *Onuma* (9,5MW$_e$), *Onikobe* (12,5MW$_e$), *Kakkonda* (50+30MW$_e$), *Uenotai* (27,5MW$_e$), *Sumikawa* (50MW$_e$), *Yanaizu-Nishi* (65MW$_e$).
Kyushu *Otake* (13,5MW$_e$), *Hatchobaru* (55+55MW$_e$), *Suginoi* (3MW$_e$), *Kirishisma* (0,1MW$_e$), *Takenoyu* (0.105MW$_e$), *Yamagawa* (30MW$_e$), *Ogiri* (30MW$_e$), *Takigami* (25MW$_e$).

Two new sites are under development *Hachijojima* Island (3MW$_e$ planned) and *Oguni* (20MW$_e$ planned). In addition, there are about 40 sites which have been investigated where high temperature geothermal systems are evident and could be developed for electricity generation.

Summary of Resources	
Exploited - plant in operation	530MWe
Unexploited - plant under construction or planned	70MWe
Unexploited - proven resources	2,800MWe
Unexploited - probable and possible resources	

Direct Uses

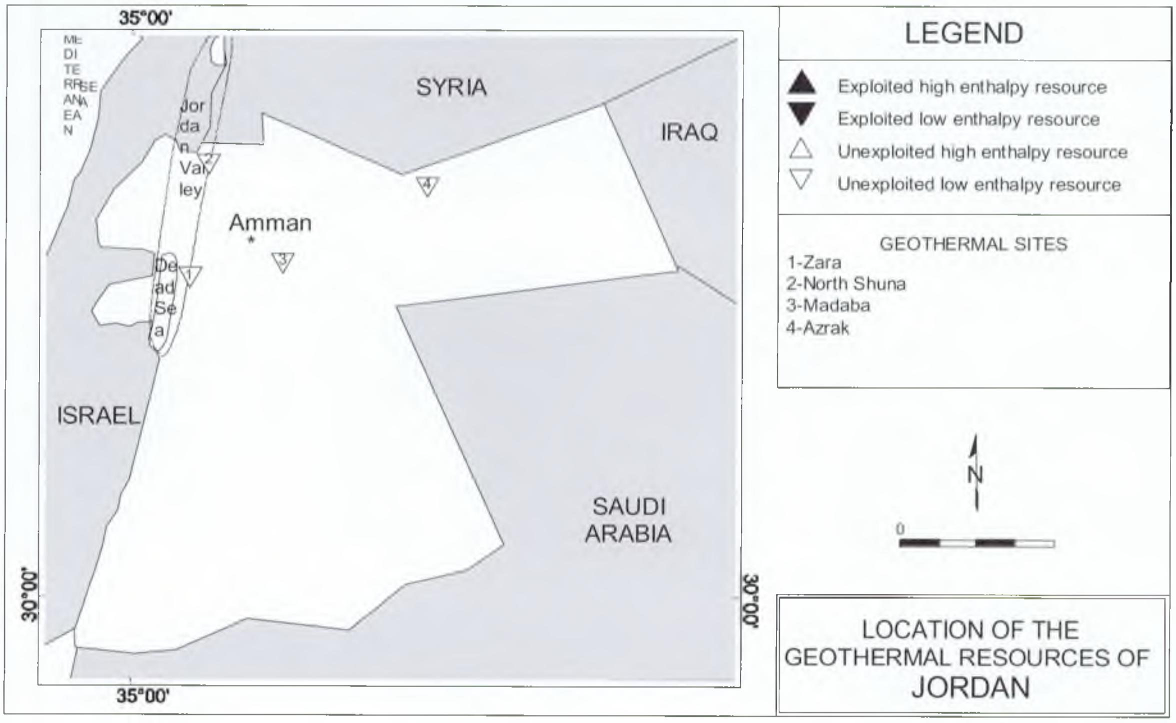
The main direct uses of thermal waters are bathing space heating, greenhouses, fish farming and, snow melting. The 244 recorded geothermal exploitations are concentrated in *Hokkaido* and *Tohoku* where heat demand is strong during winter, and in *Kyushu* where resources are abundant.
Heat discharge from 6,868 wells in the 120 largest spas is calculated to be around 1,512MW$_t$. The installed thermal power, at 1997, considering also bathing is 1,159 MW$_t$, of which 79% for bathing, 16% for space heating, and 5% for greenhouses). The total annual thermal energy use is 27.000 TJ/y or 7,500 GWh/y.
Thermal waters are mainly produced by shallow to intermediate wells with depth ranging from 100 to 1000m.

Further development would combine direct uses of thermal waters with small-scale, binary cycle electric power generation (100 to 500kW capacity). This could represent a 24MW$_e$ capacity and 35l/s of 76°C waters available for direct uses.

Summary of Resources	
Exploited - plant in operation	1,159 MWt
Unexploited - plant under construction or planned	1,512 MWt
Unexploited - proven resources	
Unexploited - probable and possible resources	

JORDAN

Size	88,946	km^2
Population (1994)	4.22	millions
Annual population growth rate (1993-94)		%
GNP per capita (1993)		USD per year
Average annual growth rate of GNP (1990-93)		%
Average annual inflation (1995)		%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1994)	5,080	GWh
Geothermal	0	GWh
Fossil fuels	5,061	GWh
Hydro	0.02	GWh
Nuclear	0	GWh
Wind		GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF JORDAN

Jordan benefits from its unique geological setting on a transform fault along the Arabian plate margin, the trace of which is marked in the landscape by the Dead Sea depression. This situation generates the possibility of hot fluids rising along the plate margin itself, or slightly within the plate, through a reactivation of existing faults.

Two are the areas of geothermal interest: along the Dead Sea depression and the Jordan Valley. These geothermal resources could support local development (greenhouses, aquaculture, tourism, etc.). The main obstacle seems to be the problem of financing such operations, although apparently, possibilities exist for foreign capital investment (tourist industry and other developments).

<u>DIRECT USES</u>
Zara springs discharge water at temperatures between 30 °C and 110°C and are located near several tourist complexes which offer the potential for developing these springs for thermal spas and air conditioning.

The *North Shuna* well produces water at a temperature of around 50°C, with a discharge rate greater than 300m^3/h. As it is located close to an agricultural area it is used for greenhouses and fish farming.

The *Madaba* area, on the Jordan Plateau, near Amman, has a greenhouse market garden industry. Winters on the plateau are cold. A shallow (<200m depth) groundwater resource exists in this area with a temperature of between 30 °C and 40°C. This geothermal energy could provide significant additional winter heating for the greenhouses.

Wells in the area east of *Azrak* produce some 50m^3/h of water at a temperature of about 50°C, however, it is a desert area with no developed activity.

LAOS

Size	236,800	km^2
Population (1994)	4.73	millions
Annual population growth rate (1994)	3.1	%
GNP per capita (1994)	300	USD per year
Average annual growth rate of GNP (1993-94)	+6.0	%
Annual inflation (1994)	6.8	%
Average annual inflation		%
Annual energy use per capita (199) oil equivalent		kg
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity (1995)		GWh
Geothermal		GWh
Fossil fuels		GWh
Hydro		GWh
Nuclear		GWh
Wind		GWh

There is no information about the geothermal potential of Laos.

Only scarce information is available about the geology of Laos. A metamorphic basement (gneisses, schists, marbles) of Proterozoic outcrops in North Laos mainly. It is overlain by a Mesozoic and younger platform cover well developed in the southern part of Laos and also along the Chinese border. It is composed of continental sediments (conglomerates, sandstones, shales, evaporites) related to a Late Triassic folding and uplift leading to intensive erosion.
More recently, a Late Cenozoic tensional regime related to the Alpine tectonic belt created small grabens filled with Neogene terrestrial sediments in northern Laos. It also generated a Quaternary basaltic volcanism with lavas covering a large area in south east Laos (*Bolovens* Plateau).

No information about thermal manifestation and the geothermal potential of Laos are available. There are similarities with the recent tectonic regime and basaltic volcanism seen in nearby Vietnam and Thailand which suggests that there could be possible geothermal resources in Laos related to the existence of a deep faulted zone. Low to intermediate temperature geothermal systems could be developed within small grabens containing Neogene deposits.

LEBANON

Size	10,230	km^2
Population (1994)	3.93	millions
Annual population growth rate (1993-94)		%
GNP per capita (1993)		USD per year
Average annual growth rate of GNP (1990-93)		%
Average annual inflation (1995)		%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1994)	5,180	GWh
Geothermal	0	GWh
Fossil fuels	4,367	GWh
Hydro	0.9	GWh
Nuclear	0	GWh
Wind	0	GWh

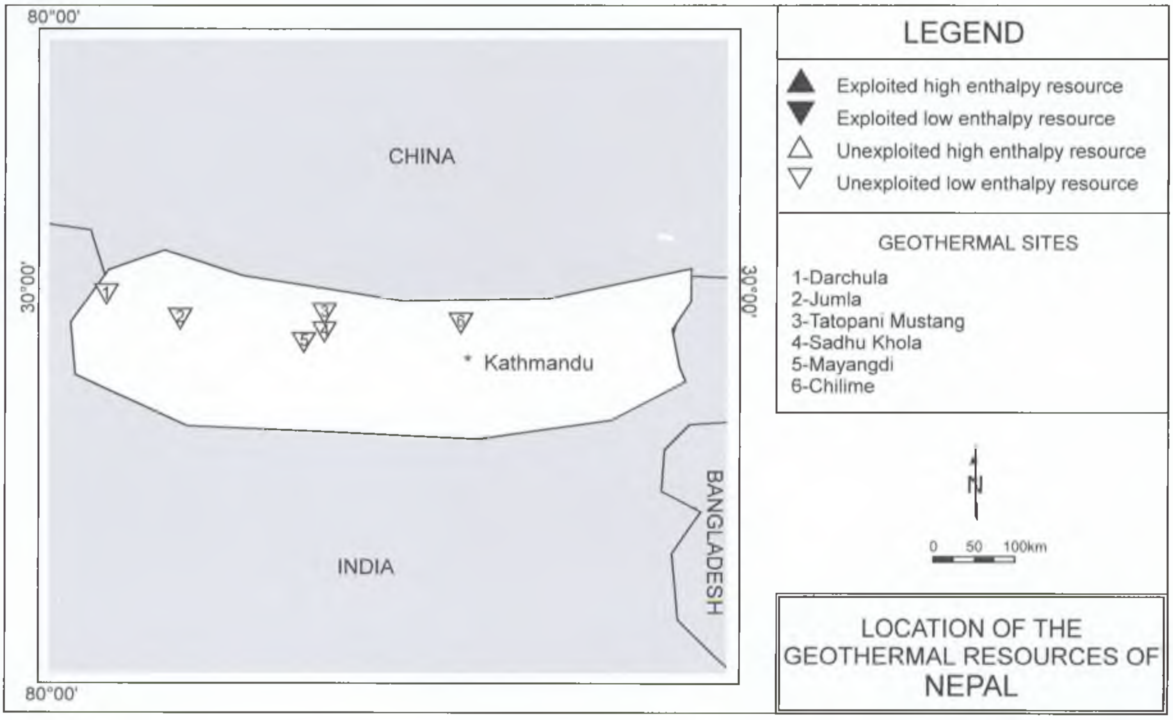
The Dead Sea structures extend up into Lebanon via Israel. Here a hot spring exists in the north of the country although, as far as we know, no particular study has been carried out of these resources.

Similar geological structures are also found in neighbouring Syria.

These resources still need to be evaluated.

NEPAL

Size	140,800	km^2
Population (1994)		millions
Annual population growth rate (1993-94)		%
GNP per capita (199)		USD per year
Average annual growth rate of GNP (199 -9)		%
Average annual inflation (1994)		%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1995)	920	GWh
Geothermal	0	GWh
Fossil fuels	20	GWh
Hydro	900	GWh
Nuclear	0	GWh
Wind	0	GWh



Nepal is endowed with a number of hot springs commonly known as Tato Pani that have been widely used for bathing, washing and therapeutic purposes by the local people. However, the demand for hot water supply, greenhouse farming, fish farming and construction of swimming pools is high.

Rior, *Bajhang-Tapoban* and *Jomsom* have minimum surface temperatures of around 50-55°C and could be used for air conditioning, animal husbandry, soil warming, swimming pools and fish farming activities.

Geochemistry indicated at *Darchula*, *Jumla*, *Tatopani-Mustang*, *Sadhu Khola*, *Mayangdi* and *Chilime* subsurface temperature are in the range of 85 to 115°C and surface temperature around 70°C. These waters could be used for space heating, greenhouses, drying of fish stock, agricultural products and cement blocks. At *Kodari* and *Syabru Besi* the subsurface temperature has been estimated to be 96.5 °C, 86.5 °C respectively, making inexpensive electricity generation unviable.

The lack of exploitation of geothermal energy in Nepal is due, according to local scientists, to the lack of knowledge of low temperature applications and to the logistical problems related to the steep Himalayan terrain. However, significant progress has been made in road construction in recent years opening good access to some geothermal localities such as *Kodari*, *Syabru Besi*, *Jomsom*.

Moreover, the construction of North-South highways in the western and far-western region of the country is now planned. Some projects have already commenced and should be completed in the next few years. These routes will connect *Darchula* and other localities.

Geothermal energy is expected to receive due attention in the Ninth Plan (1996-2001) and in the energy sub-sector plan (1997-1999).

KAZAKHSTAN

Size	2,750,000	km^2
Population (1994)	17.1	millions
Annual population growth rate (1994)	1.0	%
GNP per capita (1994)	1,400	USD per year
Average annual growth rate of GNP (1993-94)	-25	%
Annual inflation (1994)	1,100	%
Average annual inflation		%
Consumption of energy (oil equivalent) (1994)		million t
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity (1995)		GWh
Geothermal		GWh
Fossil fuels	7.6	GWh
Hydro		GWh
Nuclear		GWh
Wind		GWh

LOCATION OF THE GEOTHERMAL RESOURCES OF **KAZAKSTAN**

Kazakhstan has very large, low to medium enthalpy geothermal resource in relation to its geological setting. It is located along the southern margin of the West-Siberian Platform, and extends to the Caspian-Aral Trough, which is characterised by high thermal gradient values (up to 60 °C/km). Many deep and hot aquifers have been encountered by extensive drilling dedicated to oil production. Cretaceous formations in particular contain large aquifers in the southern part of the country. Water temperatures usually range from 40 to 120°C and salinity is low (1-2 g/l).

Areas where geothermal resources are assessed or/and used are restricted to Southern Kazakhstan. Six regions have been listed. Direct uses of hot water are sometimes mentioned, but to a rather limited scale when compare to the extent of the expected resources.

Electricity Generation

High temperature waters (170°C) are evident at a depth of 4,5km in the high valley *of Illi* (SE Kazakhstan). More information is needed before assessing potential resources for power generation.

Direct Uses

In Southern *Kazakhstan* (*Chimkent*, *Dzambul*, *Kyzyl-Orda*), wells intersecting aquifers in Cretaceous formations (1200-2100m deep) produce hot waters (45-80°C; 15-60 l/sec; 1 g/l). They are used for greenhouses (12,000 m^2) and space heating (*Kaplanbek*).

In *Chu Valley and North of Kyzyl-Kum*, Cretaceous aquifers produce 80-90°C waters with 1,5 g/l salinity. Geothermal gradient values range around 35°/km.

In the high valley *of Illi* (*Panfilov*), Cretaceous aquifers (2000-3500m deep) produce 90-115°C waters with low salinity (1,5 g/l) and high flow rates (20-90 l/s). A deeper aquifer (4500 m) has been identified with high temperature fluids (170°C).

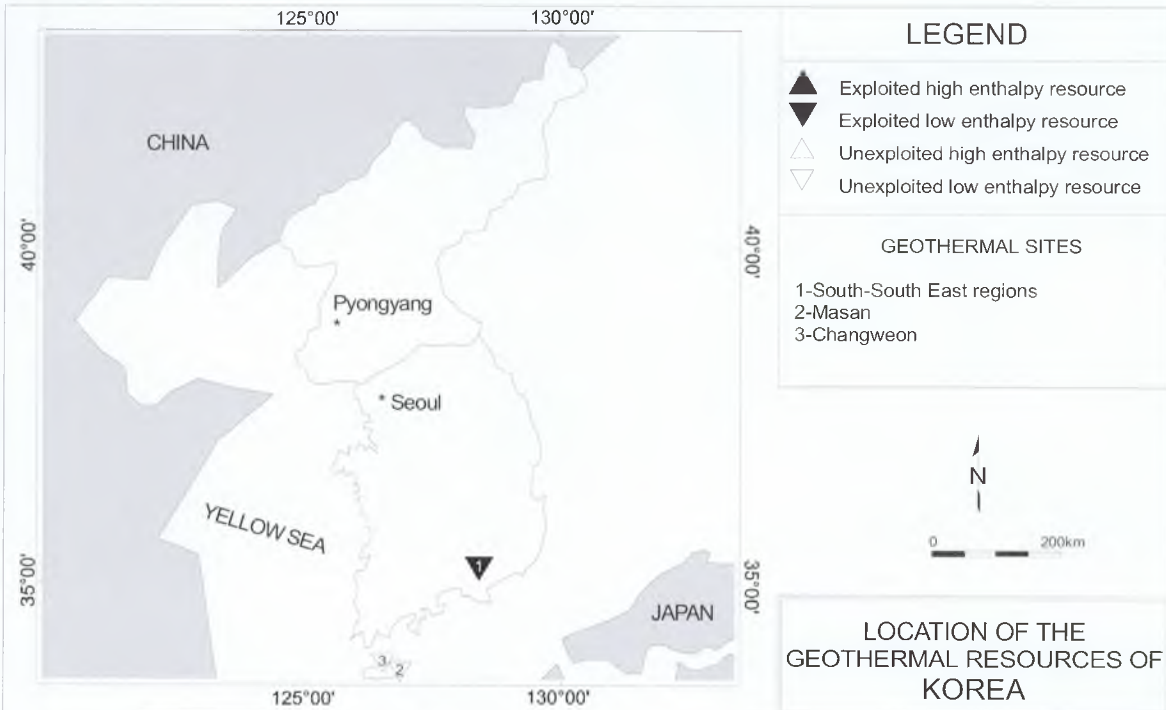
In *Alma Alta* Region, Cretaceous aquifers are 150m thick and at 2.5-3.5km depth. A well is producing 30 l/s of waters (80-120°C) at a pressure of 30-35 atm. Hot water is used for greenhouses in winter and air conditioning in summer (*Porovsky*, *Aleksev*). Projects for other direct heat uses at Alma Alta are planned.

In *Taldy Kurgan* Region (Southeastern Kazakhstan), geothermal resources are estimated to be high, with a potential of 45,000 m3/yr hot water (90°C).

In *Ust-Jur* Region (Caspian-Aral Trough), large geothermal resources are expected from data provided by oil wells. Values indicate that a thermal gradient of 60°/km is reach. Geothermal fluids could be used for heating and pressurising oil reservoirs.

KOREA

	NORTH	SOUTH	
Size	122,762	99,392	km^2
Population (1994)	19.35	44.56	millions
Annual population growth rate (1993-94)			%
GNP per capita (1993)			USD per year
Average annual growth rate of GNP (1990-93)			%
Average annual inflation (1994)			%
Annual energy use per capita (199)oil equivalent			kg
Average annual growth rate of energy use (199 -9)			%
Annual CO_2 emission per capita (199)			tonnes
Production of electricity (1995)	38,000	164,99	GWh
Geothermal	0	0	GWh
Fossil fuels	14,000	102,244	GWh
Hydro	23	5.423	GWh
Nuclear	0	58,651	GWh
Wind	0	0	GWh



Several thermal springs occur both in North (38 °C) and in South Korea (69 °C). Water temperatures have a mean value of 31.2°C and range between 25-78°C; the average temperature increases from 47.3°C in the sedimentary/volcanic/metamorphic rocks to 55.2°C in the granite areas. Permeability is controlled by faults and fractures intersection systems and reservoirs. Geothermal convection systems occur mainly in *Donglae, Boogok, and Backahm* in South Korea and *Hambook* province in North Korea.

Geothermal studies and investigations have been carried out from 1987 to 1993. In this period a total of 229 thermal wells have been drilled in South Korea with depth ranging from 250 to 800m.

Electricity generation

Due to the low temperature of geothermal water, there is no electricity generation in the country.

Direct uses

The geothermal potential for the use of low temperature resources is large but information is limited and the level of exploration very low.

Presently thermal water is used for public or private bathing and in resort areas, for swimming pools and sanatoriums for medical treatment. The establishments are mostly owned by individual and private companies.
Fish farming with ground and thermal water is practised widely in the southern and southeastern onshore parts of Korea; a few greenhouses have started limited activity in vegetable and potted plant cultivation.

Private programs set up during the late 1980's for commercial exploitation were encouraged but there is a need for governmental support particularly for drilling programs to develop new geothermal resources.

In 1993-1994 geothermal applications for space heating were investigated in *Masan* and *Changweon* area and in *Chejeu* Island.

KYRGYZSTAN

Size	198,500	km^2
Population (1994)	4.482	millions
Annual population growth rate (1993-94)		%
GNP per capita (1993)		USD per year
Average annual growth rate of GNP (1990-93)		%
Average annual inflation (1995)		%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1995)	12,932	GWh
Geothermal	0	GWh
Fossil fuels	1,208	GWh
Hydro	11.08	GWh
Nuclear	0	GWh
Wind	0	GWh

NO DATA AVAILABLE

PAKISTAN

Size	803,940	Km^2
Population (1994)	124.5	millions
Annual population growth rate (1993-94)	3.1	%
GNP per capita (1993)	430	USD per year
Average annual growth rate of GNP (1990-93)	2.5	%
Average annual inflation (1994)	12.5	%
Annual energy use per capita (1993)oil equivalent	290	kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (1993)	0.8	tonnes
Production of electricity (1995)	57,000	GWh
Geothermal	0	GWh
Fossil fuels	38,000	GWh
Hydro	18,500	GWh
Nuclear	500	GWh
Wind	0	GWh

Geothermal manifestations are numerous and widely scattered and used for balneology. There are more than two dozen known hot springs which have discharge temperatures ranging from 35-94°C.

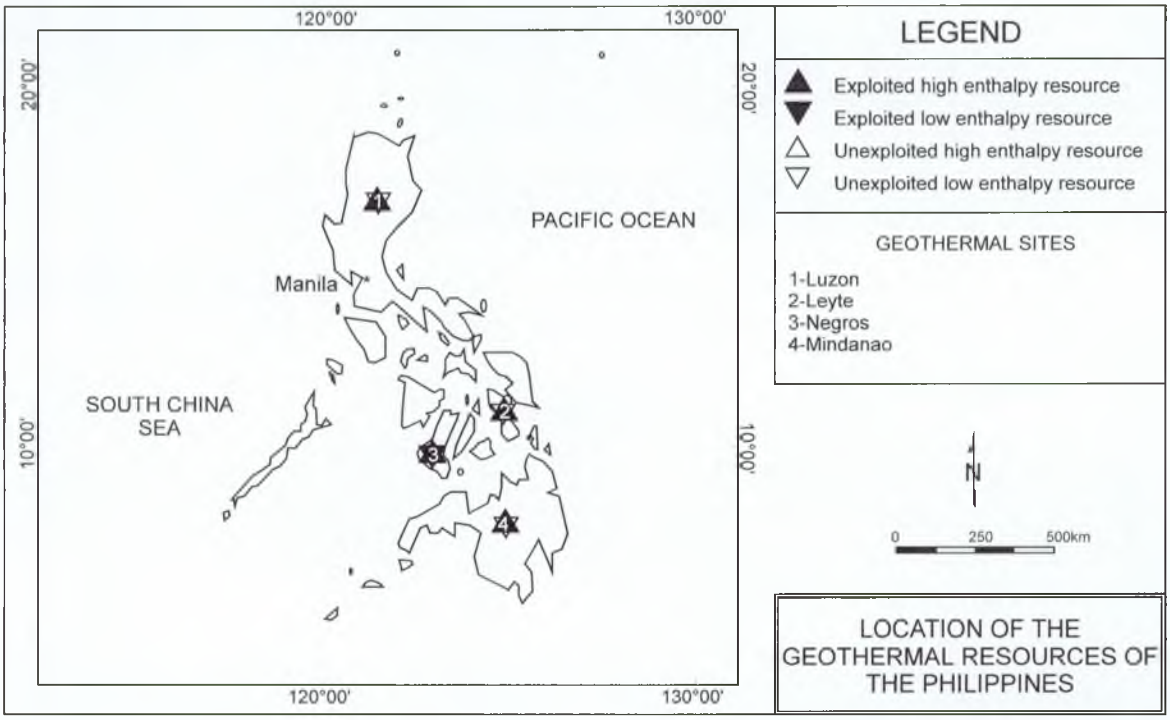
A major concentration is found in the northern part of the country, in the *Chitral*, *Hunza*, *Yasin* and *Skardu* valleys.

A second largest concentration of thermal springs is the narrow zone running NE-SW and culminating in *Dadu* district.

Studies are far from complete. Only surface temperature measurements and chemical analyses for major elements have been carried out.

PHILIPPINES

Size	300,000	km^2
Population (1994)	67.4	millions
Annual population growth rate (1993-94)	2.1	%
GNP per capita (1993)	850	USD per year
Average annual growth rate of GNP (1990-93)	4.3	%
Average annual inflation (1996)	9.3	%
Annual energy use per capita (1994)oil equivalent	287.5	kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (1994)	0.8	tonnes
Production of electricity (1995)	25,650	GWh
Geothermal	5,550	GWh
Fossil fuels	13,600	GWh
Hydro	6,500	GWh
Nuclear	0	GWh
Wind	0	GWh



The Philippines are today the world's second largest producer of geothermally generated electricity. Geothermal energy provides about 20% of the country's electricity generation.

ELECTRICITY GENERATION

In the Philippines nearly 20 years have been spent in managing with high temperature resources thus a high level of experience has been reached.

Five geothermal fields on Luzon and the Visayas islands are generating a total of 1,445MW by March 1997:

Luzon	-426MW at *Mak-Ban* field in *Bulalo*: 6×55MW units built in 1979-1984; 3×5.2MW in 1994 and 4×20MW in 1996.
	-330MW at *Tiwi* field where 6×55MW units were built in 1979-1982.
	-130MW at *Bacon Manito* field: 2×55MW in *Palayan* built in 1993-1994; 1×20MW in *Cawayan* in 1994.
Leyte	-214.5MW at *Leyte* field in *Tongonan* 3×37.5MW units in 1983, 125MW in Upper Mahiao in 1996, 1×77MW in Malitbog in 1996.
Negros	-193MW at *Southern Negros* field in *Palinpinon*: 3×37.5MW in 1983; 2×20MW in 1994 and another 2×20MW in 1995.
Mindanao	-1×52MW unit at Matingao in 1997.

Power plants planned by the year 1998 will bring an additional 455MW:

Luzon	-32MW are planned for 1998: 1×20MW in Botong and 1×12MW in Binary.
Leyte	-383MW are planned: 2×77MW in *S.Sambaloran* and 3×60MW in *Mahanagdong* by 1997; 1×17MW in *Tongonan*, 1×14MW in *Malitborg* and 3×6MW in *Mahanagdong by 1998*.
Mindanao	-1×40MW unit in *Sandawa* is planned by 1998.

All projects are fully commissioned except the plant in Sandawa (Mindanao).
By the year 2000 total geothermal power would be over 2000MW.

Reserves for geothermal power generation are estimated to be around 3,000MW (proven) while the ultimate potential ciuld be as much as 4,000MW.

SUMMARY OF RESOURCES	
Exploited - plant in operation	1445MW
Unexploited - plant under construction or planned	455MW
Unexploited - proven resources	~1000MW
Unexploited - probable and possible resources	~2000MW

DIRECT USES

A direct heat project through utilisation of waste brines from *Palimpilon* I power development was commissioned in 1994 for produce drying (hot dry fruits and fish). Similar plants are planned to be established at other sites in the country.
Facilities producing ice are also planned in *Manito*, *Albay* using brines from several exploration wells.

SRI LANKA

Size	65,610	km^2
Population (1994)	17.9	millions
Annual population growth rate (1993-94)	1.7	%
GNP per capita (1993)	600	USD per year
Average annual growth rate of GNP (1990-93)	8.5	%
Average annual inflation (1994)	8.4	%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1995)	4,650	GWh
Geothermal	0	GWh
Fossil fuels	400	GWh
Hydro	4,250	GWh
Nuclear	0	GWh
Wind	0	GWh

Along the Highland Group and the eastern Vijayan tectonic boundary of Sri Lanka there is a 350km long thermal spring line indicating a large geothermal system beneath. Thermal springs have been found in 10 locations. Chemical geothermometers yield temperatures of about 140°C at *Kapurella*, *Maha Oya* and *Marangala*. All other springs have deep temperatures of at least 100°C.

TAIWAN

Size	36,179	km^2
Population (1994)	21.387	millions
Annual population growth rate (1993-94)		%
GNP per capita (1993)		USD per year
Average annual growth rate of GNP (1990-93)		%
Average annual inflation (1995)		%
Annual energy use per capita (199)oil equivalent		kg
Average annual growth rate of energy use (199 -9)		%
Annual CO_2 emission per capita (199)		tonnes
Production of electricity (1995)	138,647	GWh
Geothermal	0	GWh
Fossil fuels		GWh
Hydro	8.77	GWh
Nuclear	33.93	GWh
Wind	0	GWh

An inventory of the geothermal resources has been carried out.

In Taiwan, large geothermal resources exist and are related to recent volcanism.

Three high temperature geothermal systems have been explored: *Datun*, *Tuchang* and *Quingshui*.

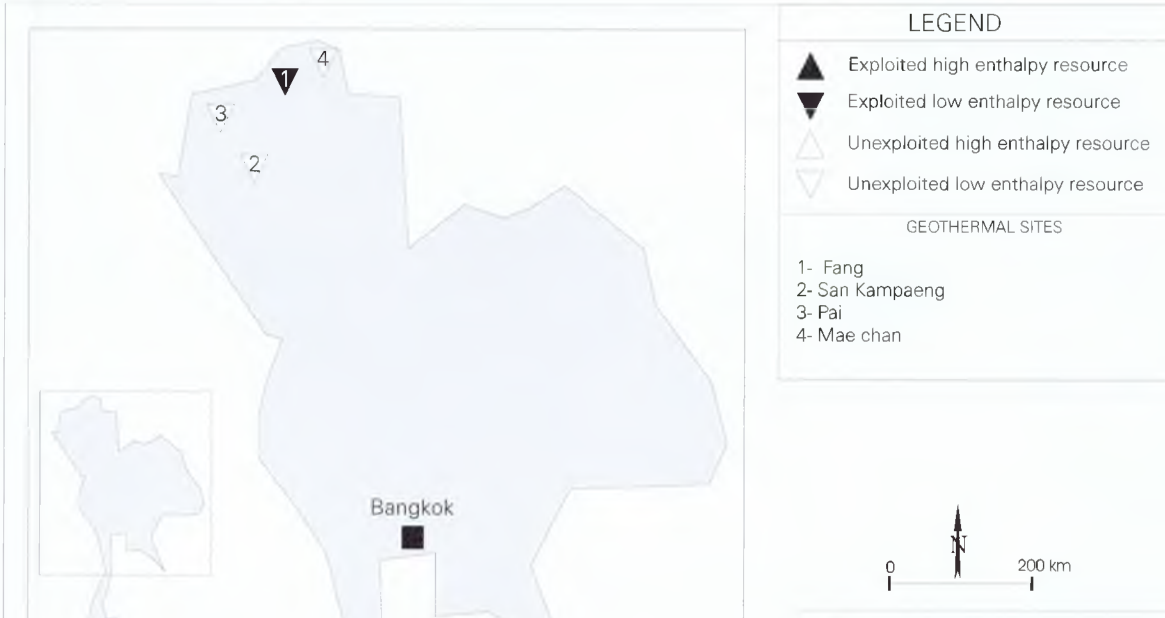
The *Datun* deep reservoir contains 293°C acid sulphate-chloride waters with a pH of around 2. The *Tuchang* reservoir produces 173°C waters and fuels a 0.3 MWe binary cycle power plant. At *Quingshui*, a 3MWe single flash power plant uses 130-150°C thermal waters.

This was halted because of the quality of the water.

Estimation of the geothermal potential is up to 100 MWe.

THAILAND

Size	514,000	km^2
Population (1994)	59.4	millions
Annual population growth rate (1994)	1.6	%
GNP per capita (1994)	2,300	USD per year
Average annual growth rate of GNP (1993-94)	+8.5	%
Annual inflation (1994)	6.3	%
Average annual inflation		%
Consumption of energy (1993) oil equivalent	37	million t
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity (1995)	63.4	GWh
Geothermal	0.012	GWh
Fossil fuels		GWh
Hydro	3.70	GWh
Nuclear	0	GWh
Wind		GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF **THAILAND**

Evaluation of the national geothermal resources began in 1979 when exploration and development started in the northern part of the country. More than 90 hot springs with temperatureS ranging from 40 °C to 100 °C have been mapped.

Until now, three areas of geothermal interest have been investigated: *Fang*, *San Kampaeng* and *Pai*. The geology of Northern Thailand is comprised of a Precambrian to Triassic basement (gneiss, schist, granite, limestone). Strike-slip and normal faulting during the tertiary developed deep-collapsed, sedimentary basins (i.e. *Fang* Basin). The hydrothermal activity is controlled by these large-scale structural features. Low to medium enthalpy geothermal systems are fracture-controlled and developed within these deep-seated faults. They are sustained by the observed active seismics.

Electricity Generation

At Fang since 1989, 134°C waters produced at about 60t/h from three 150 m-deep wells run a 300kW Ormat binary cycle power plant. In 1992-93, EGAT drilled three additional 500 m-deep wells. Well FX-2 produced 25t/h of 125°C water from a fracture at 290 metres; the other two wells were not productive.

At *San Kampaeng*, exploration survey was conducted from 1982 to 1989. In 1989, two deep wells were completed. The wells failed to yield enough data to characterise the deep reservoir, however well GTE-8 produce 40 t/h of 125°C water. Thai geochemists believe that San *Kampaeng* has a potential to produce about $5MW_e$, but its development awaits the availability of cooling water and lower cost drilling techniques.

Pre-feasibility studies at *Pai* have been planned by EGAT for 1994-95. Preliminary studies have indicated the area to be similar to Fang and to have deep temperatures of 140-180°C from geothermometry. Accordingly, the drilling of five 200-300m deep wells was scheduled in 1995. If they confirm the existence of a resource, generation of power using binary techniques will be planned.

The *Mae Chan* area will be investigated in 1996-97 to develop geothermal resources in this isolated area for local purposes.

Summary of Resources	
Exploited - plant in operation	$0.3MW_e$
Unexploited – proven resources	
Unexploited – probable and possible resources	$5MW_e$
Unexploited - possible resources	

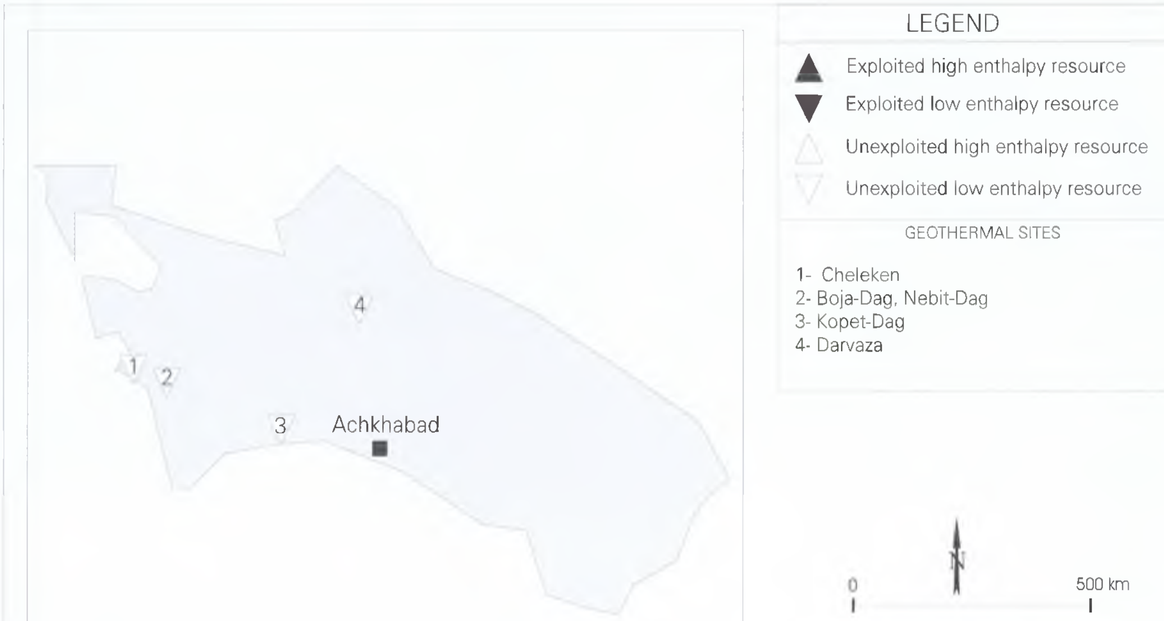
Direct Uses

Direct uses of thermal waters (drying and cooling process, tourism) are mentioned at *Fang*, in connection with the electricity generation.
At *San Kampaeng*, available hot water from exploration wells is being used for tourism and bathing.

Summary of Resources	
Exploited - plant in operation	$1.73MW_t$
Unexploited - plant under construction or planned	
Unexploited - proven resources	
Unexploited - probable and possible resources	

TURKMENISTAN

Size	488,000	km^2
Population (1994)	4.0	millions
Annual population growth rate (1994)	2.6	%
GNP per capita (1994)	1,350	USD per year
Average annual growth rate of GNP (1993-94)	-19.5	%
Annual inflation (1994)	2,397	%
Average annual inflation		%
Consumption of energy (1992) oil equivalent	11.15	million t
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity (1995)		GWh
Geothermal		GWh
Fossil fuels		GWh
Hydro		GWh
Nuclear	0	GWh
Wind		GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF **TURKMENISTAN**

Turkmenistan is located on the southern margin of the West-Siberian Platform. Its geological setting is dominated by the existence of a large depression (*Kara-Kum*) developed along the back of the Himalayan Chain (*Elbruz*, *Kopet-Dag*, *Karakorum*). This sedimentary basin is filled by thick terrigeneous deposits and shows high gradient anomalies at the top of the underlying basement.

DIRECT USES

The occurrence of low enthalpy geothermal reservoirs have been reported in three regions: the Caspian coast (*Cheleken*, *Boja-Dag*, *Nebit-Dag*), the *Kopet-Dag* region (SE *Karakorum*), the *Darvaza* region (central *Kara-Kum*). They are developed within sedimentary formations between 2,000-3,500m depth. They are characterised with low to medium temperature conditions (70-100 °C), high to very high salinities (50-150g/l), and have variable productivity.

On the *Caspian* Coast, several aquifers have been recognised with high flow rates (250-1400l/s), high salinities (50-100g/l) and a temperature of around 80°C.
In the *Kopet-Dag* Foothills (South Turkmenistan), wells intersected deep aquifers (2000-2500m; 70-80°C) with lower productivity (15-55l/s).
In the *Darvaza Region* (Central *Kara-Kum*), deep aquifers (3000-3500m; 100°C) produce highly saline waters (150g/l).

No direct utilisation of geothermal resources for heating is known to date. Mineral extraction (Iodine, Bromine, Lead, Zinc, Copper) from highly saline fluids are mentioned in the area of *Cheleken* and *Boja/Nebit-Dag*, Caspian Coast.

UZBEKISTAN

Size	447,000	km^2
Population (1994)	22.3	millions
Annual population growth rate (1994)	2.8	%
GNP per capita (1994)	900	USD per year
Average annual growth rate of GNP (1993-94)	-2.6	%
Annual inflation (1994)	723	%
Average annual inflation		%
Consumption of energy (1994) oil equivalent	46.0	million t
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity (1995)		GWh
Geothermal		GWh
Fossil fuels		GWh
Hydro		GWh
Nuclear		GWh
Wind		GWh

LOCATION OF THE GEOTHERMAL RESOURCES OF **UZBEKISTAN**

Uzbekstan is located at the southern margin of the huge West-Siberian Platform, where sedimentary basins have developed along the fringe of the Himalayan Belt (*Pamir*, *Alaj*, *Tianshan*). Drilling for oil exploration has provided some information about deep temperature conditions and flow rates. Geothermal gradient values range from 30 to 40°/km.

Low to medium temperature aquifers (65° to 120 °C) have developed within sedimentary formations and represent large but not well-assessed geothermal resources.

DIRECT USES

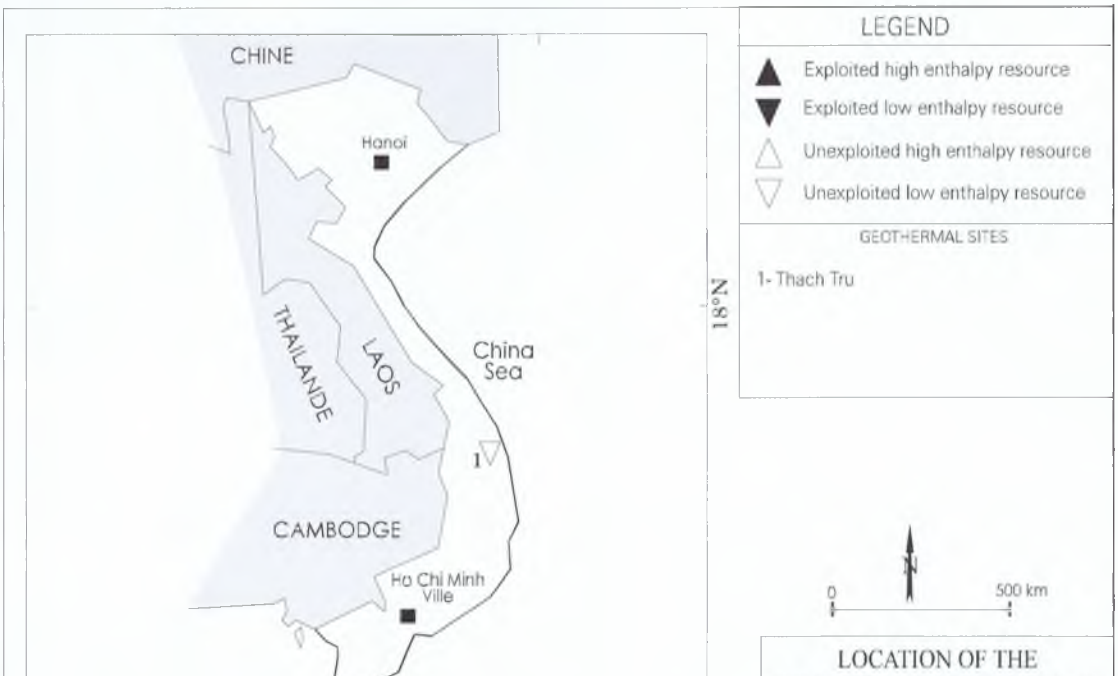
Four sedimentary basins of geothermal interest have been identified: *Amu Darja*, *Surkhan-Darinskaja*, *Tachkent* and *Fergana*.

- In the *Amu Farja* Basin where geothermal gradient is 38°C/km, a geothermal reservoir with a temperature of 122°C has been identified at a depth of 2,950m.
- In the *Surkhan-Darinskaja* Basin, an aquifer produces 830l/s of hot waters (65°C).
- In the *Tachkent* Basin, The Lower Cretaceous Formations (2000-2500m.deep) produces hot waters (75-80°C) with low salinity (1g/l) and high flow rate values (500l/s).
- In the *Fergana Neogene* Basin where geothermal gradient is 32°C/km, 5-6 aquifers produce hot waters (70-90°C) with flow rates ranging from 30 to 500l/s. Annual production of 20 existing wells is estimated around 350-400 TEC/yr.

At *Tachkent*, a geothermal heating plant uses hot waters (65°C; 1g/l) produced by the deep Cretaceous reservoir for space heating.

VIETNAM

Size	236,800	km^2
Population (1994)	4.73	millions
Annual population growth rate (1994)	3.1	%
GNP per capita (1994)	300	USD per year
Average annual growth rate of GNP (1993-94)	+6.0	%
Annual inflation (1994)	6.8	%
Average annual inflation		%
Consumption of energy (1994) oil equivalent		million t
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity (1994)	12.30	GWh
Geothermal		GWh
Fossil fuels		GWh
Hydro (1994)	9.10	GWh
Nuclear (1994)	0	GWh
Wind		GWh



LOCATION OF THE GEOTHERMAL RESOURCES OF **VIETNAM**

Vietnam lies along the tectonic suture between two major tectonic belts, the Eurasian and Pacific belts. This leads to the development of several graben and rift zones, accompanied with Neogene to Quaternary basaltic volcanism (inland and offshore).

Geothermal resources in Vietnam have been investigated recently with the support of New Zealand and Italian organisations. More than 300 hot springs have been listed with temperatures ranging from 30 °C to 105 °C. They are closely connected with the recent tectonic activity and rift faulting in the north-western region, in addition with recent volcanic activity in the southern central region. The geology of these individual geothermal prospects indicates that they are likely to be low to medium temperature systems developed in deep faulted zones.

ELECTRICITY GENERATION

The *Thach Tru* area (Southern Central Region) is considered to be the most promising area, with a 130-180°C estimated reservoir temperature. These temperature values are considered to be suitable for a 300 kW electricity generation plant.

No utilisation of geothermal resources are known to date. A project for electricity generation with a 300 kW power plant at *Thach Tru* is planned.

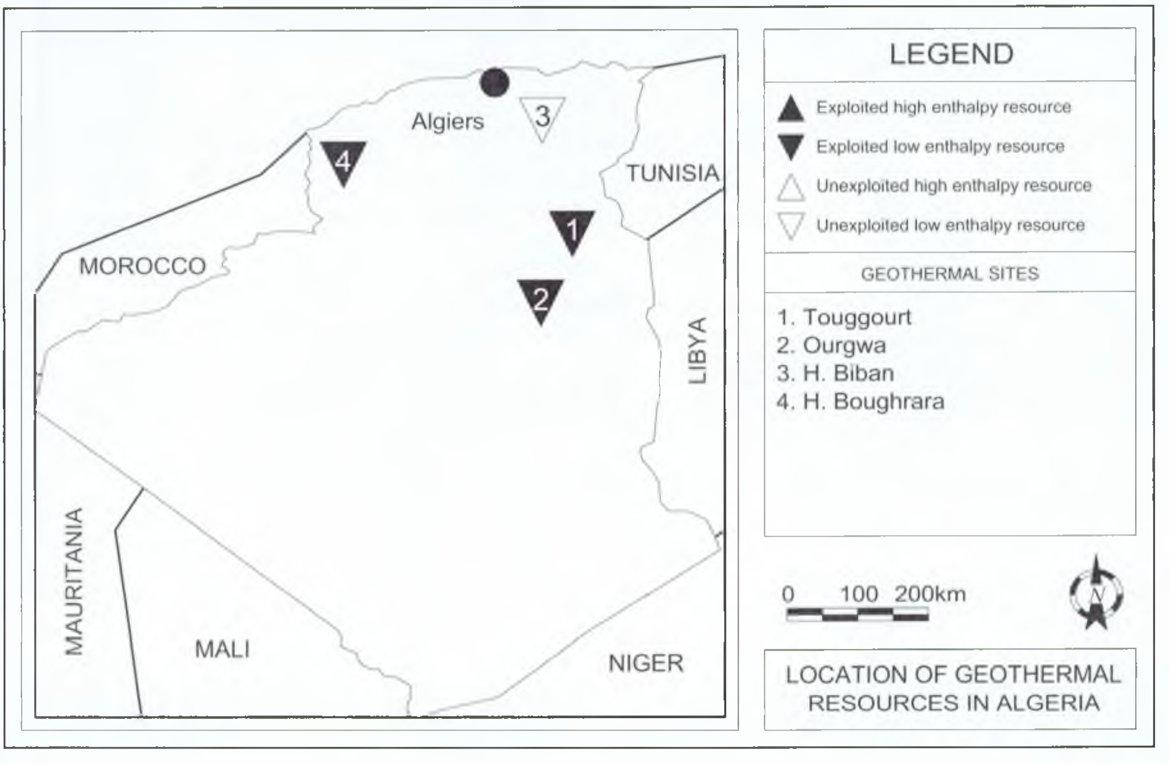
SUMMARY OF RESOURCES	
Exploited - plant in operation	
Unexploited - plant under construction or planned	$0.3MW_e$
Unexploited - proven resources	
Unexploited - probable and possible resources	

Africa

Algeria
Burundi
Djibouti
Egypt
Eritrea
Ethiopia
Kenya
Madagascar
Malawi
Morocco
Mozambique
Rwanda
Tanzania
Tunisia
Uganda
Zambia
Zimbabwe

ALGERIA

Size	2,382,000	km^2
Population (1993)	26.6	millions
Annual Population growth rate (1994)	2.5	%
GNP per capita (1994)	1690	USD per year
Average annual growth rate of GNP (1985-1994)	-2.4	%
Average annual inflation (1985-1993)	15.9	%
Annual energy use per capita (oil equivalent)	1075	kg
Average annual growth rate of energy use	-1.4	%
Annual CO_2 emission per capita	2.92	tonnes
Production of electricity (1993)	19,415	GWh
Geothermal	0	GWh
Fossil fuels	19,062	GWh
Hydro	353	GWh



Algeria has three main geothermal zones all of low enthalpy: the Tlemcenian dolomites in the West; the carbonate formations in the East, the sandstone Albian reservoir in the Sahara.

An inventory of known hot springs exceeds 240 entries although detailed information is known on just 30% of these.

DIRECT USES

The western zone can be sub-divided into two areas. The southern area is characterised by homogeneous geological formations of dolomites and carbonates whilst the northern area is set in allochotonous terrains. Studies of the first area gave little information about the reservoir although it is believed that the waters are from a deep origin. The

Tlemcenian dolomites constitute a shallow reservoir with 15 or so recorded springs at temperatures ranging from 25^{O}C to 47^{O}C.

The eastern zone is characterised by springs with both a high flow rate (100 litres per second) and temperatures up to 96^{O}C. The reservoir covers an area of 15,000km^2.

Although the southern zone covers some 600,000km^2 there are few thermal springs in this area. Those that are recorded have temperatures of around 50 °C. The area is mainly exploited by wells for domestic and agricultural purposes.

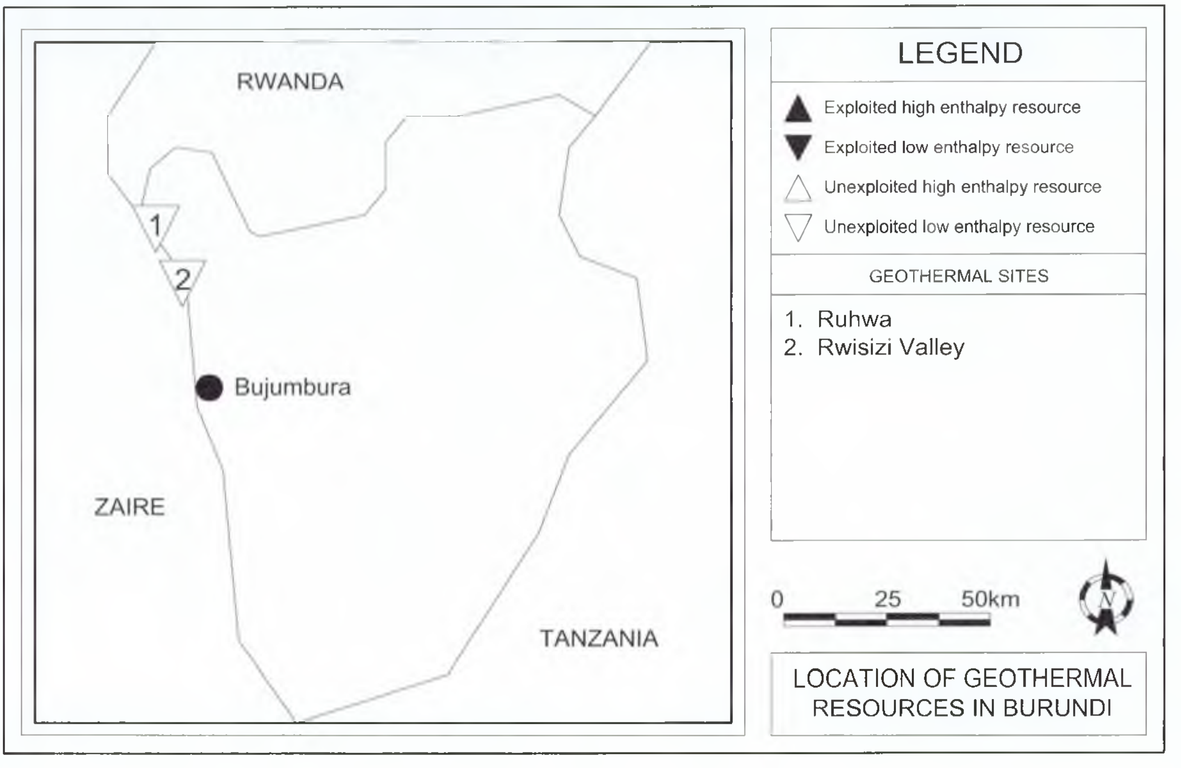
Geothermal heat is being used in two locations in the Sahara. At *Ouargla* and *Touggourt*, greenhouses covering an area of 72,00m^2 are heated by geothermal water at 57 °C to maintain a greenhouse air temperature of 12 °C. The scheme has been operating since 1992 and has resulted in a claimed 50% increase in the production of melons and tomatoes.

Considering the springs for which adequate data has been gathered, approximately 30% of all springs, it is estimated that the geothermal potential is some 640MW$_t$. The total potential is rather higher but insufficient data exists to formulate a reliable estimate.

SUMMARY OF RESOURCES	
Exploited - plant in operation	1MW$_t$
Unexploited - plant under construction or planned	0
Unexploited - proven resources	640MW$_t$
Unexploited - probable and possible resources	no data

BURUNDI

Size	27,834	km^2
Population (1993)	6.13	millions
Annual Population growth rate (1994)	3.0	%
GNP per capita (1994)	150	USD per year
Average annual growth rate of GNP (1985-1993)	-1.0	%
Average annual inflation (1985-1994)	16.4	%
Annual energy use per capita (oil equivalent)	191	kg
Average annual growth rate of energy use	0	%
Annual CO_2 emission per capita	0.84	tonnes
Production of electricity (1993)	117	GWh
Geothermal	0	GWh
Fossil fuels	2	GWh
Hydro	115	GWh

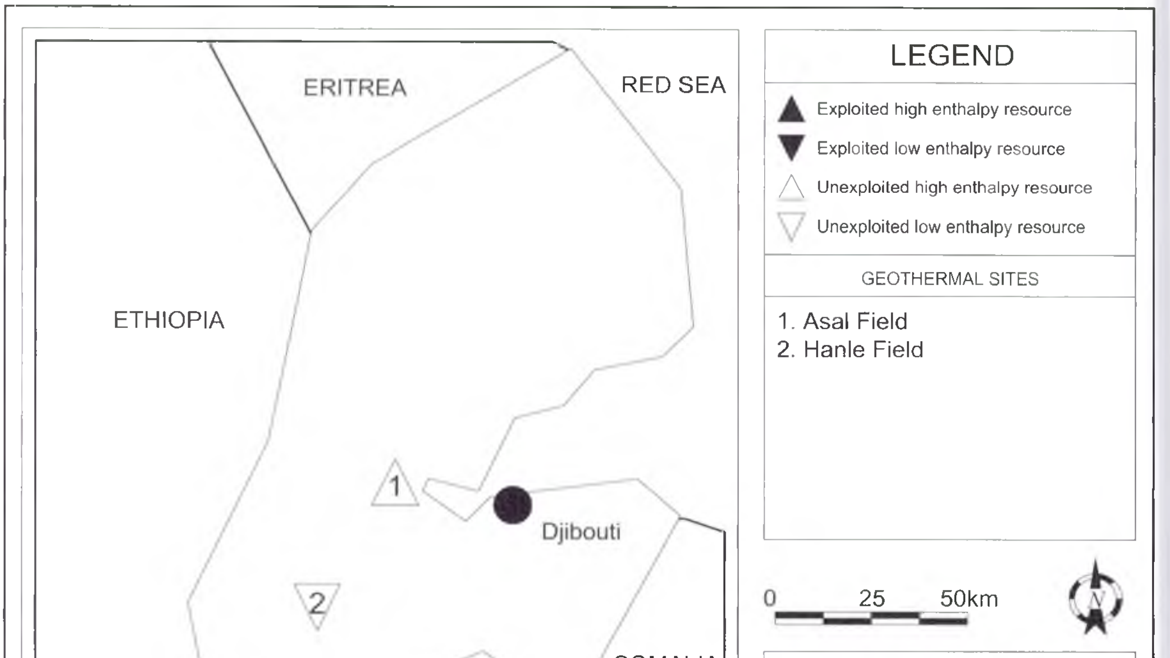


LOCATION OF GEOTHERMAL RESOURCES IN BURUNDI

Research conducted in the early 1980s identified a hot spring with a temperature of 68°C at *Ruhwa* in north west Burundi. This is the highest recorded temperature for a geothermal source in the country. The same research concluded that an exploitable geothermal resource, with a temperature in the range 100 to 160 °C, exists in the *Ruisizi* Valley and probably extends into Zaire and Rwanda. Whilst the temperature is insufficient for electricity generation, it is probably adequate for industrial or domestic use.

DJIBOUTI

Size	23,200	km^2
Population (1994)	0.5	millions
Annual Population growth rate (1994)	4.1	%
GNP per capita (1994)	780	USD per year
Average annual growth rate of GNP		%
Average annual inflation (1985-1993)	4.4	%
Annual energy use per capita (oil equivalent)	764	kg
Average annual growth rate of energy use	85[1]	%
Annual CO_2 emission per capita	2.64	tonnes
Production of electricity (1993)	182	GWh
Geothermal	0	GWh
Fossil fuels	182	GWh



LOCATION OF GEOTHERMAL RESOURCES IN DJIBOUTI

Djibouti is located in East Africa at a point where three important tectonic features meet; the Red Sea, the East African Rift Valley and the Gulf of Aden. These features are responsible for the formation of the Afar Depression. Nearly the entire area of Djibouti is covered with volcanic rocks.

There are two main geothermal areas in Djibouti, the *Asal* Rift and *Hanle* Plain. The *Asal* Rift is the most active structure in the Afar Depression. It is characterised by a volcanic series represented by basalts. It is thought that this volcanism is fed by a chamber that still exists below the rift. The *Hanle* Plain is one of many tectonic depressions lying parallel to the *Asal* Rift. Both areas have been the subject of geothermal exploration and research since the 1970s and research continues to the present day.

During 1987-88 four exploration wells were drilled in the *Asal* Rift and two in the *Hanle* Plain. The *Asal* Rift wells all encountered high temperatures, with a maximum of

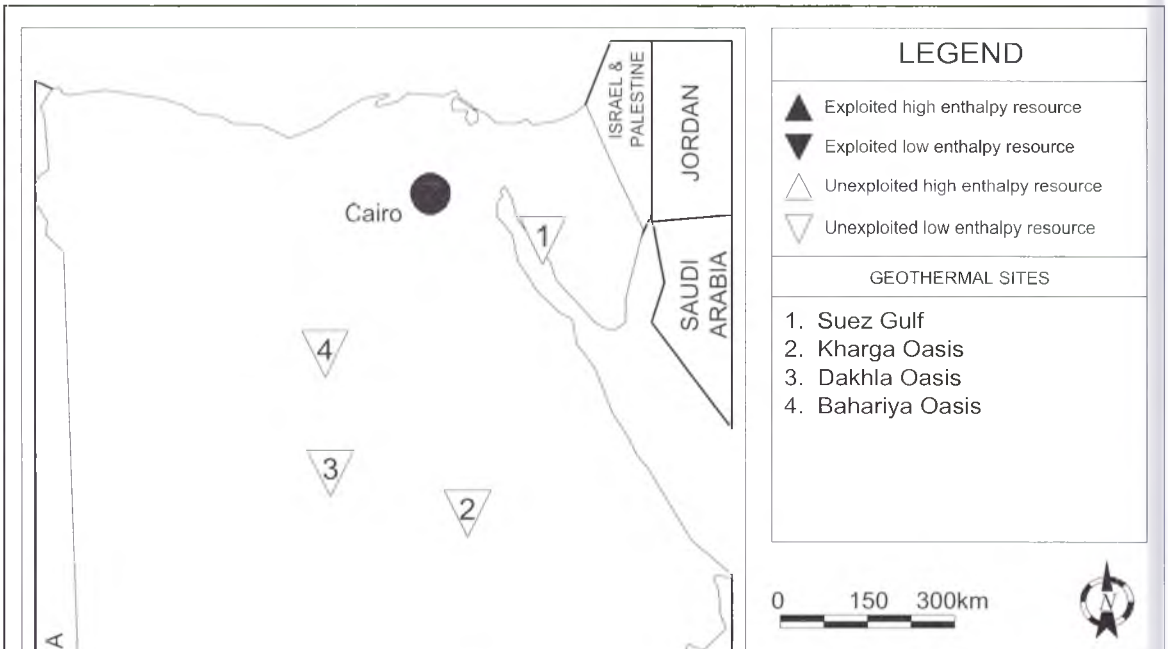
[1] Note: Consumption grew from 217 kg/capita to 775 kg/capita in 1992.

358^{O}C, but have low permeability. Two wells showed production potential, with temperatures of 260 °C at 1,300m, if problems surrounding their high salt content could be overcome.

The two *Hanle* wells encountered a maximum temperature of 124 °C at 2,000m - a temperature which was considered too low for geothermal electricity generation.

EGYPT

Size	998,000	km^2
Population (1994)	57.9	millions
Annual Population growth rate (1994)	2.0	%
GNP per capita (1994)	710	USD per year
Average annual growth rate of GNP (1985-1994)	1.6	%
Average annual inflation (1985-1993)	16.9	%
Annual energy use per capita (oil equivalent)	501	kg
Average annual growth rate of energy use	2.3	%
Annual CO_2 emission per capita	1.54	tonnes
Production of electricity (1993)	47,470	GWh
Geothermal	0	GWh
Fossil fuels	38,950	GWh
Hydro	8,520	GWh



LOCATION OF GEOTHERMAL RESOURCES IN EGYPT

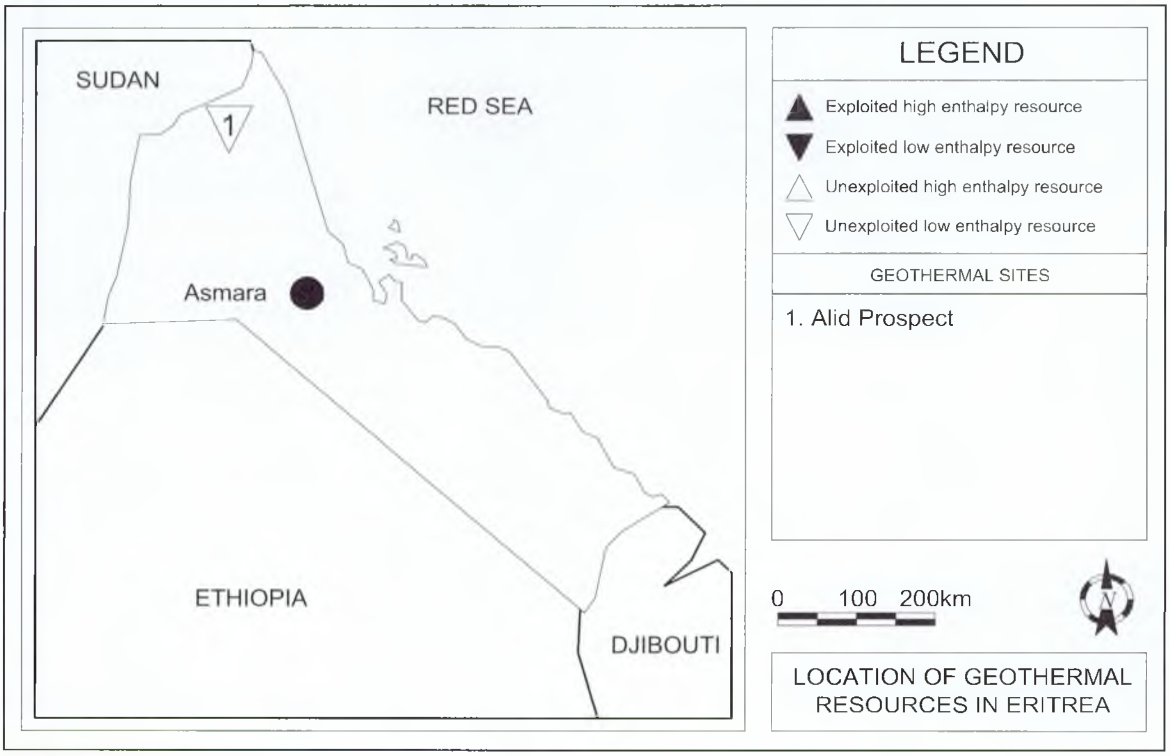
Exploration for geothermal resources has identified the hottest springs are along the eastern shore of the Gulf of Suez. Aquifer temperatures of up to 70 °C have been recorded.

Despite an above average thermal gradient, just one thermal well has been reported in the Eastern Desert whilst in the Western Desert the major oases produce large volumes of water up to 43 °C.

No thermal springs are reported to exist in northern Egypt.

ERITREA

Size	121,144	km^2
Population (1991)	3.44	millions
Annual Population growth rate (1994)	3.0	%
GNP per capita (1994)	51	USD per year
Average annual growth rate of GNP (1985-1994)		%
Average annual inflation (1994)	9.6	%
Annual energy use per capita (oil equivalent)		kg
Average annual growth rate of energy use		%
Annual CO_2 emission per capita		tonnes
Production of electricity		GWh



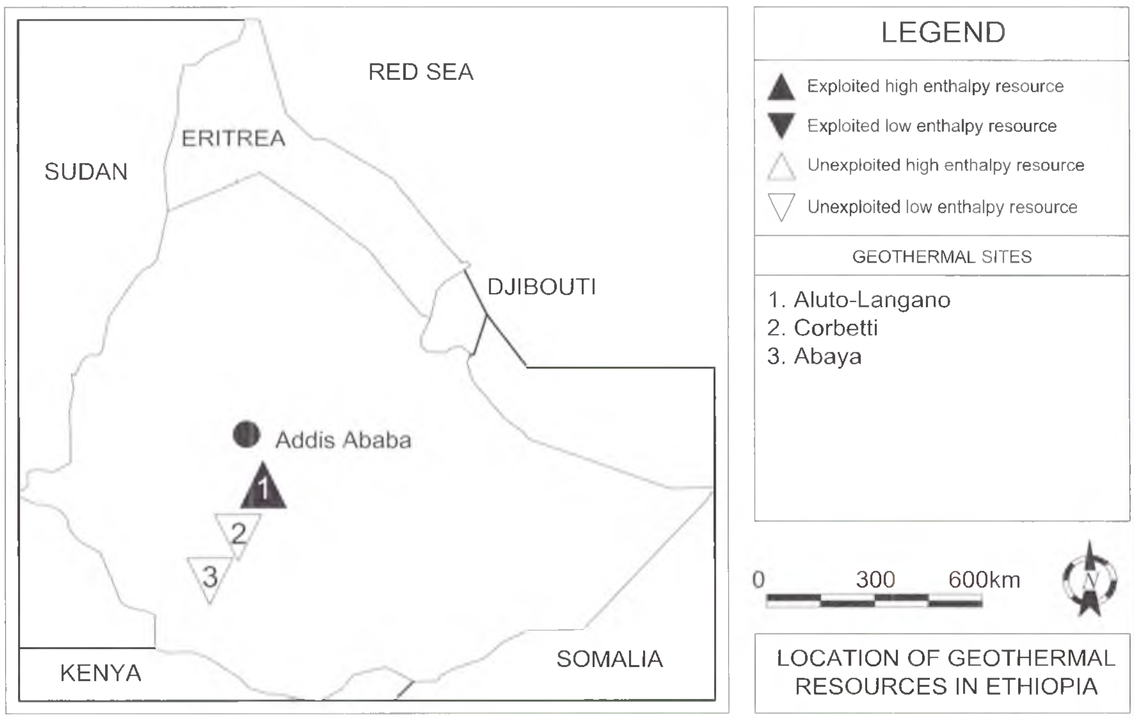
The *Alid* volcanic range in Eritrea, at the most northerly tip of the triangular Afar Depression, is characterised by very high geothermal gradients. Recent volcanic, fumarolic and hot spring activity indicate a geothermal resource.
The *Alid* volcano is 900m above sea level and approximately 700m above the surrounding quaternary plains of marine and red bed sediments.

Three different water groups have been identified and investigations suggest that there is little contact between these. The three groups are:

- *Gelti* hot springs, near the southern coast of the Gulf of *Zula*, which have temperatures in excess of 60 °C.
- *Boya* River water well at the eastern edge of the western escarpment.
- *Alid* Caldera where water temperatures exceeding 100 °C have been recorded.

ETHIOPIA

Size	998,000	km^2
Population (1994)	54.9	millions
Annual Population growth rate (1994)	2.9	%
GNP per capita (1994)	130	USD per year
Average annual growth rate of GNP (1985-1994)	-0.6	%
Average annual inflation (1985-1993)	6.7	%
Annual energy use per capita (oil equivalent)	215	kg
Average annual growth rate of energy use	0.0	%
Annual CO_2 emission per capita	0.95	tonnes
Production of electricity (1993)	1293	GWh
Geothermal	68	GWh
Fossil fuels	90	GWh
Hydro	1135	GWh



LOCATION OF GEOTHERMAL RESOURCES IN ETHIOPIA

Two hundred kilometres south of Addis Ababa in the *Aluto-Langano* geothermal field, eight wells have been drilled during various exploration studies. The field is situated in the Ethiopian Rift Valley.

Exploration studies have shown that the most important aquifer is a Tertiary ignimbrite which lies some 1400m below surface level. Temperatures in the hottest wells reach 360°C and well fluids contain concentrations of sodium bicarbonate. This is a high enthalpy, water dominated field.

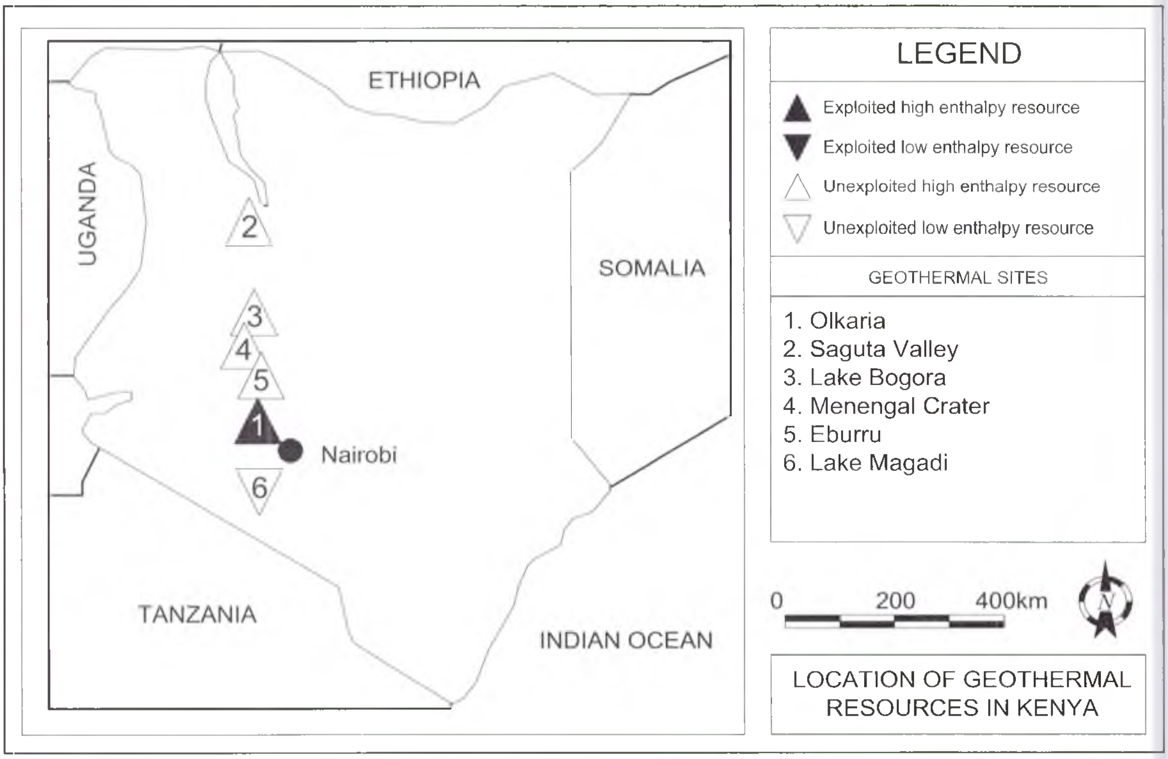
The energy potential of the area has been estimated based on the thermal energy of the saturated water. Fluid temperatures are in the range 220 °C to 360 °C and porosity reaches 7%. These results suggest that 3,000 to 6,000MW.year/km^3 is the extent of the possible resource. This is equivalent to 10-20MW_e/km^3 for more than 30 years. Researchers have suggested that the actual potential could be higher than this. Because of the uncertainty surrounding the size of the upflow zone a conservative estimate was made.

Of the eight wells drilled to date, four are productive. A plant 7.8MWe is under construction in Alucto by Ormat.

Summary of Resources	
Exploited - plant in operation	0
Unexploited - plant under construction or planned	7.8MW$_e$
Unexploited - proven resources	15MW$_e$
Unexploited - probable and possible resources	

KENYA

Size	580,000	km^2
Population (1994)	29.3	millions
Annual Population growth rate (1994)	2.9	%
GNP per capita (1994)	260	USD per year
Average annual growth rate of GNP (1985-1994)	0	%
Average annual inflation (1990-1994)	30.6	%
Annual energy use per capita (oil equivalent)	406	kg
Average annual growth rate of energy use	-3.3	%
Annual CO_2 emission per capita	0.4	tonnes
Production of electricity (1993)	3396	GWh
Geothermal	272	GWh
Fossil fuels	131	GWh
Hydro	2993	GWh



LOCATION OF GEOTHERMAL RESOURCES IN KENYA

Kenya's geothermal activity is a result of its proximity to the East African Rift Valley. It has already been established that geothermal energy is the least cost option for Kenya. However, the development of geothermal resources has been hampered by the country's legal framework. This is now under review with the aim of opening the market to allow private sector investment into the energy sector.

Kenya has declared a plan to have 450MW_e of geothermal power by 2012; this supply 30% of Kenya's current power demand.

Exploration of the resource is continuing particularly in the *Olkaria* geothermal field.

ELECTRICITY GENERATION

In the Eastern Production Field, a 45MW$_e$ station (3×15MW$_e$ Mitsubishi turbines) is in operation although its output has dropped to 31MW$_e$ due to a decline in steam output. In an attempt to bring the steam generation back up to capacity, four new wells have been drilled. The original project, which cost US$ 60M, was funded by the World Bank.

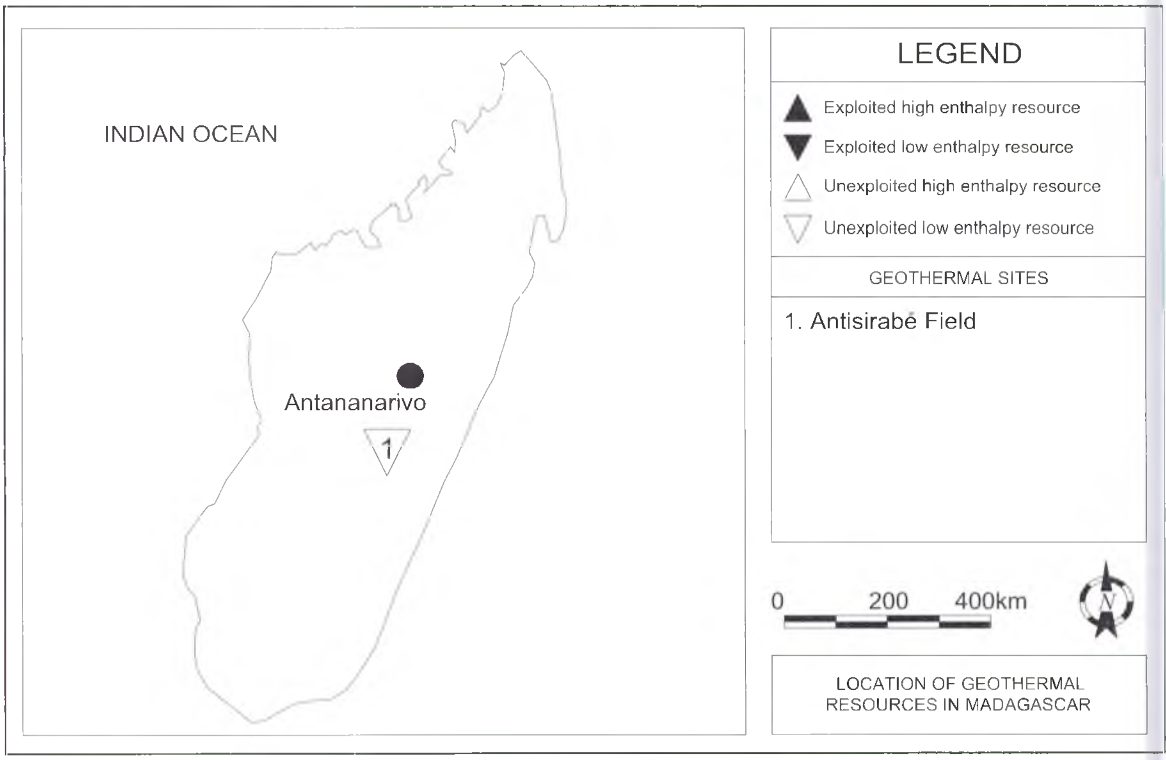
Construction of a 64MW$_e$ plant in the *Olkaria* North East Field has been delayed pending the outcome of Kenya's restructuring programme. Once complete, it is hoped that the plant will be built.

Funding from the World Bank has helped Kenya develop its geothermal infrastructure and human resources in the past few years. Over the past four years Kenya has trained several professional geothermal staff.

SUMMARY OF RESOURCES	
Exploited - plant in operation	45MW$_e$
Unexploited - plant under construction or planned	64MW$_e$
Unexploited - proven resources	450MW$_e$
Unexploited - probable and possible resources	600MW$_e$

MADAGASCAR

Size	587,041	km^2
Population (1993)	12.1	millions
Annual Population growth rate (1994)	3.6	%
GNP per capita (1994)	230	USD per year
Average annual growth rate of GNP (1985-1994)	-1.7	%
Average annual inflation (1985-1993)	13.7	%
Annual energy use per capita (oil equivalent)	167	kg
Average annual growth rate of energy use	0	%
Annual CO_2 emission per capita	0.8	tonnes
Production of electricity (1993)	599	GWh
Geothermal	0	GWh
Fossil fuels	252	GWh
Hydro	347	GWh



The *Antsirabe* geothermal field is a large volcanic plateau of approximately $1000km^2$. The area consists of basaltic and sedimentary formations overlaying an old basement of gneisses and migmatites.

A number of warm water springs exist in the area with temperatures ranging up to $49^{O}C$. Estimates suggest that at depth the fluid temperature may reach $180^{O}C$.

The proximity of a major town close to the field raises the possibility of using geothermal energy for industrial purposes.

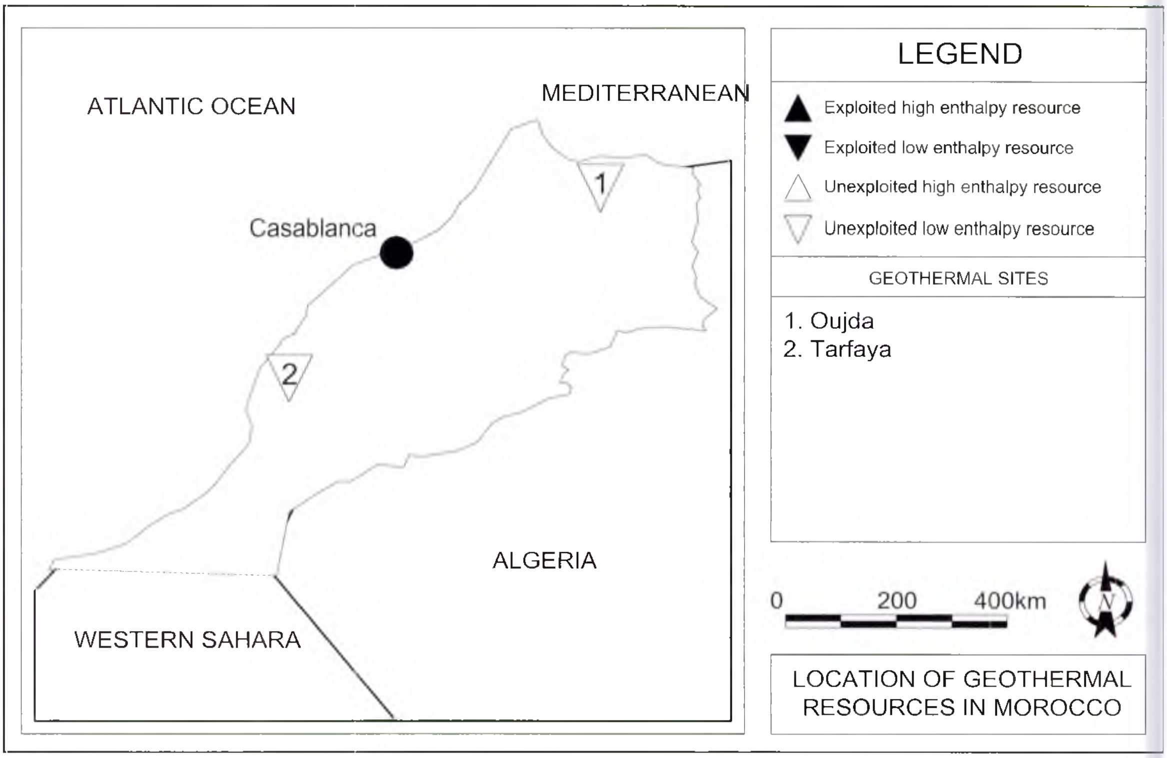
MALAWI

Size	118,484	km^2
Population (1993)	9.7	millions
Annual Population growth rate (1994)	3.4	%
GNP per capita (1994)	140	USD per year
Average annual growth rate of GNP (1985-1994)	-2.0	%
Average annual inflation (1985-1993)	18.8	%
Annual energy use per capita (oil equivalent)	239	kg
Average annual growth rate of energy use	0	%
Annual CO_2 emission per capita	1.2	tonnes
Production of electricity (1993)	795	GWh
Geothermal	0	GWh
Fossil fuels	16	GWh
Hydro	779	GWh

No geothermal data have been available.

MOROCCO

Size	711,000	km^2
Population (1994)	26	millions
Annual Population growth rate (1994)	2.2	%
GNP per capita (1994)	1150	USD per year
Average annual growth rate of GNP (1985-1994)	1.1	%
Average annual inflation (1985-1994)	5.3	%
Annual energy use per capita (oil equivalent)	287	kg
Average annual growth rate of energy use	0.0	%
Annual CO_2 emission per capita	0.9	tonnes
Production of electricity (1993)	9917	GWh
Geothermal	0	GWh
Fossil fuels	9474	GWh
Hydro	443	GWh



Two sources of information exist concerning the geothermal resources of Morocco; shallow borehole data and deep oil well data. Data from these sources has revealed the following regional characteristics.

The Precambrian domain of the Anti-*Atlas* has the lowest heat flow density of any region in Morocco at 40mWm^{-2}. The thermal gradient is reported as being 14^{O}Ckm^{-1}.

The High Plateaux and Moroccan Meseta both have heat flow densities in the range 55 - 60mWm^{-2}.

High anomalies exist in the Northern domain particularly in the Northern Middle *Atlas*, Eastern *Rif* and *Oujda* regions. Many warm springs exist in these areas. One notable case concerns a mining borehole drilled NE of *Oujda*; at a depth of 680m, water at 95^{O}C was located. The heat flow density at this location exceeds 200mWm^{-2}.

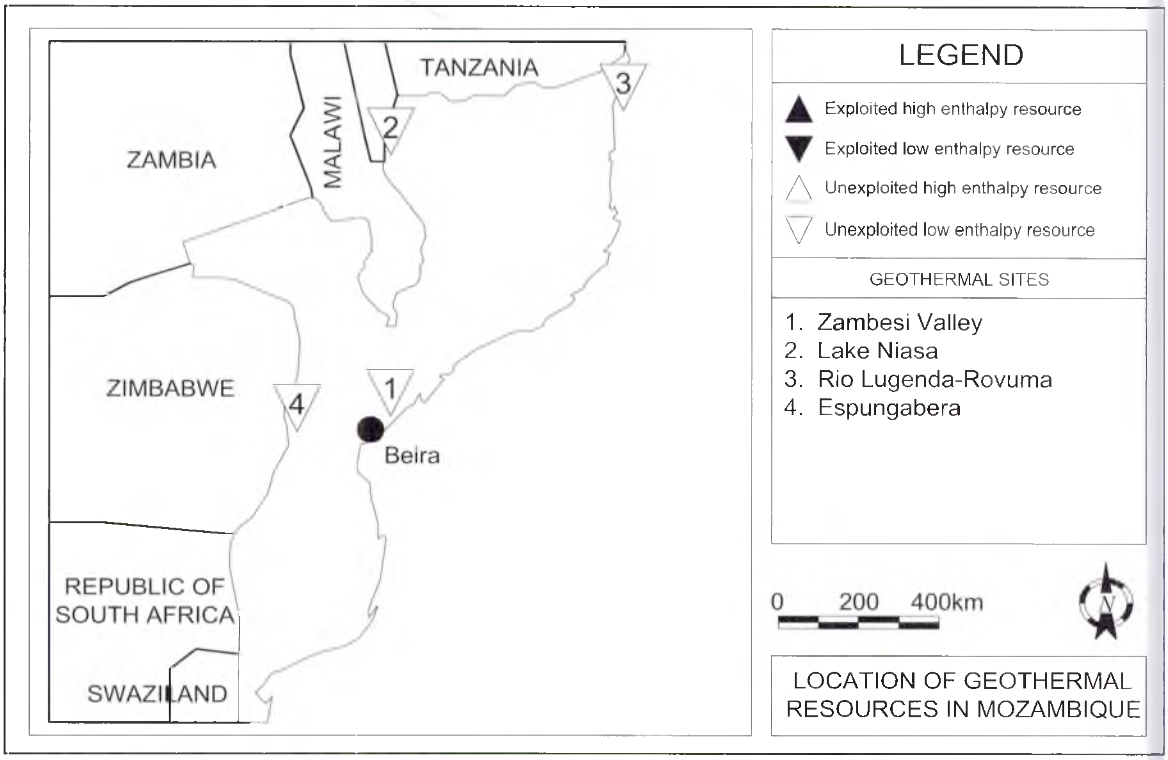
There is an absence of volcanism in the Western *Rif*. Despite this many warm springs exist. These are thought to have their origin in deep circulation.

In the south, the Atlantic margin and coastal Saharan basins have high heat flow densities and extensive hyperthermalism. An oil exploration borehole near *Tarfaya* found hot water and steam. Several similar deep wells have produced water at $100^{O}C$ at depths between 2000 and 3000m.

The *Tindouf* basin, which extends into Algeria, has a heat flow density of ~$90mWm^{-2}$.

MOZAMBIQUE

Size	799,000	km^2
Population (1994)	16.6	millions
Annual Population growth rate (1994)	2.0	%
GNP per capita (1994)	80	USD per year
Average annual growth rate of GNP (1985-1994)	3.5	%
Average annual inflation (1985-1993)	53.5	%
Annual energy use per capita (oil equivalent)	263	kg
Average annual growth rate of energy use	0	%
Annual CO_2 emission per capita	1.0	tonne
Production of electricity (1993)	490	GWh
Geothermal	0	GWh
Fossil fuels	440	GWh
Hydro	50	GWh



Faults and tectonic activity associated with the East African Rift Valley have created hydrothermal fields in Mozambique. In fact 10% of the country lies within the valley and associated fracture zones. Exploratory work conducted during the 1970s and 80s deduced that Mozambique has a geothermal potential in excess of $25MW_e$.

Mozambique's geology can be divided into two regions;
The north west half consisting of crystalline and metamorphic rocks of mainly Precambrian age but also Mesozoic and late Palaeozoic and the late Mesozoic and Cainozoic sediments.

The Direccao National de Geologia has identified the following areas as potential geothermal sites worthy of further exploration: *Chire Urema* Valley, *Zambesi* Valley, *Niasa Lake* area, *Ilha de Mozambique*, *Pebane*, *Vila Necuagas*, *Espungabera*, *Rio Lugenda-Rovuma*.

At least 38 thermal springs have been identified. Some of these issue boiling water whereas for others the water temperature is <60^{0}C. Investigations have confirmed the potential for small scale power generation which is particularly suitable for Mozambique.

SUMMARY OF RESOURCES	
Exploited - plant in operation	0
Unexploited - plant under construction or planned	0
Unexploited - proven resources	25MW$_e$
Unexploited - probable and possible resources	50MW$_e$

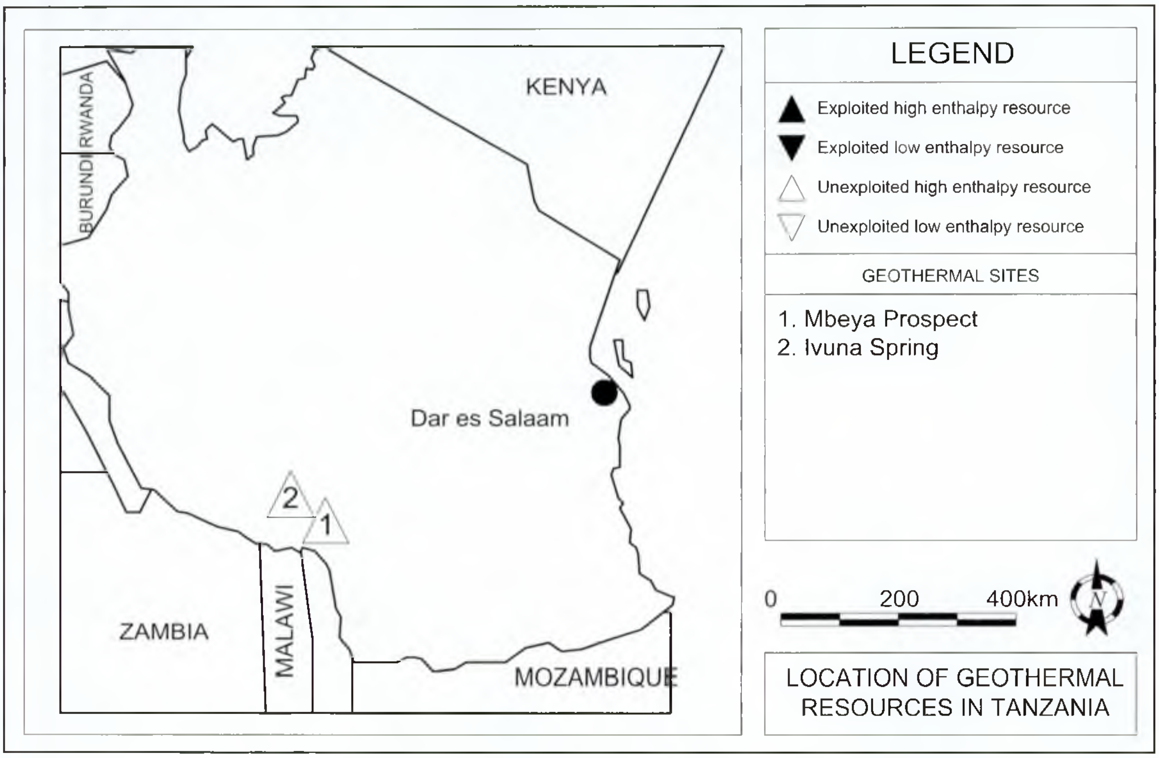
RWANDA

Size	26,338	km^2
Population (1991)	7.2	millions
Annual Population growth rate (1994)	2.7	%
GNP per capita (1994)	210	USD per year
Average annual growth rate of GNP (1985-1993)	-3.5	%
Average annual inflation (1985-1993)	6.4	%
Annual energy use per capita (oil equivalent)	191	kg
Average annual growth rate of energy use	-4.0	%
Annual CO_2 emission per capita	0.9	tonnes
Production of electricity (1993)	234	GWh
Geothermal	0	GWh
Fossil fuels	4	GWh
Hydro	230	GWh

No geothermal data were available.

TANZANIA

Size	945,100	km^2
Population (1995)	30.3	millions
Annual Population growth rate (1994)	3.1	%
GNP per capita (1994)	100	USD per year
Average annual growth rate of GNP (1985-1993)	1.4	%
Average annual inflation (1984-1994)	29.4	%
Annual energy use per capita (oil equivalent)	310	kg
Average annual growth rate of energy use	3.0	%
Annual CO_2 emission per capita	1.3	tonnes
Production of electricity (1993)	907	GWh
Geothermal	0	GWh
Fossil fuels	282	GWh
Hydro	625	GWh



There are a couple of potential geothermal sites in Tanzania none of which are exploited at the present time. Perhaps the most significant of these is the *Mbeya* prospect in south-west Tanzania.

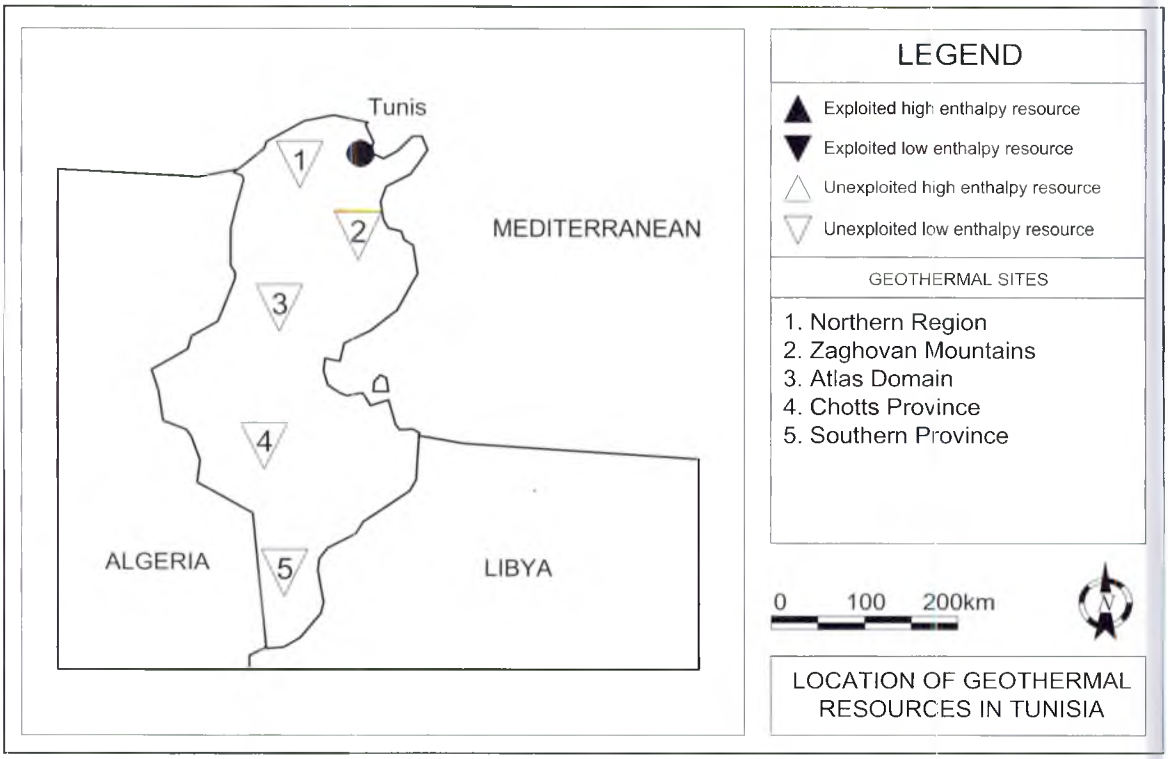
The *Mbeya* prospect is associated with a volcano that exists on a fault sequence. Exploration has revealed high enthalpy bicarbonate-sulphate-chloride fluids. At the *Ivuna* spring these fluids are predicted to reach a temperature of nearly $220^{O}C$.

Development of the prospect may prove attractive since there is a nearby need for electricity at a large cement works.

Some of the country's hot springs, whose fluids have a surface temperature up to $78^{O}C$, are used for salt extraction.

TUNISIA

Size	154,500	km^2
Population (1994)	8.8	millions
Annual Population growth rate (1994)	2.3	%
GNP per capita (1994)	1800	USD per year
Average annual growth rate of GNP (1985-1994)	1.8	%
Average annual inflation (1985-1993)	6.5	%
Annual energy use per capita (oil equivalent)	693	kg
Average annual growth rate of energy use	4.0	%
Annual CO_2 emission per capita	2.1	tonnes
Production of electricity (1993)	6416	GWh
Geothermal	0	GWh
Fossil fuels	6352	GWh
Hydro	64	GWh



LOCATION OF GEOTHERMAL RESOURCES IN TUNISIA

Tunisia has experienced a threefold increase in energy consumption between 1970 and 1986. It was once a net exporter of energy but is now a net importer; hence the drive to develop domestic resources including geothermal energy.

Tunisia is situated on the intersection of 3 tectonic plates; the African, European and Mediterranean. Geologically the country can be considered to comprise the Saharan platform in the south, the alpine fold mountains in the north and an eastern region consisting of five geological provinces that all differ from one another in their geology but nonetheless oil exploration and hydrological studies have indicated that each province could contain a geothermal resource.

Province 1, the northern region whose geology is affected by the alpine nappes, incorporates a thick sandy layer. The hottest springs have temperatures in the range 20 to 73 °C at the surface and 110 °C below surface. The discharge rate is 1 to 40l/s and the geo-gradient is in the range 80-90^{O}C/km. The region is related to the Tuscan Italian province and therefore is expected to be a high energy geothermal region.

Provinces 2 and 3 constitute the 'Atlas' domain and consist of layers of sands, sandstone and limestone. The domain has a good potential with province two containing several hot springs with temperatures >60^{O}C and flow rates of 40-60l/s making it a promising low temperature resource. Heat flow is >90mW/m^2.

Province 4 contains an important feature - the '*Tebaga* anticline'. This forms a transition from the Atlas and Sahara domains. It consists of sedimentary rock of Jurassic and Cretaceous ages and >4,000m of clays and sandstones. This is the most important aquifer in the North African Sahara. Provinces three and four share similar geothermal characteristics and good potential. Water at 50 °C has been recorded at 50m depth and the geothermal gradient varies between 25 and 45 °C/km. Heat flow varies between 80 and 120mW/m^2.

Province 5, in the south of Tunisia, contains the biggest sedimentary basin in the country covering half of Tunisia. Here the geothermal gradient is in the range 25 to 35^{O}C/km and the heat flow 80 to 140mW/m^2.

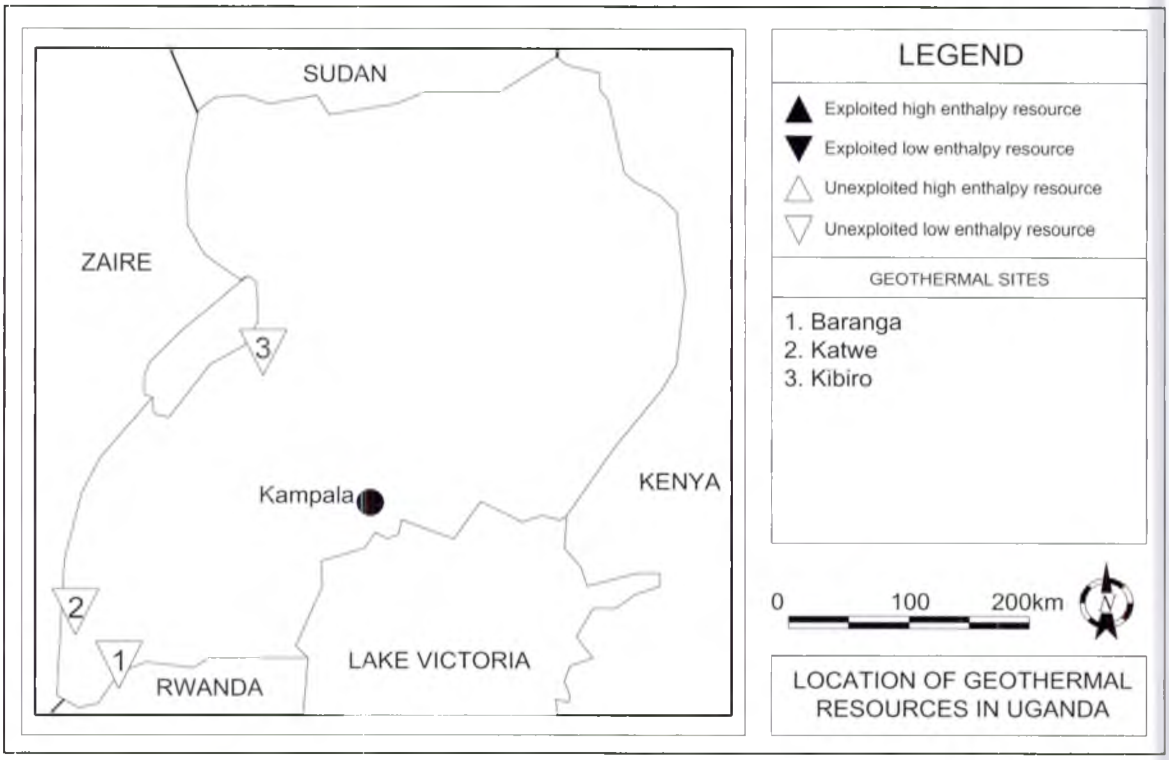
Useful information about the geothermal resources has come from the 70 existing hot springs, and the 230 hydrogeologic and 350 oil wells drilled as part of groundwater and oil exploration programmes.

To date the exploitation of the geothermal resource is limited to the use of hot ground water for agricultural greenhouses. One hundred hectares of such greenhouses existed in 1985. This figure had grown to 3000ha by 1995 with thermal energy consumption estimated at 70MW.

Summary of Resources	
Exploited - plant in operation	$70MW_t$
Unexploited - plant under construction or planned	0
Unexploited - proven resources	no data
Unexploited - probable and possible resources	no data

UGANDA

Size	241,800	km^2
Population (1991)	16.7	millions
Annual Population growth rate (1994)	2.5	%
GNP per capita (1994)	200	USD per year
Average annual growth rate of GNP (1985-1994)	3.0	%
Average annual inflation (1990-1994)	31.7	%
Annual energy use per capita (oil equivalent)	191	kg
Average annual growth rate of energy use	0	%
Annual CO_2 emission per capita	0.9	tonnes
Production of electricity (1993)	788	GWh
Geothermal	0	GWh
Fossil fuels	7	GWh
Hydro	781	GWh



On the basis of a report written by a UN technical adviser in 1984, geothermal exploration was initiated in the areas of *Buranga*, *Katwe* and *Kibiro*. All three areas are near Uganda's western border and are influenced by the African Rift Valley.

In 1992 a geothermal exploration project set out to study the three areas with a view to establishing which were the most promising for drilling exploratory wells. The study concluded that all three areas were suitable.

At 120 °C- 135 °C aquifer temperatures at *Buranga* were the lowest of the areas considered but had the highest flow rates (>15 litres/second). Estimates put the geothermal field at a minimum of $0.1km^2$.

Both *Katwe* and *Kibiro* had lower flow rates (>0.5 and 6.5 litres/second respectively) but higher temperatures approaching 200^OC in both cases. The added advantage of these two areas is that they are only 5 to 10km from existing power transmission lines.

Studies have shown that all three geothermal areas have similar economics to small scale hydro-power and that *Katwe* and *Kibiro* could be on a par with larger hydro plants under certain circumstances.

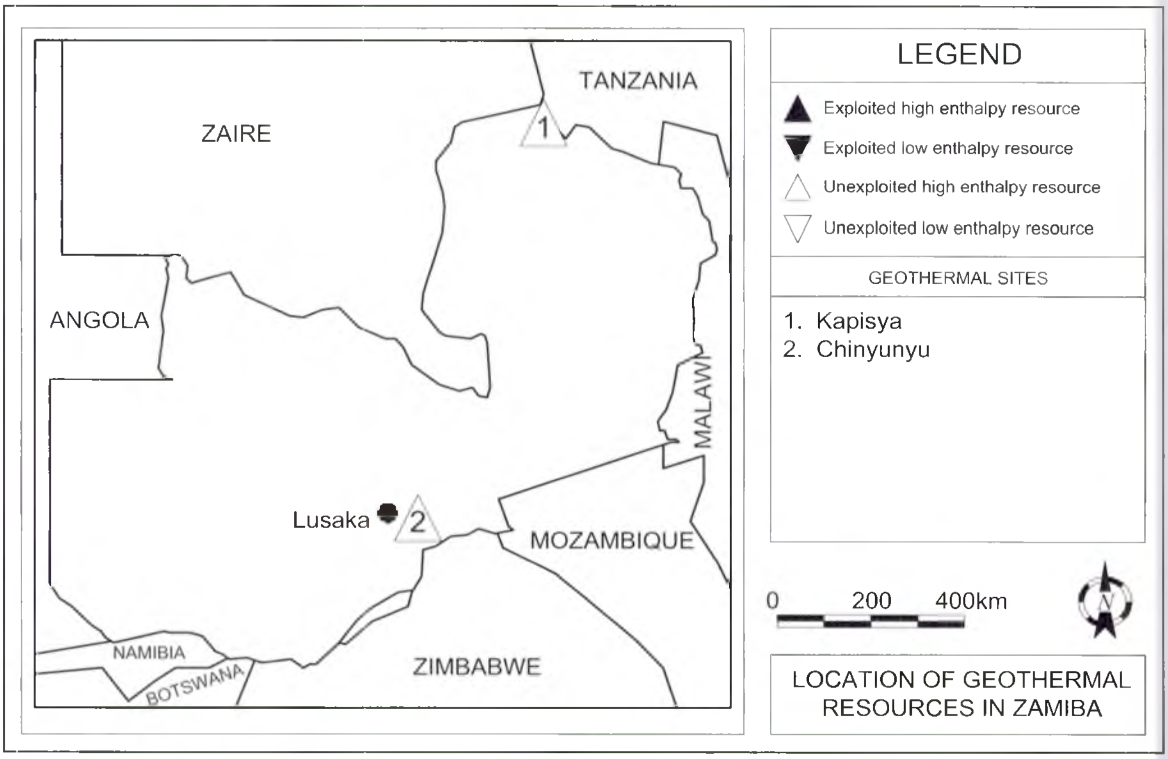
To date no geothermal development has taken advantage of these investigative studies. It has been suggested that if funds can be found that there are two further study options;

- conduct a $24km^2$ geological survey of the *Buranga* area. The aim of the study would be to provide information that would allow the appropriate siting and installation of a small power plant to supply electricity to the local community and a demonstration plant for crop drying.

- complete the geophysical exploration of *Katwe* and *Kibiro* to establish whether the fields are suitable for providing electricity to the national grid. The study areas are $200km^2$ and $32km^2$ respectively. The selected site would require 3 drill holes to be bored down to 1600 - 1800m.

ZAMBIA

Size	752,614	km^2
Population (1994)	8.0	millions
Annual Population growth rate (1985-94)	3.3	%
GNP per capita (1994)	350	USD per year
Average annual growth rate of GNP (1985-1994)	-1.3	%
Average annual inflation (1994)	~54	%
Annual energy use per capita (oil equivalent)	478	kg
Average annual growth rate of energy use	-3.0	%
Annual CO_2 emission per capita	2.8	tonnes
Production of electricity (1993)	7785	GWh
Geothermal	0	GWh
Fossil fuels	40	GWh
Hydro	7745	GWh



Two geothermal energy developments are under construction in Zambia

The first, the *Kapisya* geothermal project, is on the shores of *Lake Tanganyika* in *Sumbu*. A pilot plant was built in 1986 after exploration found that the hot springs were favourable for development. Two organic Rankine Cycle turbogenerators, with a total nominal capacity of 200kW, have been installed. Due to a lack of funds, the construction of the power transmission line has not progressed so the surrounding communities and fishing and tourism industries have not benefited from the development.

The second project, currently at the planning stage, concerns the development of a health resort and potentially construction of a geothermal power plant. The plan is to provide cheap power to the community at *Chinyunyu* Hot Springs, fifty kilometres east of *Lusaka*.

Summary of Resources	
Exploited - plant in operation	0
Unexploited - plant under construction or planned	200kW
Unexploited - proven resources	no data
Unexploited - probable and possible resources	no data

ZIMBABWE

Size	390,759	km^2
Population (1992)	10.4	millions
Annual Population growth rate (1994)	3.0	%
GNP per capita (1994)	490	USD per year
Average annual growth rate of GNP (1985-1994)	-0.6	%
Average annual inflation (1985-1993)	39.8	%
Annual energy use per capita (oil equivalent)	597	kg
Average annual growth rate of energy use	1.5	%
Annual CO_2 emission per capita	2.4	tonnes
Production of electricity (1993)	7,643	GWh
Geothermal	0	GWh
Fossil fuels	5,950	GWh
Hydro	1,693	GWh

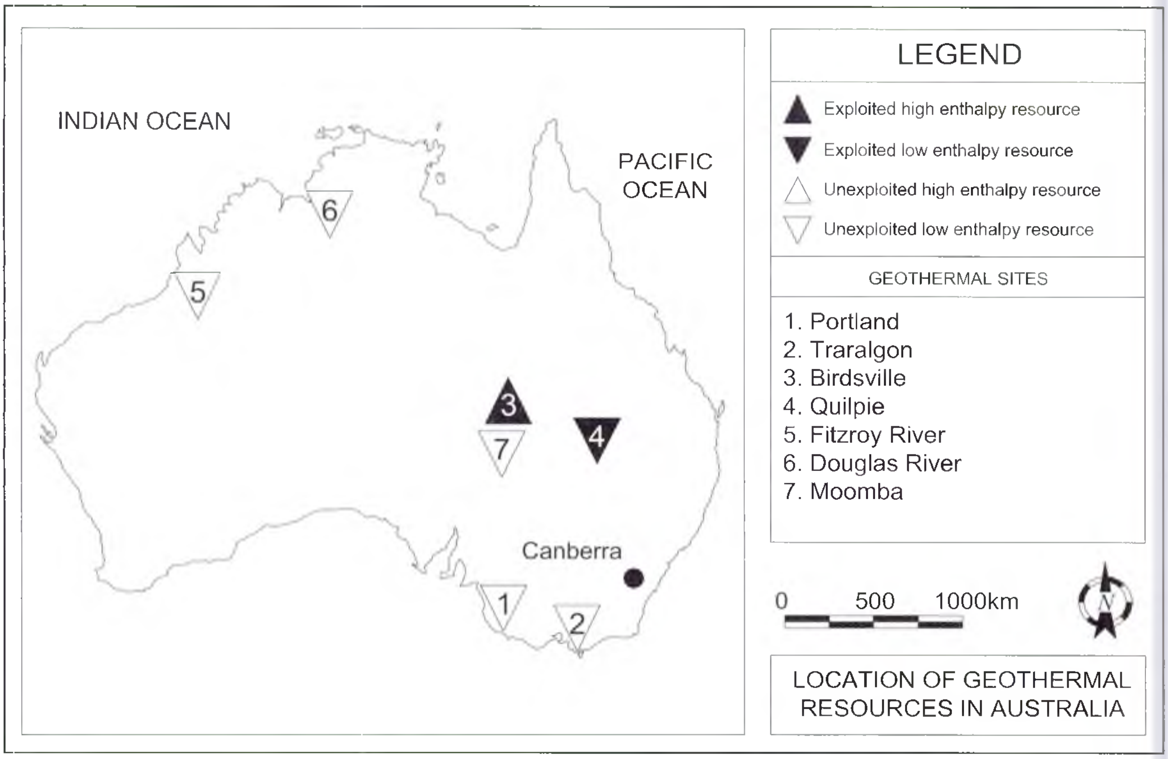
No geothermal data were available.

Oceania

Australia
Fiji
New Zealand
Papua New Guinea
Other Pacific Islands

AUSTRALIA

Size	7,682,000	km^2
Population (1993)	17.7	millions
Annual Population growth rate (1993)	1.5	%
GNP per capita (1994)	17,980	USD per year
Average annual growth rate of GNP (1985-1994)	1.2	%
Average annual inflation (1984-1994)	1.9	%
Annual energy use per capita (oil equivalent)	5,492	kg
Average annual growth rate of energy use	0	%
Annual CO_2 emission per capita	18.5	tonnes
Production of electricity (1993)	163,557	GWh
Geothermal	0.7	GWh
Fossil fuels	147,013	GWh
Hydro	16,539	GWh
Wind	4	GWh
Production of heat (1993)	3,514	TJ
Geothermal heat	1	TJ
Thermal plant	3,513	TJ



The Australian continent comprises sedimentary basins overlying Precambrian shield and Palaeozoic metamorphic complexes. Three high heat flow areas exist; the Western, Central and Eastern. Heat flows in the Western region are low whilst those in the Eastern region of the continent are high benefiting from a more recent magmatic intrusion into the upper crust.

The *Otway* Basin is an east-west trending formation of Cainozoic sediments. These reach a maximum depth of over 6,000m at their thickest point in the south. Water temperatures up to 62^{O}C have been recorded with water flowing north-south. The main aquifers discharge to the sea along 240km of coast representing a heat flow of 1160MW$_{(t)}$. The east-west trending graben rocks of the *Grippsland* basin contain Cainozoic sediments of up to 6,000m thickness. Water, in the range 19 to 167^{O}C, flows mainly NW to the sea at a rate of ~1800ML/year. Good quality water is available in three of the *Grippsland* sub-basins at 50^{O}C. The Great Artesian Basin covers almost 20% of Australia and consists largely of mesozoic sediments up to 3000m thick. Water exists within these sediments at 30 to 50^{O}C but in some areas water at 120^{O}C is available. Water flows from individual bore holes can exceed 10,000m^{3}/day. Boiling water from certain bore holes has been flowing for many years.

ELECTRICITY GENERATION

The *Birdsville* Power Station was constructed as a demonstration to show how low temperature thermal energy can be converted into electricity. Water from the town's bore hole is used to operate an organic Rankine cycle engine rated at 150kW$_{e}$. The geothermal power station, which augments diesel units, takes water from a depth of 1220m. Water has been flowing for 75 years with a surface temperature of 99^{O}C. The station has been operating since 1992 and has achieved a service factor of 50%. After consideration of parasitic losses etc. the station's efficiency is only 4%. *Birdsville* town has a power demand that varies between 60 and 150kW$_{e}$. Geothermal energy is sufficient to meet the low demand but when demand is higher the diesel sets have to be brought in. Station performance is to be reviewed after the initial four years as a demonstration plant is completed i.e. during 1996.

SUMMARY OF RESOURCES	
Exploited - plant in operation	0.15MWe
Unexploited - plant under construction or planned	0
Unexploited - proven resources	50MWe
Unexploited - probable and possible resources	1200MWe

DIRECT USES

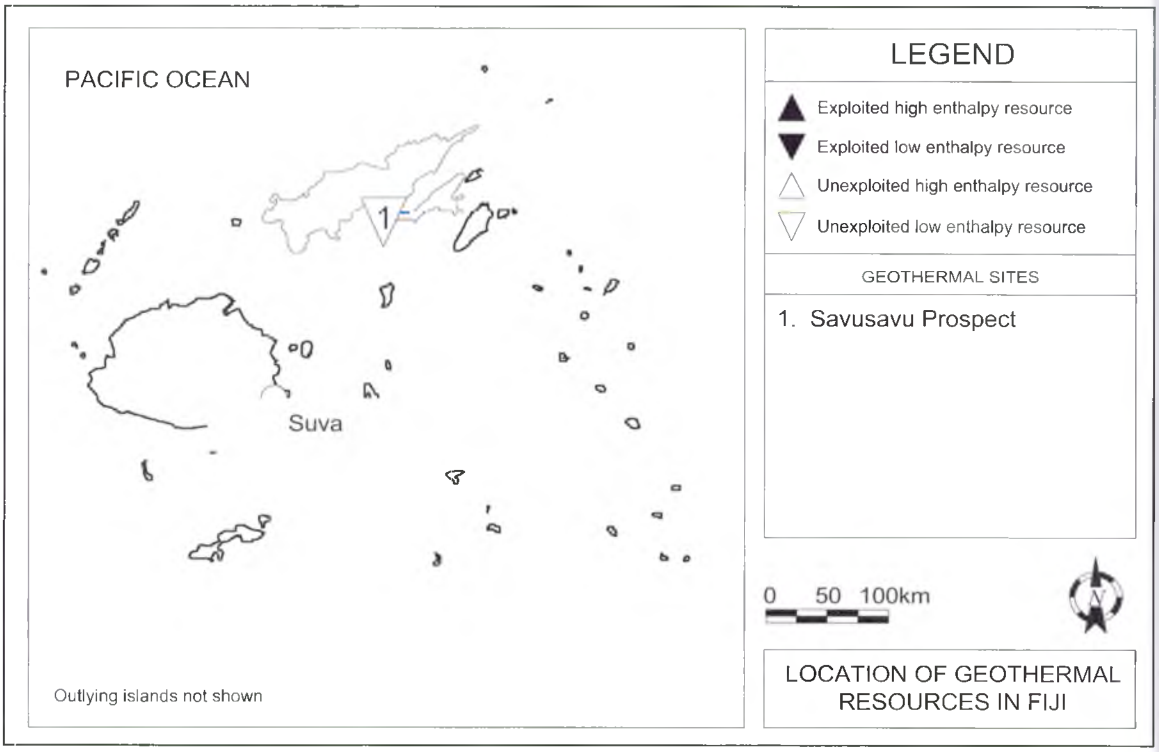
Development of the *Otway* Basin has occurred in the town of *Portland*. Since 1956 water has been drawn from a depth of 1400m using four bore holes. Until 1983 all the water, at a temperature of 56 to 59^{O}C, was cooled for consumption. Presently however, one of the bore holes provides water to heat municipal and private buildings (total area 18,990m^{2}) including an open air swimming pool. The latter has a thermal energy requirement of 800kW. In the 20 years that the project has been operating, there has been only a slight drop in the static head, due to climate changes, of 1m. There has been no change in the bore head water temperature. The project saves approximately A$300k a year. Other bore holes may be exploited in new developments.

During the 1950s, 68^{O}C water was used in paper manufacture near *Traralgon*. Water was brought to the surface using two bores from a depth of 600m. The project however, was abandoned after a few years. No reasons were specified.

Water supplies drawn from hot aquifers are fairly common in inland Australia. For example, at *Quilpie*, *Queensland*, boiling water from the Great Artesian Basin, is drawn up from 1,000m and cooled for domestic use. In another development, binary cycle systems and flash steam generators of 20kW$_{e}$ were tested at the *Mulka* cattle ranch saving an estimated 15,000 litres per year of diesel fuel. However this system has not been developed commercially.

FIJI

Size	18,376	km^2
Population (1994)	0.8	millions
Annual Population growth rate (1994)	1.4	%
GNP per capita (1994)	2,180	USD per year
Average annual growth rate of GNP (1985-1994)	2.0	%
Average annual inflation (1984-1994)	5.6	%
Annual energy use per capita (oil equivalent)	693	kg
Average annual growth rate of energy use	-5.1	%
Annual CO_2 emission per capita	2.6	tonnes
Production of electricity (1993)	465	GWh
Geothermal	0	GWh
Fossil fuels	80	GWh
Hydro	385	GWh



From evidence of hot spring activity, the two main islands of Fiji, *Vanua Levu* and *Vitu Levu*, both have a geothermal resource. Over the years a number of surveys have been undertaken to examine the most promising geothermal areas. In some instances survey work was performed to support oil exploration. Data has been gathered from aeromagnetic, infra-red thermal imagery, electrical resistivity and traversing and sound surveys.

On the island of *Vanua Levu*, two areas with promising geothermal potential were identified; *Savusavu* and *Labasa*. The *Savusavu* peninsula has an estimated potential of $25MW_e$ whereas the indications are that the *Labasa* prospect will only be able to provide process heat for industry.

From survey results a model has been proposed for the *Savusavu* prospect. This suggests that the geothermal gradient is as high as $80^{O}C/km$. Ground water circulates to a depth of 2km where its temperature reaches 180^{o}C. It is envisaged that ground water could exist at a greater depth perhaps as far down as 2.5km where its temperature would be near 225^{o}C.

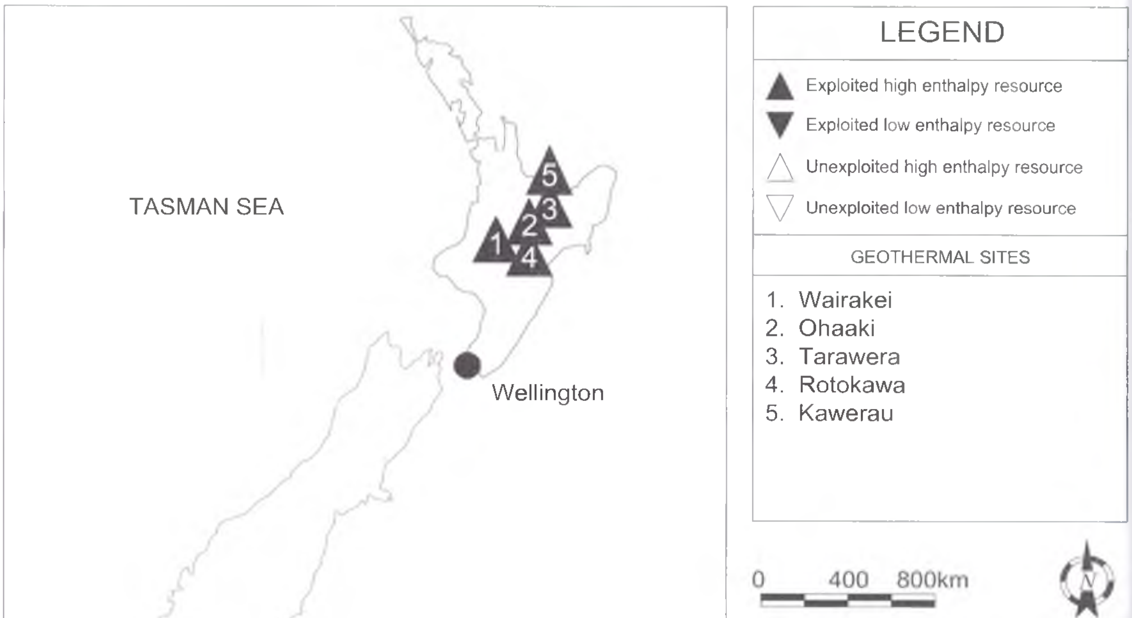
Fiji's electrical power supply is predominantly supplied from hydro schemes for which, particularly on *Vanua Levu*, there is limited scope for expansion. Therefore if the economics of geothermal potential can be assessed and proven, geothermal energy could supplement existing hydro capacity. A programme for exploration via deep drilling, which would do much to prove the economics, has been developed.

During the 22nd Annual Session of the South Pacific Applied Geoscience Commission (SOPAC), Fiji, along with other South Seas island communities, proposed to participate in a regional geothermal programme co-ordinated by SOPAC. It is envisaged that the deep drilling exploration of Fiji would progress under this programme. Funding for such an activity was being sought during 1996.

Summary of Resources	
Exploited - plant in operation	0
Unexploited - plant under construction or planned	0
Unexploited - proven resources	25MW$_e$
Unexploited - probable and possible resources	no data

NEW ZEALAND

Size	271,000	km^2
Population (1994)	3.5	millions
Annual Population growth rate (1994)	0.9	%
GNP per capita (1994)	13,190	USD per year
Average annual growth rate of GNP (1985-1994)	0.5	%
Average annual inflation (1985-1994)	5.9	%
Annual energy use per capita (oil equivalent)	3869	kg
Average annual growth rate of energy use	1	%
Annual CO_2 emission per capita	9.1	tonnes
Production of electricity (1993)	31,248	GWh
Geothermal	1,600	GWh
Fossil fuels	8,375	GWh
Hydro	21,269	GWh
Biomass	4	GWh



LOCATION OF GEOTHERMAL RESOURCES IN NEW ZEALAND

There has been little development of geothermal resources in New Zealand since 1990. This is primarily because of the low energy cost (the average 1994 wholesale price was less than NZ 6 cents/kWh). However the restructuring of the energy industry has meant that competition arising from the ‘free market’ is keeping prices low. Consequently there has been a slowing of geothermal development.

1995 installed geothermal capacity was 286MW; updated installed capacity at 1997 is 365 MWe.

Electricity consumption in New Zealand is predicted to achieve 3-5% growth per year for the foreseeable future. New generating plant is therefore likely to be needed before the year 2000. With optimisation of steam field management under way, the cost effectiveness of geothermal energy will improve making geothermal an attractive option.

ELECTRICITY GENERATION

Seven geothermal fields have been developed or show potential: *Wairakei*, *Ohaaki*, *Ngawha*, *Mokai*, *Rotokawa*, *Tauhara*, *Lake Rotoma*.

Over the past five years, the *Wairakei* field has been maintained at 150MW producing on average 1180GWh/year. Field steam production is falling however, at approximately 4% per year due to a reduction in the fluid temperature. Construction of an additional 15 to 20MW is imminent.

Over the past five years, high pressure steam production at he *Ohaaki* field has declined rather more rapidly than predicted. The cause would appear to be cooler water seeping into the well resulting in a drop in the well temperature of 5°C/year. As a result some plant (~20MW$_e$) may be decommissioned earlier than envisaged. More optimistically, at a depth >2,500m, the reservoir temperature is almost 300°C; plans are being devised to develop this resource.

Despite its low heat content and high dissolved mineral content, development of the *Ngawha* field is planned during 1997/98. An 8MW$_e$ plant is scheduled for construction and a second stage (16MW$_e$) is planned for a later date.

The *Mokai* field is situated 20km NW of *Taupo*. Exploratory drilling has revealed a source of ~3,200PJ with reservoir temperatures, at >320°C, amongst the highest in New Zealand. Proposals to develop a 50MW$_e$ plant are under consideration.

Situated ~13km NW of *Taupo* and ~9km east of *Wairakei*, the *Rotokawa* field has eight exploratory wells. Temperatures of ~320°C have been recorded. An 18MW$_e$ plant is under construction.

The *Tauhara* field is located NE of *Taupo* town. It is connected at depth to *Wairakei*. Proposals for a 10MW$_e$ plant are under consideration.

Studies at the *Lake Rotoma* field, 26km NE of *Rotorua* city, have indicated that the field could sustain a 50 to 150MW$_e$ plant. Currently approval is being sought for a 55MW$_e$ development.

SUMMARY OF RESOURCES	
Exploited - plant in operation	286MWe
Unexploited - plant under construction or planned	157MWe
Unexploited - proven resources	no data
Unexploited - probable and possible resources	no data

DIRECT USES

Several low enthalpy projects have been developed;

At *Kawerau*, a paper making factory uses plant totalling ~5MW to separate 170^{O}C water. A timber drying facility at the same location uses 16 tonnes per hour of 9 bar steam.

An alfalfa drying factory located on the *Ohaaki* field, uses 100t/h of hot water and 4t/h of steam.

Waste hot water from the *Wairakei* field is used to heat prawn breeding ponds. This capacity will be used to advantage when the prawn ponds are extended shortly.

New Zealand currently employs some 80 geothermal professionals.

Summary of Resources	
Exploited - plant in operation	5MWt
Unexploited - plant under construction or planned	
Unexploited - proven resources	
Unexploited - probable and possible resources	

PAPUA NEW GUINEA

Size	462,840	km^2
Population (1993)	3.92	millions
Annual Population growth rate (1994)	2.2	%
GNP per capita (1994)	1160	USD per year
Average annual growth rate of GNP (1985-1994)	2.1	%
Average annual inflation (1985-1993)	5.2	%
Annual energy use per capita (oil equivalent)	525	kg
Average annual growth rate of energy use	0	%
Annual CO_2 emission per capita	2.3	tonnes
Production of electricity (1993)	1790	GWh
Geothermal	0	GWh
Fossil fuels	1330	GWh
Hydro	460	GWh

It has been estimated that the geothermal potential for Papua New Guinea is some 300MW$_e$. Further this energy source is considered to be competitive with other technologies.

Summary of Resources	
Exploited - plant in operation	0
Unexploited - plant under construction or planned	0
Unexploited - proven resources	300MW$_e$
Unexploited - probable and possible resources	300MW$_e$

OTHER PACIFIC ISLANDS

Island	Land area (km^2)	Population in 000's (1990)
American Samoa	197	39.6
Northern Marianas	471	23.0
Papua New Guinea	462,243	3910.0
Solomon Islands	27,556	318.7
Tonga	699	96.0
Vanuatu	1,880	142.6
Western Samoa	2,935	158.0

Profile of Several Islands with Geothermal Potential

Geothermal resources are unevenly distributed throughout the Pacific. Most of the eastern islands and central and western equatorial atolls lack a significant resource. The resource however is abundant on Hawaii and on the many volcanic islands near tectonically active zones or near crustal plate boundaries.

Most Pacific island communities depend upon diesel generation sets for electricity with some using hydro-power and biomass combustion. Thus they are vulnerable to supply and price variations affecting imported oil. Consequently the communities would welcome a reliable and economic electricity source.

Geothermal energy may have a role to play. The resource is available in many areas around the Pacific and is cost competitive with electricity from alternative technologies. Additional benefits of geothermal energy are that it is relatively pollution free and can be developed in a small area.

The potential for Geothermal Power Generation on Some Pacific Islands (MW_e for next 30 years) is below listed.

Country	MW_e
Papua New Guinea	300
Solomon Islands	50
Taiwan	200
Tonga	50
Vanuatu	100
Total	*700*

Annex 2.1
TECHNICAL ISSUES

INDEX

1. INTRODUCTION

1.1 Classification of Geothermal Resources

A geothermal field and more broadly a geothermal resource takes place in special tectonic settings when some typical geological, hydrological, structural and physical conditions coexist:

- Heat source: usually a shallow young intrusion which generates the thermal anomaly. The thermal gradient in the surrounding shallow crust is higher than ~3°C/100m which is the normal gradient.
- Reservoir: a host rock with sufficient permeability and on a larger scale transmissivity – either primary or secondary – which allows the circulation of geothermal fluids, but has retentive properties to enable fluids to heat within the reservoir. When convection occurs, viscosity and dilatation coefficient of the fluid are also involved and the system reaches maximum efficiency.
- Sealing: a cover formation, over the reservoir, with sufficient impermeability - either primary or secondary - to insulate the geothermal system from surface low thermality water.
- Recharge: for the restoration of the reservoir when extraction is in progress.

When the above conditions are complied, water from the recharge flows into the reservoir and reaches thermal equilibrium with the host rock exposed to the heat source. A transfer fluid has a maximum efficiency when in the reservoir a convective circulation system is triggered off. This condition allows the system to obtain shallow hot fluids and makes the exploitation of geothermal deposits easier and more economically favourable.

Hot Dry Rock resources and geopressured resources have been the subjects of R&D investigation. Major technical difficulties still need to be resolved before these concepts can be commercially developed.

Hot Dry Rock resources occur in regions at economically drillable depth, devoid of naturally occurring water, where temperatures are high enough to heat water that is introduced via drillholes to an useful temperature. Most regions investigated sofar have not been totally «dry». At present this technology represents an investment for future and could be used in conventional high enthalpy reservoirs.

Geopressured resouces occur in deep regions where the thermal energy in the fluid found in the rocks is augmented by a very high pressure resulting from a great depth of burial and entrapment under a highly impermeable seal. These resources still await proper evaluation and development.

The common parameter for classifying geothermal resources is the Enthalpy of geothermal fluids. Enthalpy is used to state the heat content - thermal energy - of the fluids.

Thus, geothermal resources are roughly divided into low, medium and high enthalpy resources, according to different criteria:

- Thermal criteria:

	Muffler & Cataldi, 1978	*Hochstein, 1990*	*Benderitter & Cormy, 1990*	*Haenel, Rybach & Stegena, 1988*
Low Enthalpy	<90C°	<125C°	<100C°	≤150C°
Medium Enthalpy	90-150°C	125-225°C	100-200°C	—
High Enthalpy	>150°C	>225°C	>200°C	>150°C

- Utilisation criteria: According to the available exploitation technology.

High Enthalpy	Suitable for electricity generation
Medium-Low Enthalpy	More suitable for direct heat use

- Physical criteria: According to the physical state of geothermal fluid.

High Enthalpy	Vapour/dry steam dominated geothermal systems
	Water dominated geothermal systems T>210÷220 °C
Medium-Low Enthalpy	Liquid dominated geothermal systems

In water-dominated systems liquid water is the continuum and the pressure-controlling phase. Some vapour may occur as discrete bubbles. These geothermal systems are the most widely distributed in the world. Depending on temperature and pressure conditions: hot water, water and steam mixtures, wet steam and in some cases dry steam can be produced.

In vapour-dominated (or dry steam) systems liquid water and vapour normally coexist in the reservoir, with vapour as the continuum and pressure-controlling phase. Geothermal systems of this type, the best-known of which are Larderello, in Italy and The Geysers in California. These high temperature systems are somewhat rare. In these fields dry to superheated steam is produced.

Saturated steam plants are the simplest and most used plants in Italy, California, Japan and have an high output, generating over 70% electricity from geothermal energy.

1.2 Exploitation of Geothermal Resources

Geothermal resources are suited to different types of application. The following diagram of Fig. 2.1.1 summarises the possible uses.

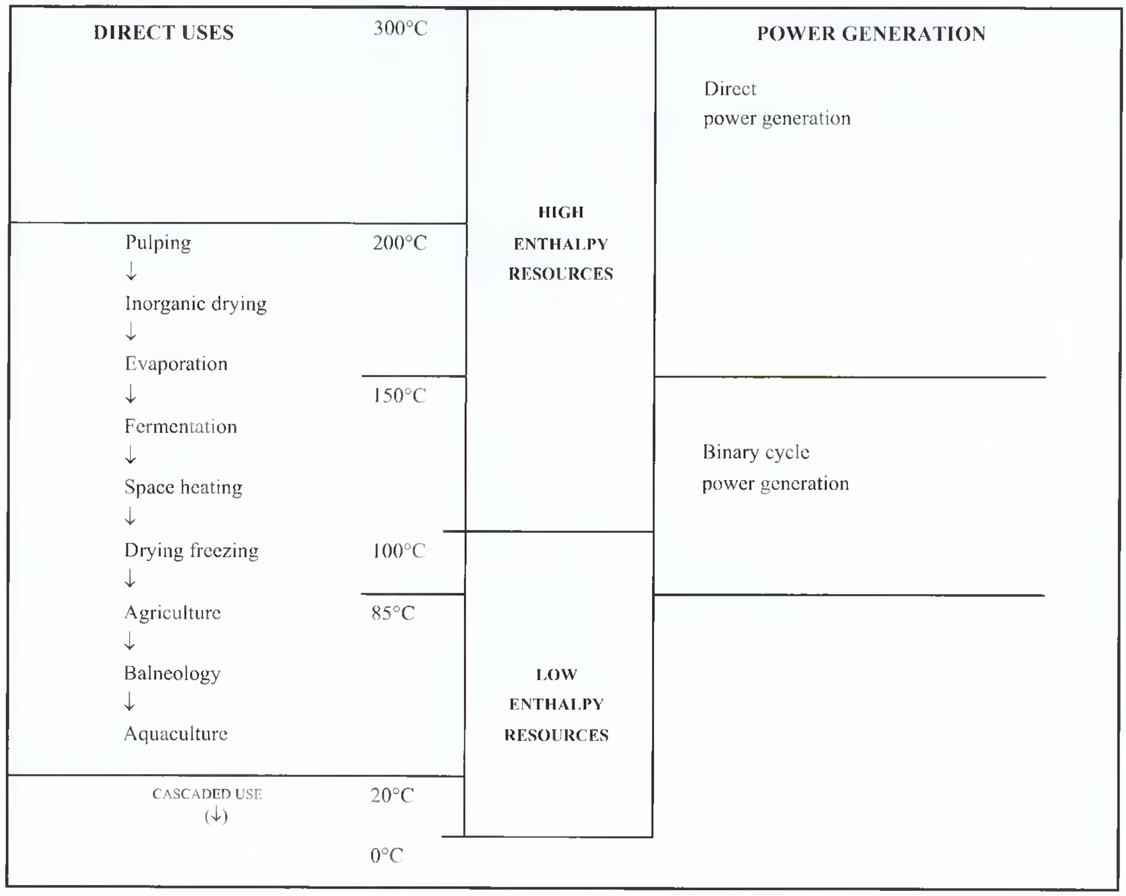


Fig. 2.1.1 Exploitation of geothermal resources.

This diagram emphasises some important aspects of the utilisation of geothermal resources:

- the ways to exploit geothermal resources can be arranged into two main classes according to the type of application: direct uses and electricity generation, which is possible at/or above 85°C.
- by combining applications through the use of cascade systems it is possible to enhance the heat-utilisation of geothermal projects, before recycling the exhausted fluid.

The temperature of the resource may limit the possible uses; at temperatures equal or below 20°C resources are exploited only in very special conditions or by using heat pumps.

The Lindal diagram (Lindal, 1973), (see Fig. 2.1.2), shows the most common uses of geothermal fluids and their typical temperatures.

	180°C -	Evaporation of highly concentrated solutions	
		Refrigeration by ammonia absorption	
		Digestion in paper pulp, kraft	
	170°C -	Heavy water via hydrogen sulphide process	
		Drying of diatomaceous earth	
SATURATED STEAM	160°C -	Drying of fish meal	
		Drying of timber	
	150°C -	Alumina via Bayer's process	
	140°C -	Drying farm products at high rates	
		Canning of food	
	130°C -	Evaporation in sugar refining	
		Extraction of salts by evaporation and crystallisation	
	120°C -	Fresh water by distillation	
		Most multiple effect evaporation, concentration of saline solution	
	110°C -	Drying and curing of light aggregate cement slabs	
	100°C -	Drying of organic materials, seaweed, grass, vegetables, etc.	
		Washing and drying of wool	
	90°C -	Drying of stock fish	
		Intense de-icing operations	
	80°C -	Space heating	
		Greenhouses by space heating	
WATER	70°C -	Refrigeration (lower temperature limit)	
	60°C -	Animal husbandry	
		Greenhouses by combined space and hotbed heating	
	50°C -	Mushroom growing	space heating with heat pumps
		Balneological baths	
	40°C -	Soil warming	
	30°C -	Swimming pools, biodegradation, fermentation	
		Warm water for year-round mining in cold climates	
		De-icing	
	20°C -	Hatching of fish	
		Fish farming	

Fig. 2.1.2 Typical fluid temperature for direct applications (modified from Lindal, 1973).

2. ELECTRICITY GENERATION

Geothermal energy can be converted into electric energy through the following systems:

- Conventional cycle   superheated or saturated steam.
  single-flash.
  multi-flash steam.
- Binary cycle
- Bi-phase rotary separators coupled with electric generators
- Combined systems
- Indirect cycle

2.1 Conventional cycle

In conventional cycle systems the generation of electricity occurs when dry steam - directly from the dry well or after separation from a wet well - is passed through a turbine coupled with an alternator.

Conventional steam turbines are available in the form of prefabricated modular units or expressly designed with either atmospheric (backpressure) or condensing exhaust.

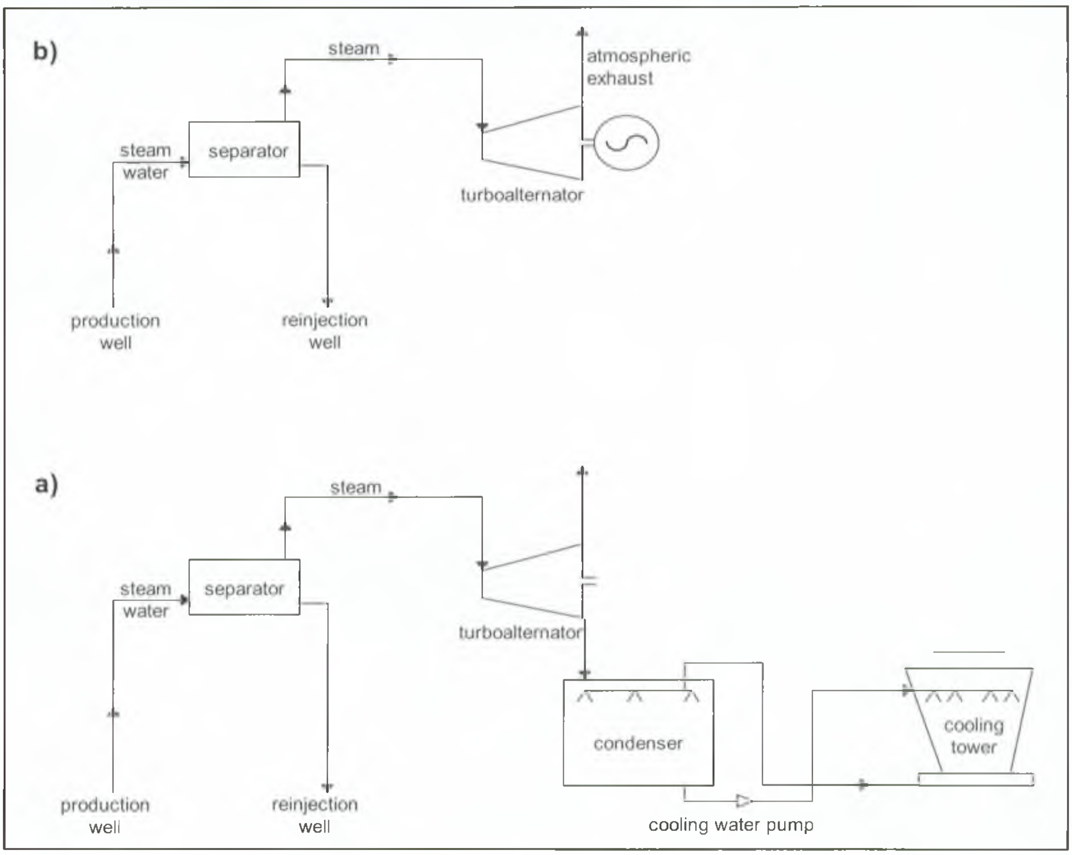


Fig. 2.1.3 Schematic diagram of a backpressure (a) and a condensing unit (b).

2.1.1 Backpressure units

In backpressure units the steam after passing the turbine is exhausted directly into the atmosphere.

Atmospheric exhaust turbines are used when the percentage of non-condensable gases in the geothermal fluid is higher than 12-15% in weight, or when the duration of the production system is uncertain.

Moreover, they are extremely useful as pilot plants, stand-by plants, in the case of small supplies from isolated wells, and for generating electricity from test wells during field development.

These units are cheaper, can be constructed and installed very quickly and put in operation in around 13-14 months.

On the other hand, performance is lower with respect to the condensing type, due to the high steam consumption per kilowatt-hour produced (almost double from the same inlet pressure).

2.1.2 Condensing units

In condensing units instead of discharging the steam from the turbine to the atmosphere it is discharged to a condensing chamber that is maintained at very low pressure and passed through a cooling tower.

They consist of:

- Condensing or backpressure turbines
- Direct contact or surface condenser
- Compressor-extractor of non-condensable gases and intermediate refrigerant
- Cooling tower
- Instrumentation and control system
- Electric system

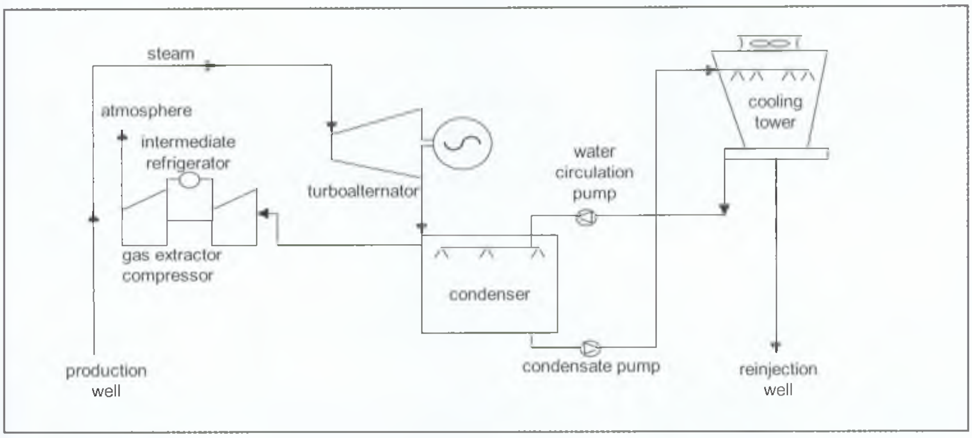


Fig. 2.1.4 Schematic diagram of a superheated or saturated steam plant.

In the *direct contact condenser* geothermal fluid and cooling water are mixed together while in the *surface condenser* expanded geothermal steam flows among a set of pipes through which the cooling water circulates.

2.1.3 Single flash plants

The fluid from the reservoir is generally a high temperature liquid and when reaching the surface - where pressure is lower - turns, usually only partially, into vapour (flashing).

These plants are used if geothermal fluid, at the well head, is a two phase mixture of liquid and vapour in varying percentages depending on the reservoir properties and well head pressure.

After separation from the fluid, vapour is admitted to the turbine.

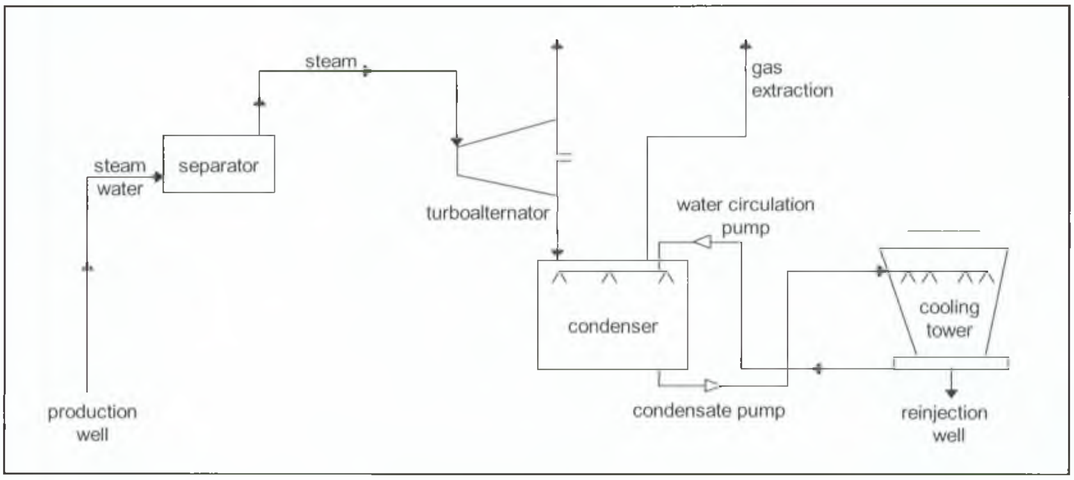


Fig. 2.1.5 Schematic diagram of a single flash type geothermal plant.

Flash type installations exist in Japan (Hatchobaru, Otake, Onuma, etc.), Iceland (Krafla), New Zealand (Wairakei), Mexico (Cerro Prieto), El Salvador (Ahuachapan), Philippines, former USSR (Pauzhetka), Miravalles (Costa Rica) and other countries.

2.1.4 Multi-flash plants

Multi-flash systems are similar to the single-flash apart from additional flash tanks for the production of further steam from the hot water coming from the separator.

The steam produced during the first flash stage - that takes place in the well - is sent to the first stage of the turbine, while the steam produced from the following flashes - that take place on the surface - is admitted in intermediate turbine stages.

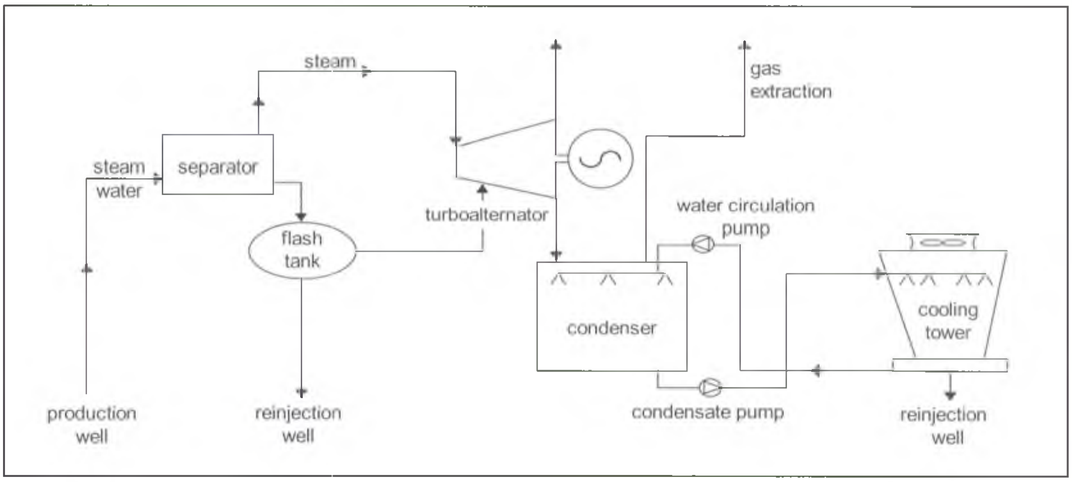


Fig. 2.1.6 Schematic diagram of a multi-flash type geothermal plant.

2.2 Binary cycle

In a binary cycle the secondary organic fluid is the working fluid of a closed subcritical Organic Rankine Cycle (ORC).

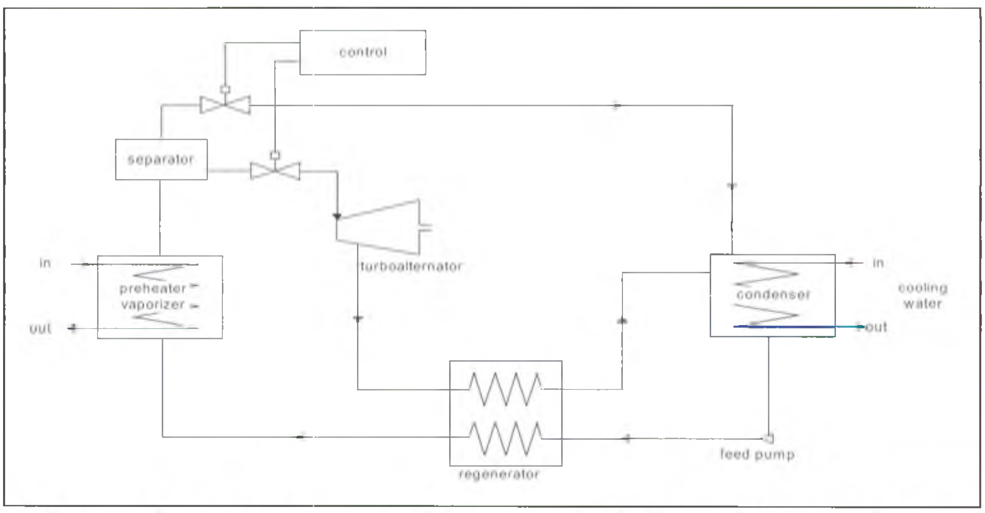


Fig. 2.1.7 Schematic diagram of the most recent Organic Rankine Cycle system.

Properly selected organic fluids result in the use of smaller, efficient turbines; they eliminate the necessity for superheaters, and allow the application of sealed units, similar to refrigeration compressors, requiring little maintenance.

In recent years ORC cycles have been extensively applied in different conditions as:

- Water extracted from medium-low temperature reservoirs with downwell pumps.
- Separated residual water (to be reinjected) from the lowest temperature flash stage in an existing flashed steam plant (bottoming cycles).
- Waste steam from turbines with atmospheric discharge.

ORC systems can incorporate simpler single stage turbines, whereas traditional steam systems often require complex multi-stage turbines to handle the large pressure drop.

Mixtures of working fluids (saturated hydrocarbons, or halogenated hydrocarbons or ammonia/water mixtures) give improved performance over Rankine cycles with pure working fluids executing single, multiple or supercritical cycles.

A limit to cycle performance is given by the minimum temperature to which the geofluid can be cooled, depending on silica deposition which occurs at temperatures increasing as resource temperature increases. Theoretical calculations indicate that only at resource temperatures below 140°C the geofluid can be cooled below ambience temperature.

In order to overcome this problem, with the contribution of recent technological improvement, different solutions have been found out:

- *Brine dilution with condensate.*
  In the case of two-phase geothermal fluid, steam is separated from brine and used as a heating medium in the working fluid vaporiser. Thus, the geothermal condensate at vaporiser exit may be mixed with the hot separated brine to provide a preheating medium for the organic fluid. Since the onset of silica precipitation is related to its concentration in the brine, dilution of the brine with the condensate reduces precipitation temperature of the silica.
- *Recovery of internal heat*
  A recuperator heat exchanger is added between the organic system turbine and the condenser. Since the organic fluid has a retrograde dew point - or saturation curve - organic vapour tends to superheat, or become drier when the steam is expanded through the turbine. The recuperator is used to recover the superheated steam for the preheating of the organic fluid prior to further heating in the economiser or preheater. The heat exchanger is relatively low cost since no corrosion or material problems are associated with organic fluids.
- *Cascade units*
  The cascade concept, developed in the early 80s is aimed at increasing the whole cycle efficiency. The units are cascaded at various levels of brine temperature with the result that more heat is extracted from the source by cooling the brine to a lower optimal temperature than with a parallel arrangement.
  the thermal efficiency of existing ORC plants, intended as the ratio between the electric power available at generator terminals and the heat released by the

geothermal fluid, generally range from 10% to 15.5% for resources at 100°C to 160°C and is slightly higher (17%) for temperatures up to 190°C, with a two-phase geothermal fluid.

2.2.1 Binary plants

Generating electricity from low-to-medium temperature geothermal fluids and waste hot waters coming from the separators in water-dominated geothermal fields has made considerable progress in recent years, thanks to improvements made in binary fluid technology.

Binary technology is based on the principle of heat transfer from the geothermal fluid, with temperature in the range of ~85-170°C to a secondary working fluid, usually an organic fluid.

In the domain of low-to-medium temperature applications, organic fluids have several special properties which provide them with an advantage over water (steam) and allow a higher cycle efficiency: a low boiling point allows the organic fluids to flash at low temperatures, a high molecular weight and low enthalpy drop allow organic fluids to operate with a lower flow rate and hence the turbomachinery to be simpler, "non-wetting" (non-condensing) characteristics during expansion (steam in part condenses on the turbine blades during expansion, resulting in reduced efficiency if it is not superheated sufficiently therefore requiring higher temperatures), a low preheat and vaporisation energy ratio. Furthermore, geothermal fluids often have a high salt content which cause problems in design and construction of good quality heat exchangers.

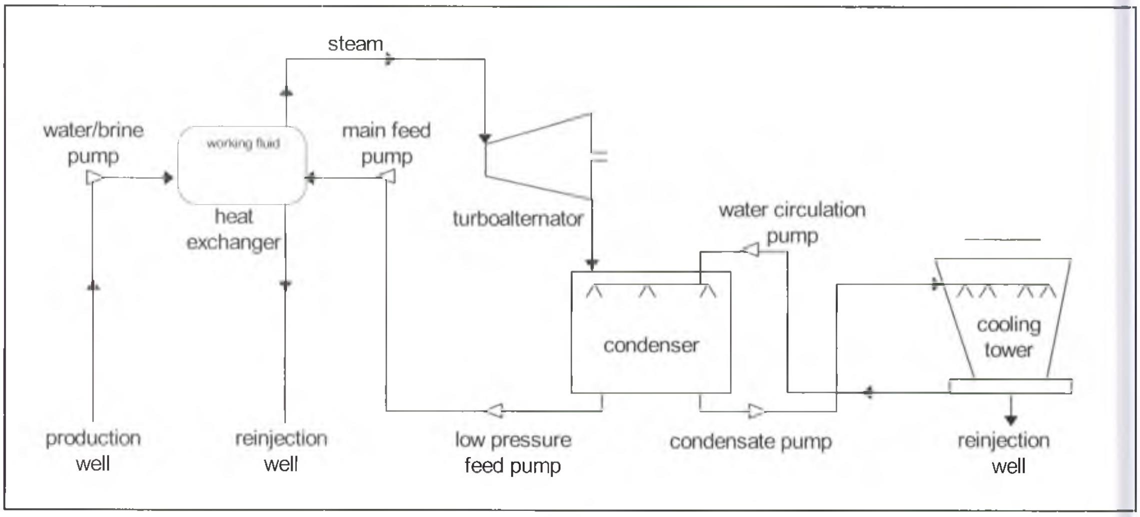


Fig. 2.1.8 Schematic diagram of a binary cycle type geothermal plant.

Apart from low-to-medium temperature geothermal fluids and waste fluids, binary systems can also be used for non-artesian wells or where the flashing of geothermal fluids should be avoided (i.e. to prevent well sealing). In this case, downhole pumps can be used to keep the fluids in a pressurised liquid state, and energy can be extracted from the circulating fluid by means of binary units.

With the exception of the plants that work with ammonia, for technical reasons, binary plants are usually constructed in small modular units of a few hundreds kW to ~10MW capacity. These units can then be linked up to create power plants to some tents of megawatts.

2.2.2 Kalina[1] Cycle

The more developed non-organic fluid Rankine cycle at present is the Kalina cycle which uses a water-ammonia mixture as a working fluid (85-15 weight %). According to H.M.Leibowitz and D.W.Markus of Energy Inc., Hayward, California, this cycle achieves a thermodynamic efficiency (brine effectiveness) that is approximately 50% greater than that of standard binary Rankine plants.

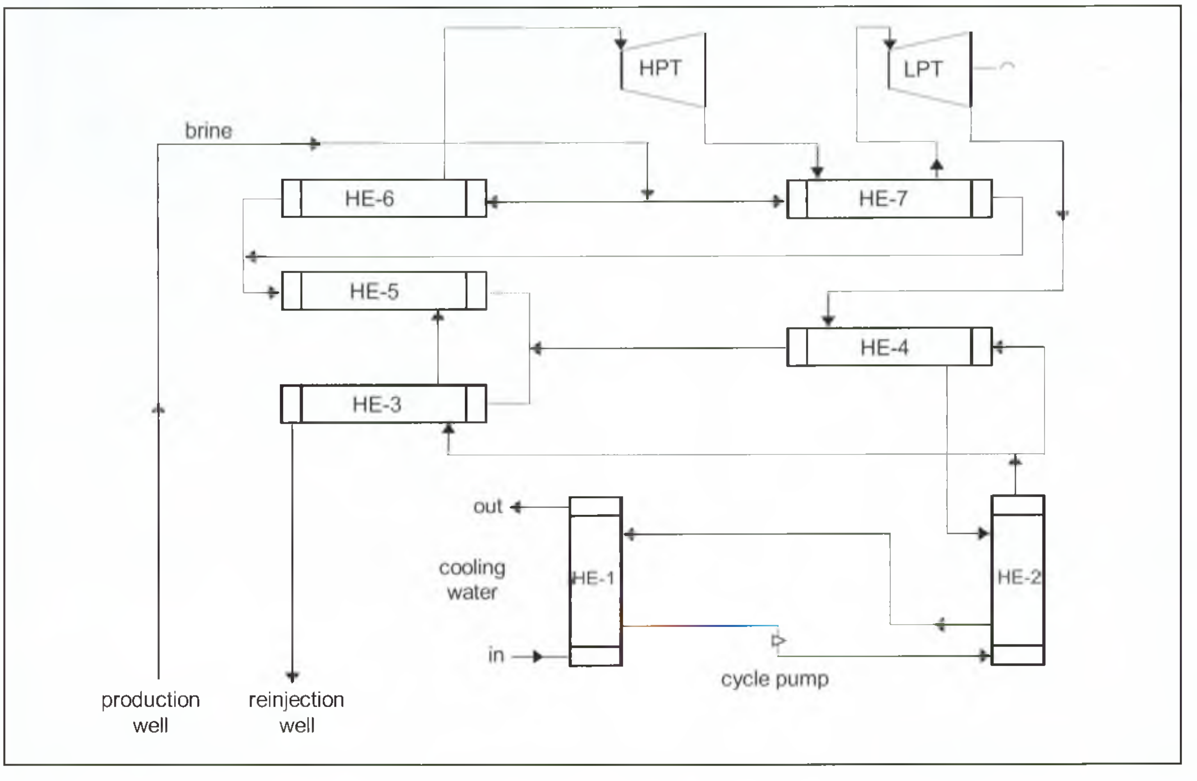


Fig. 2.1.9 Schematic diagram of a Kalina Plant cycle

The hot brine from the geothermal well is used firstly to both superheat and reheat the working fluid and then to evaporate and preheat it before being reinjected into the ground.

The working fluid, in superheated condition, is expanded through the H.P.turbine stages and then reheated before entering the L.P.turbine stage. After the second expansion, the

[1] Kalina technology is the property of Energy Inc., Hayward, California. Ansaldo Energia, Genoa, Italy is licensed for plant construction.

saturated vapour moves through a recuperative boiler before being condensed in a water cooled condenser.

The features that distinguish the Kalina cycle from other binary Rankine plants are:

- *Variable boiling temperature*
  The 85% ammonia/water mixture allows a variable temperature process in a conventional subcritical boiler. At a pressure of 31.2bar, the working fluid begins to boil at 74°C (bubble point) and completes boiling at 149°C (dew point). This process produces a very good working fluid/brine match.

- *Highly recuperative cycle*
  The two recuperative heat exchangers (HE-4 and HE-2) provide approximately 38% of the total heat transferred to the working fluid improving the net brine effectiveness i.e. kWh/kg. Only through the use of mixtures it is possible to transfer heat from the turbine exhaust at 9.2bar to the incoming working fluid at 31.2bar. Even though the turbine exhaust pressure is lower than in the boiler, the temperature at which the exhaust vapour begins to condense (dew point) is approximately 35°C higher than the temperature at which the working fluid begins to boil.

  By contrast, the turbine exhaust in binary plants that work with organic fluids cannot be used for boiling. The recuperation is limited to the small amounts of superheat remaining in the exhaust, which may be used for liquid preheat duty.

- *Standard steam turbine*
  The molecular weight of ammonia is very similar to that of water (17 and 18 respectively). Thus, standard steam turbines may be used for ammonia/water duty. Molecular weight allows the fluid to reach its sonic velocity which, in turn, sets the blade heights and rotational speed. Except for the zero leakage mechanical seal, the ammonia/water turbine is identical to conventional steam turbines.
- *Heat exchanger design*
  The specific heat of ammonia/water mixtures is more than twice that of hydrocarbons or chloro-fluoro-carbons, even though mixtures have lower conductance than pure components, surface per unit of heat transferred is reduced proportionally. Carbon steel is specified throughout.

Kalina technology has been tested in a 3MW demonstration plant located at the Energy Technology and Engineering Centre (ETEC), a DOE facility, near Canoga Park, California.

The demo-plant was in the form of a waste-heat drive bottoming cycle using - as heat-source - combustion gases generated in an adjacent facility at 540°C.

During the tests some problems occurred in the labyrinth seal of the turbine, the packing stuffing box of the plunger type feed pump, and in the removal of dissolved solids from the working fluid, but the general reliability of this relatively new technology has been proven.

Applications in geothermal fields have get to be deployed.

2.2.3 Working fluids

From a theoretical standpoint, any fluid may be used to produce a Rankine cycle as long as it boils and condenses at heat source and sink temperature respectively. Among these, organic fluids possess several properties which allow them to produce higher cycle efficiency at low temperature.

The selection of a proper working fluid is not easy. Different applications and equipment will require different properties from the working fluid. Each application should be studied in detail to select the fluid that will provide a better performance.
As discussed, the properties that will affect the performance are molecular weight, boiling point (vapour pressure/temperature relationship), temperature/entropy relationship and thermal/chemical stability.

Other factors to be considered are toxicity, flammability, availability and cost.

Selection often depends on considerations regarding the physical and thermodynamic properties of the fluid with respect to the operating conditions.

Thermal and chemical instability and oxygen exposure can result in fluid decomposition which may lead to system failure. If failure does not occur, non-condensable gases may be produced and could reduce the heat transfer rate in the condenser causing accelerated corrosion of the system components.

The fluid must also coexist with the lubricants within the system, since decomposition may also be caused by the mixing of these two substances. This becomes critical around the turbine shaft and bearings. In addition, vapour pressure of the working fluid will decrease when oil is absorbed and therefore specific oils which are insoluble within the working fluid are required.

Organic working fluids can be classified into:

- *Chloro-carbons* and *chloro-fluoro carbons* (CFCs).
  CFCs are commonly used as refrigerants in refrigeration and air conditioning equipment. They have limited thermal stability, but they are safe from an operational standpoint.
- *Hydrocarbons* or *partially substituted hydrocarbons*.
  Hydrocarbons are more stable at high temperature and more environment friendly, but are highly flammable and require greater safety procedures.

R - 11	Allied P - 1D (1)
R - 12	Gentron 113A (1)
R - 22	Dowtherm A (1)
E - 113	Isobutane
R - 114	Toluene
Monochlorobenzene	Methanol
Perchloroethylene	Pentane
Trifluoroethanol	Ethane
Fluorinol 85	

Table 2.1 Commonly used organic working fluids. (1) Trade name.

Non-organic fluids such as ammonia have also been mentioned for low temperature heat recovery application. Some systems using ammonia Rankine cycle have been recently built and put into operation.

2.3 Other systems

2.3.1 Biphase rotary separators

Biphase rotary separator turboalternators were recently developed to extract power from two-phases steam/water mixtures. While the systems described above utilise steam turbines, this system uses liquid turbines. Biphase units can be used coupled with conventional turbines which are driven by the steam discharged from the biphase rotary separator. In 1989 only one geothermal rotary separator plant was operating, and another was under construction thus operating experience is still rather limited.

2.3.2 Combined systems

Systems of this type consist of cascade application of different systems aimed to optimise the exploitation of the geothermal fluid energy content. It is worth mentioning the coupling of flash steam with binary cycle plants and geothermal with oil-burning traditional power plants.

2.3.3 Indirect cycles

A heat exchanger is placed between the well and the turbine for the production of clean steam, in a closed cycle. In this system it is necessary to recover the chemicals contained in the fluid but the installation is much more complex and costly, compared to direct cycle plants.

3. NON ELECTRICAL USES

Space and district heating, agricultural applications such as greenhouses and aquaculture are the most widespread forms of utilisation.
Other industrial applications can be taylored for specific processes where the geothermal resource meets a local demand.

For few years, development of Heat Pump (HP) technology increase the field of application for geothermal energy. HP can use very low temperature resources and can produce both heat and cold for air conditioning systems

The entire range of temperature of geothermal fluids, whether steam or water, can be utilised in industrial process heating. The most important process uses of geothermal energy are drying and dehydration, followed by evaporation, distillation, washing, and salt and chemical extraction.

The equipment and components are a function of the characteristic of the resource and the type of final use.
For example, for geothermal district heating,(see Fig. 2.1.10) only the geothermal well(s) and the geothermal plant are specific to geothermal energy. The parts dedicated to the end users (the district heating network is indicated in the below Figure) can require some specific adaptation (in this case, mainly due to the temperature of the geothermal fluid).

In this paragraph we describe only the main significant equipment and components connected with the geothermal exploitation

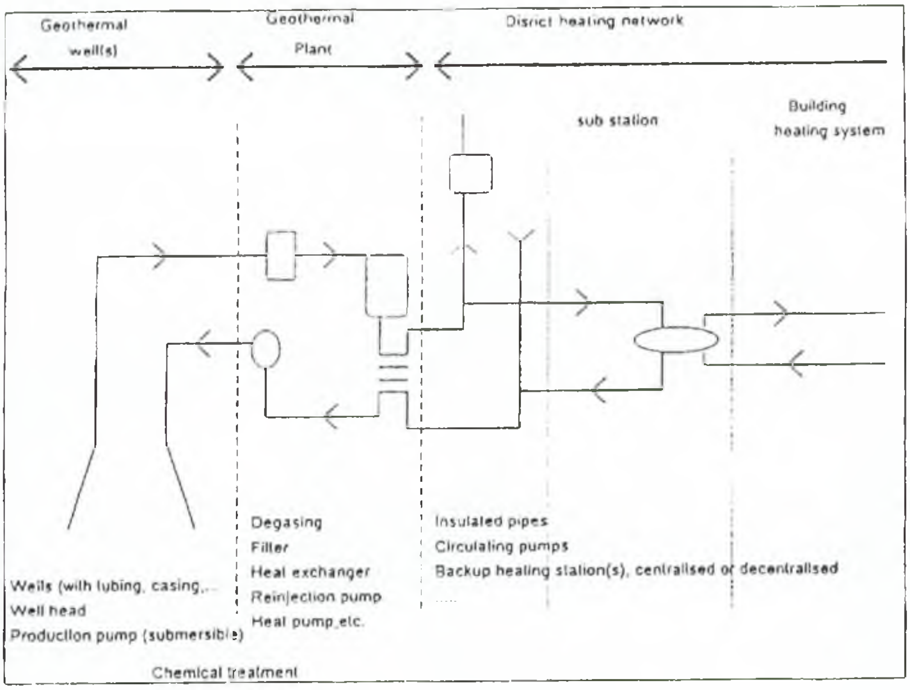


Fig. 2.1.10 Geothermal district heating

3.1. Well Casing

Casing is the heavy metal pipe, lowered into a well during drilling and cemented into place to line the well and enhance fluid recovery.
The most common casing material is carbon steel.
Because geothermal fluid is corrosive, a novel well concept (see figure 2.1.11) has been tested in France (supported by EU- the well is operation since 1997).
This new well design combines cemented steel casing and Fiberglas liners while the annular is kept free. The well casing provide mechanical strength while the liners furnish chemical resistance and protect the steel casing. It is a material alternative to the corrosion of chemical, microbiological or galvanic origin.

3.2 Wellhead

The wellhead is flanged on the top end of a well casing, in order to control more efficiently the geothermal fluid resources. A typical geothermal wellhead consists of the following main components: expansion spool, gate valves, flowline delivery device. Gate valves are usually manufactured with material suitable for corrosive fluids, such as gas with high H_2S content and can work up to 300°C and about 150bar.

3.3 Piping

Pre-insulated or insulated pipes are needed to transport geothermal fluid from the production field to the plant. The transmission pipeline diameter has to be designed so that the pressure drop in a straight section of pipe, at maximum flow rate, is of the order of 0.5 to 1bar/Km.

The most common pipe material is carbon steel or flexible copper (max. temperature 138°C). Insulation is usually provided by polyurethane foam and a protective polyethylene or spiral wound sheet aluminium or stainless steel metal cover.

Various other materials like fibreglass, polypropylene, polybuthylene, polyethylene and other plastic are installed for small size piping and/or lower temperature.

Steel alloys and even titanium are used for high temperature applications.

3.4 Pumps

Production pumps
When the artesian flow is deemed to be insufficient for the needs of the project, the installation of a production pump might be necessary. Depending on the setting depth and water temperature different types of pumps are currently in use, see Figure 2.1.12.

- *Shaft driven submersible pumps* consist of a multistage downhole centrifugal pump set in the well with a surface mounted motor and a long drive assembly extending from the motor to the pump. This pump is the most currently used up to a depth of 200m, because of lower cost and easier maintenance. Water temperatures must be in the range of 80 to 130ºC.

- *Electric submersible pump* consists of a multistage centrifugal pump connected to an electrical motor, directly set in the well on the bottom of the pump. They can be used deeper and have a capacity up to 2,000 l/m, about seven times more that of the shaft driven pumps.

Because 50% of the pump breakdowns are due to electrical problems, any water infiltration must be eliminated by the waterproof design for the motor. In the case of bottom hole high fluid temperature (200°C), special electric oil filled motors are available.

Submersible turbopumps have a hydraulic part driven by a turbine, itself driven by pressurised geothermal water circulation at the surface aided by a pump. Although the energy efficiency of these pumps is lower than that of the two others, this is compensated for by lower maintenance costs.

Reinjection pumps
According to modern practice geothermal fluids must often be removed and dumped at shallow level by reinjection wells, where all fluids are returned to the geothermal aquifer by a reinjection pump. Usually for produced water reinjection horizontal pumps are adopted. They have a capacity up to 1,500 l/min and operate **with water temperature up to 80°C.**

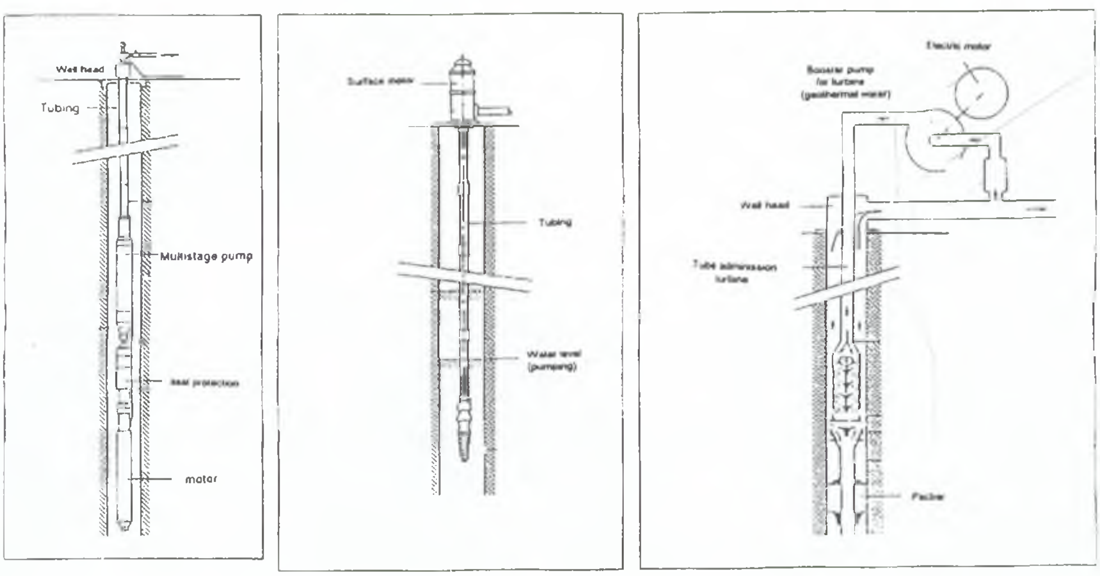
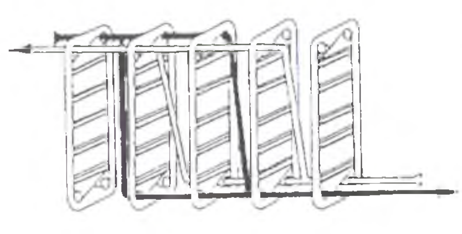


Fig. 2.1.11 Types of pumps: a) electric submersible, b) shaft driven, c) turbopump

3.5 Heat exchangers

A ***plate heat exchanger*** consists of a pack of metal plates with portholes for the passage of the two fluids. The plates are fitted with a gasket which seals the channel and directs the fluid in two alternate directions. Different solutions (plate corrugations or wiring grid between plates) promote fluid turbulence to reduce fouling between the plates. The plate pack is assembled between a frame plate and a pressure plate by means of tightening bolts. The typical performance limits are temperatures up to 130°C and pressures up to 25bar.



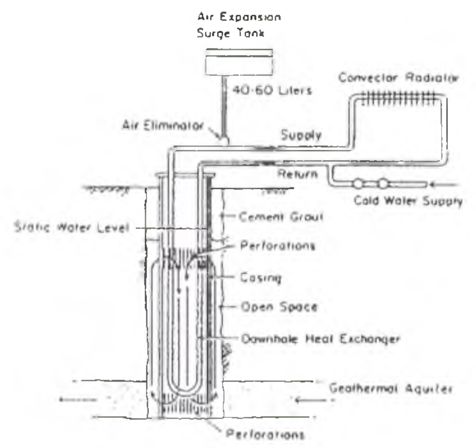


Fig. 2.1.12 Plate heat exchanger

Fig. 2.1.13 Down hole heat exchanger

The ***brazed plate heat exchanger*** is a variation on the normal plate heat exchanger and consists of a pack of metal plates fitted without interplate gaskets. The pack of plates is tightened by bolts between a frame plate and a pressure plate; special gaskets are installed between the a.m. external plates and the pack of plates. The plates are brazed together in a vacuum oven to form a compact pressure-resistant unit. The turbulence created by the plate corrugations promotes heat transfer and reduces fouling. The system is designed to work up to 225°C and 30bar.

Shell and tube is the most conventional type of heat exchanger; it consists of a series of tubes surrounded by an enclosing shell. The tubes can have a U-tube configuration but in order to facilitate cleaning of the tubes, the solution with straight tubes and removable heads at both ends is usually adopted. Operating limits are 130°C and 25bar.

The components of the heat exchangers must be made, when necessary, of corrosion resistant material, such as titanium.

The Downhole Heat Exchanger (DHE) is essentially a passive means to extract heat, without removing water from the well. Clean water is pumped or circulates by natural convention through the DHE.

Depending on the depth of the well, shallow type DHE (from 30 to 200m deep) are currently used in Europe. The deep type DHE (depth up to 2300m, research program on going in Switzerland) must also be considered.

3.6 Geothermal heat pumps

It is possible using the heat pump technique to extract thermal energy from a heat source with a low temperature to make thermal energy available at a higher temperature.
Heat pumps can be used for heating or for cooling or for both in combination, e.g. cooling in the summer and heating during the winter.

Heat pumps are widely used in Europe and U.S.A. space and/or district heating systems. They can be used alone for heating and/or cooling buildings or individual houses; they can also be use as a part of a larger scheme, for example in district heating scheme to increase the quantity of energy extracted from the geothermal fluid.

The heat source can be of different types, e.g. outside air, ground water or waste heat form industry or the heat in the ground.
Geothermal water at low temperature, say 20 °C- 40 °C, which is too low for direct application in space heating, is an ideal heat source for heat pumps in a district heating plant because the economics of a heat pump installation is closely related to the temperature of the heat source. When used in a close or open loops it is called a geothermal heat pump.

Heat pump need external energy input to work. The most common are electric motor driven heat pumps (see Fig. 2.1.15) there are also gas motor (see Fig. 2.1.16) or chemical absorption systems (see Fig. 2.1.17).

A heat pump works like a refrigerator, where the working fluid is circulated in a closed circuit removing heat from inside the freezer and discharging it to the surrondings.
In the heat pump, the working fluid extracts heat from the heat source through evaporation and discharges it by condensation to the district heating water.
To do this work external energy input is required and the most commonly used type is a compressor driven by an electric motor, but chemical absorption, gas compression and other methods are available.

The ration of the output energy to operating energy input is the basic measure of the effectiveness of a heat pump and very important to the economics of the heat pump operation, as previously referred to. This ratio is known as the "Coefficient of Performance" COP, and it is very attractive for heat sources with a temperature in the range 20 °C – 40°C.
For example, if the geothermal resource is 30°C and is cooled down to 20 °C, and the hot water to space heating is 55 °C, then the COP factor could be around 4.
This means that the heat output for space heating is about four times the energy input to the compressor motor.

The typical performance limits of geothermal heat pumps are:
- Geothermal source temperature range: from 18 °C to 65 °C
- Geothermal water flow: from 50 °C to300 m^3/h

- Heating water temperature range: from 50 °C to 90 °C
- Heat capacity: from 0.5 to about 30 MW

In a heat pump plant the following equipment is installed:

Evaporator: in the evaporator geothermal water transmits its heat to the working fluid and brings it to boiling point at low pressure, causing its evaporation.

Turbine compressor: an electrical motor driven turbine compressor increases the pressure and therefore the temperature of the gas.
Different heat capacity of the heat pump plant can be achieved by combining the various compressor frame sizes with the various commercially available working fluids.

Condenser: in the condenser the heated working fluid (gas) transfers its heat to the circuit of the heated water and is brought back to liquid phase.

Pressure control valve: after the condenser the pressure of the working fluid is decreased by a reduction valve and the working fluid (after the flash box), is return to the evaporator in order to complete the cycle and can than be re-used.

3.7 Well protection and maintenance devices

Due to the fluid composition, corrosion and scaling could cause problems during geothermal exploitation both for electricity generation and non electrical uses. In order to overcome such difficulties, effective protection from corrosion and scaling can take place through a chemical inhibition system. The treatment is generally based on inhibitors based on quaternary amines, whose filming capacity ensures an optimum protection of the casing.
Systems, such as **down-hole injection lines**, have been installed in production wells (more than 40 operations in Europe)

New techniques for the fabrication of continuous injection lines as well as new materials for this product are being developed. New inhibitors and the chemical compatibility of these inhibitors with the other materials used in the well loop, are routinelly tested.

Specific geothermal plants need periodic rehabilitation work which is necessary for the elimination of scale and reconditioning of boreholes. Different methods are available:

- mechanical cleaning with a scraping tricone tool hanging from a rod assembly
- hydraulic jetting with a cool-tubing unit of small diameter
- combined hydraulic-mechanical processes

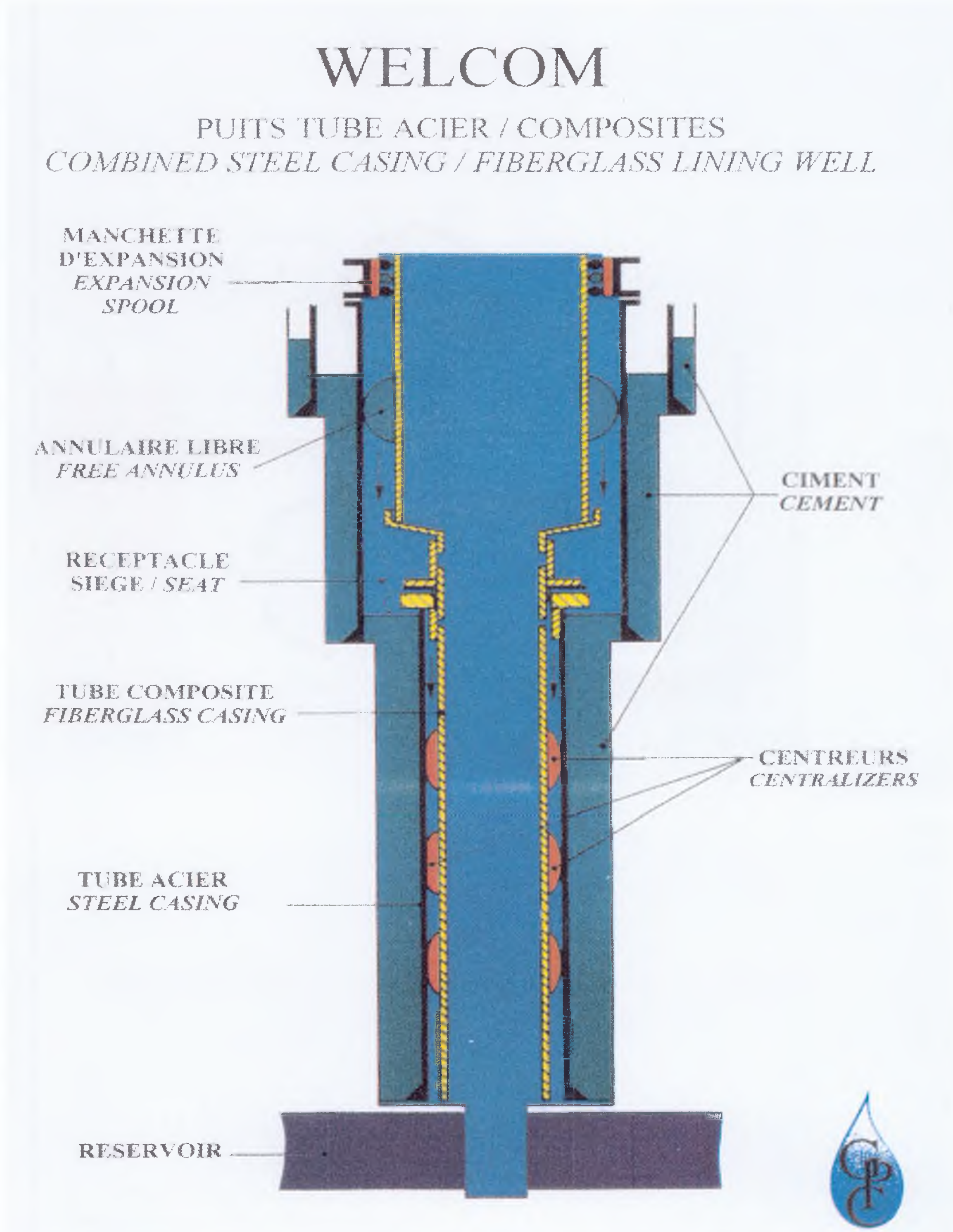


Fig. 2.1.14 Novel well concept

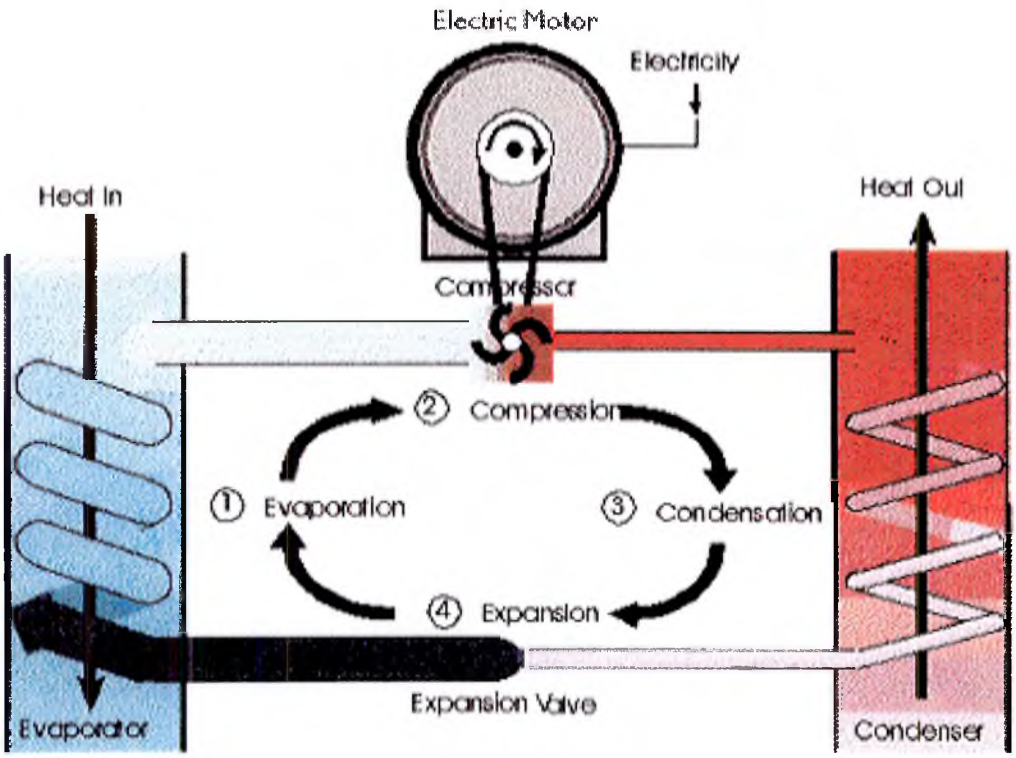


Fig. 2.1.15 Closed cycle electric motor driven vapour compression heat pump

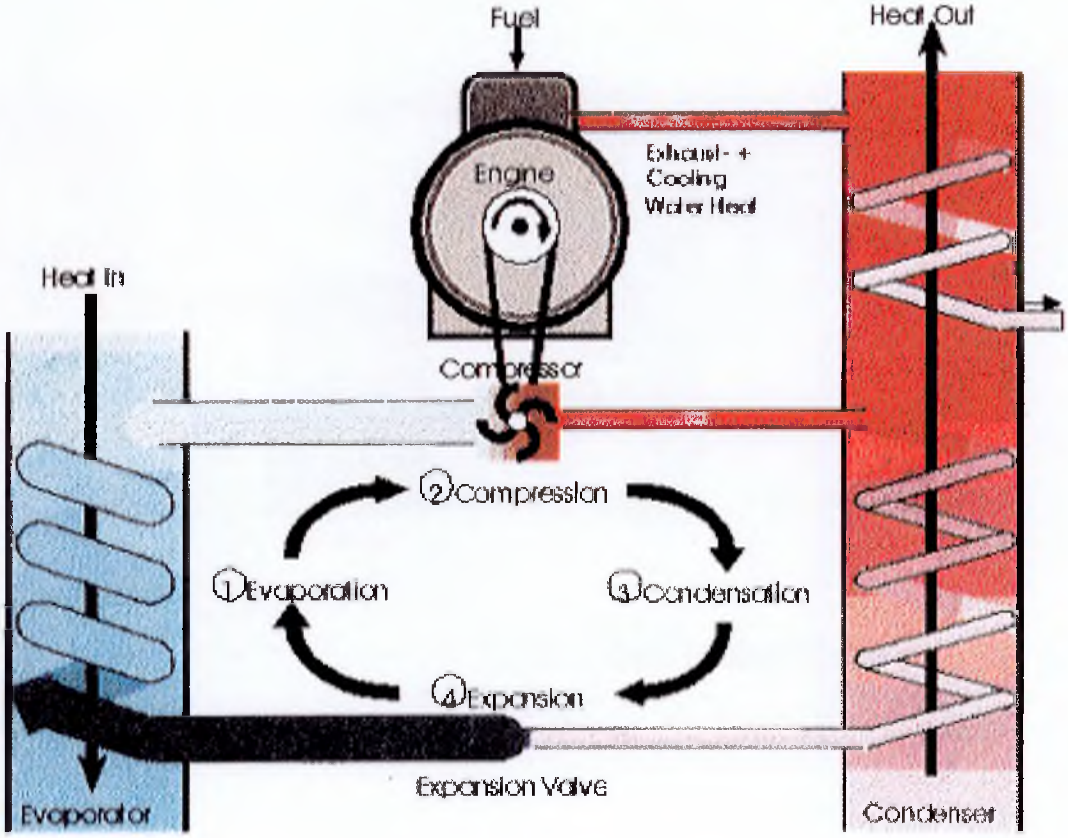


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Fig. 2.1.16 Closed cycle, engine driven vapour compression heat pump

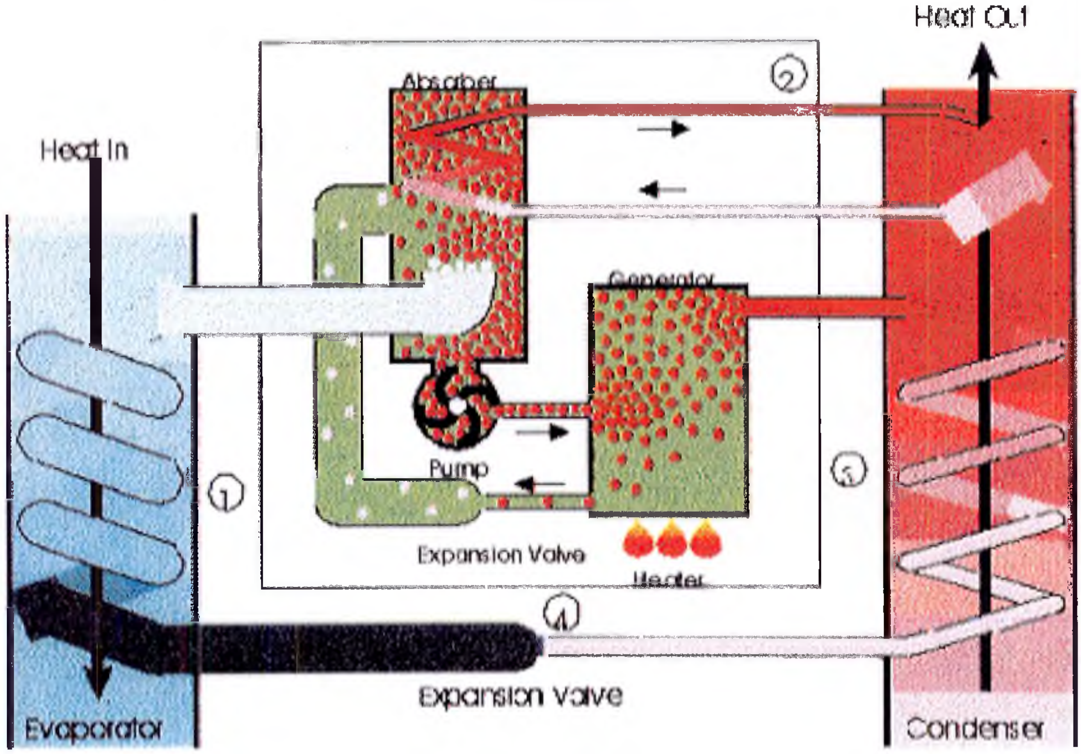

Fig. 2.1.17 Absorption heat pump

4. NEW APPLICATIONS AND TECHNOLOGY

Development of geothermal systems and equipment in the low-enthalpy field is continuous. Here we outline a selection of new solutions to improve performance or durability.

Patch-flex

Thermo-setting resins can now be used to manufacture a flexible composite tube called a Patch-flex.

The resin is run in through narrow diameter flexible tubing, the Patch-flex is inflated and hardened in-situ to create a tough impermeable sleeve that is self-sealing and pressure resistant along its entire length. The permanent sleeve of the Patch-flex will remain downhole and is made of thermo-setting resins, fibres and elastomers. The Patch-flex can be used as an efficient and economical means of repairing perforated or badly corroded casing.

Down hole line

Continuos down hole, injection and/or control line could be developed.
Early applications aimed at chemical injection, in resident mode, of corrosion and/or scaling inhibitors and, occasionally, of biocides.

Performances recorded since the implementation in 1990 of the first prototypes have been promising and future extension of the concept is contemplated, including the following:

- *High temperature service*
  A two-fold Teflon encapsulated line makes it possible to operate a resident inhibition line at a temperature as high as 280°C, provided special care is taken with inhibitor selection (stability at high temperature), material definition and inside coating of the injection tubing.
- *Instrumental lines*
  A prototype line connected to a pressure/temperature transducer (quartz gauge) is currently operating on a Paris basin geothermal well. It includes two pre-encapsulated copper wires connected via a rope socket to gauge telemetry. This application allows remote monitoring of bottom hole pressure and temperatures by means of a teleprocessing system.
- *Coiled tubing services, wire line logs, slim hole drilling*
  Present research trends are now directed towards the development of coiled tubing services and logging applications for strongly deviated and horizontal wells. The implementation of high resolution video cameras and optical transmission appears a promising route for this type of logging operation.
  In the long run, down-hole line technology should move towards intelligent instrumental lines and slim hole drilling technology.

Innovative drilling of geothermal well

Within the framework of a cross border European project for the exploitation and utilisation of the geothermal potential in the region of Braunau (A) and Simbach am Inn (D); and in co-operation between local Authorities and private local energy suppliers, an innovative technique for geothermal well drilling has been proposed. The innovation consists of the drilling of a large hole (670mm diameter) to a depth of 650m and from there drilling two deviated smaller holes in opposite directions to a depth of 2,300m. It is possible to reach a distance of 2,000m between the extraction and the re-injection point with this technology. Moreover the production hole will be oriented horizontally through the upper layer of dolomite to increase the probability of finding karst development for the required yield (only the top 50 to 100m of the dolomite exhibits karst development and is therefore exploitable). In this way drilling is only necessary at one location for both production and re-injection.

Temperature profiling/bottom pressure monitoring

A system for monitoring the wellbore temperature profile and bottomhole pressure in a geothermal well at the same time continuously, was tested by Geothermal Energy Research and Development Co. Ltd., Tokyo, Japan in a test well of the Yunomori Field (Iwate Prefecture) from November 1993 to June 1994, up to a depth of about 700m with a maximum temperature of 160°C.

The in-hole system consists of a pressure chamber and a sinker bar that are suspended by 6.35mm O.D. × 3.86mm I.D. capillary tube (Incoloy 825 or SUS 316L). Polyimide-coating fibre optics (GI type, 50/125mm) with 1.8mm O.D. sheath (SUS 316L) is inserted in the capillary tube. The bottom hole pressure change at the chamber is transmitted to a surface pressure gauge (quartz type) through the annular space inside of the capillary tube and outside the optical fibre. The optical fibre is separated from the pressurised capillary tube at the surface and connected to the optical fibre sensor system consisting of a laser diode drive circuit, a high speed averaging unit, and a personal computer to process data and display temperature distribution.

The temperature measurement is based on a laser pulse light transmitted via optical fibre. The velocity v (<light velocity in a vacuum) through fibre optics and generated scattered light can be used to determine the temperature. A part of the scattered light returns to the input end as back scattered light. The position of the scattered light point (x) is determined as $x=v*t/2$ by the delay time (t) from the pulsed light input to its return. The temperature at the scattered light point of origin can be known from intensity of the Raman scattered light, Stokes light and anti-Stokes light, as a function of temperature.

The existing Polyimide coated fibre has a temperature limit below 300°C. Since many deep wells have temperature over 350°C, the current temperature specification is not sufficient for this application. Therefore a new type of optical fibre which can work below 400°C is under development.

Deep downhole heat exchangers

Down hole heat exchangers (less than 100m deep) associated with Heat Pump are currently use in Switzerland, Sweden and other European countries, for heating (and/or cooling) individual houses and buildings. It would be interesting to adapt this concept with deeper wells (1000 to 2000 m deep).

Annex 3.1

THE CASE FOR GEOTHERMAL ENERGY AND ACCEPTABILITY

INDEX

1. ENVIRONMENTAL ISSUES

1.1 Environmental impact

The exploitation of geothermal resources has an impact on the environment although the effects are not as marked as other resources. These effects will, however, depend on a number of interacting factors. These include the characteristics of the reservoir, the type of extracted fluid, the type of application, the size of the plant and the terrain in which the project is developed. Each plant will, invariably, present its own site-specific problems and solutions.

The first perceptible effect on the environment is drilling, whether the boreholes are shallow ones for measuring the geothermal gradient in the pre-feasibility exploration phase, or deep exploratory/production wells. Installation of a drilling rig plus all the accessory equipment entails the construction of an access road and a drilling pad. The latter will cover an area ranging from 300-500m^2 for a small truck-mounted rig (max.depth 300-700m) to 1200-1500m^2 for a small-to-medium mobile rig (max.depth 2000m).

These operations will only modify the surface morphology of an area temporarily. Wells should be sealed with tubular steel lining or casing when crossing potential groundwater aquifers to prevent the mixing of drilling fluids with groundwater. Blowouts can also pollute water, and blow-out preventers need to be installed when drilling geothermal wells where high temperatures and formation pressures are anticipated.

During drilling or flow-tests, undesirable gases may be discharged into the atmosphere, but these operations are temporary and limited to few months. The drilling mud, is generally a bentonite clay slurry but in some cases it can include other substances which can be harmful to the environment. In these cases the mud needs to be treated and separated from the liquid after use. The water can be re-utilised but the solid matter, with drilling cuttings, should be stocked in special waste tanks or ponds. However, the impact on the environment caused by drilling ends once drilling is completed and is limited to a relatively small area.

The next stage is the installation of pipelines for the fluid collection and disposal system and the construction of utilisation plants. These two stages affect the surface morphology in the immediate vicinity of these structures and can caused some

disturbance to flora and fauna. The landscape will be modified, although in some areas such as Larderello, Italy, the network of pipelines criss-crossing the countryside and the power-plant cooling towers have become an integral part of the panorama.
The environmental impact associated with the exploitation of geothermal resources is limited to the area surrounding the generation or heat abstraction plants. There are no transportation, processing or distribution activities which would otherwise expand the area of potential risk. In addition to this advantage there are several environmental protection measures which can be readily implemented to minimise potential detrimental effects.

Environmental problems can arise during plant operation. Geothermal fluids (steam or hot water) usually contain gases such as carbon dioxide (CO_2), hydrogen sulphide (H_2S) and methane (CH_4), as well as dissolved substances whose concentrations usually increase with temperature. For example, sodium chloride (NaCl), boron (B), and in some cases traces of arsenic (As) and mercury (Hg) are a source of pollution if discharged directly into the environment.

Some geothermal waters such as those utilised for district-heating in Iceland are comprised of freshwater, but this is an exception to the rule.

The waste waters from geothermal plants also have a higher temperature than the surface environment and therefore constitute a potential thermal pollutant.

The potential environmental pollution, both thermal and chemical caused by the discharge of waste water, is generally avoided by the re-injection of these waste fluids into the reservoir. These operations need to be performed by specialists with wide experience in this field, to avoid polluting freshwater aquifers and cooling the geothermal reservoir.

Moreover, re-injection properly applied at the right site and to a correct depth has the effect of recharging the geothermal reservoir extending its lifetime and preventing possible subsidence phenomena.

Electricity generation in binary cycle plants will affect the environment in the same way as direct heat uses. The effects are potentially greater in the case of conventional back-pressure or condensing power-plants, especially with regard to air quality, but can be kept within acceptable limits, particularly where small geothermal resources and small plants (<10 MWe) are involved. The odour threshold for hydrogen sulphide in the air is about 5 parts per billion by volume and subtle physiological effects can be detected at slightly higher concentrations. Various processes, however, can be used to reduce emissions of this gas. Green-house gas emissions from geothermal plant are very limited as the figures presented below indicate.

Binary cycle plants used for electricity generation and district heating plants may also cause minor problems with hydrogen sulphide emissions. These can be overcome simply by adopting closed-loop systems that prevent gaseous emissions.

Organic Rankine Cycle (ORC) systems are potential sources of environmental pollution where the risk comes almost exclusively from the working fluids. In fact for geothermal fluids, complete re-injection systems return virtually all the liquids, solids and gases that make up the geothermal brine to underground reservoirs.

Several other aspects related specifically to the safety and environmental effects of organic fluids used in ORC systems have now been established. The Montreal Protocol of 1987, drastically restricted the use of several Freons and various substitutes for chloro-fluoro-carbons (CFCs) are currently under development as a result. For this and other reasons, the most recent ORC systems use different kinds of hydrocarbon or inorganic fluids such as ammonia as working fluids.

Although ORC units are sealed, a loss of organic fluid into the atmosphere can occur during system operation. For well-designed systems the leakage rate is minimal, approximately 3% of the total fluid content or 150kg/yr, well below the limits established by current regulation. However, because some of these fluids are flammable, comprehensive fire protection must be provided.

Low-to-moderate temperature geothermal fluids used in most direct use applications generally contain low levels of chemicals and the discharge of spent geothermal fluids is seldom a major problem. Chemical and thermal pollution can be overcame by using downhole heat exchangers wherever possible. The thermal fluid circulated through the heat exchanger may be pure water or a suitable low-boiling fluid, depending on the aquifer temperature. Potential pollutants are therefore retained within the aquifer.

1.2 Green House Gas Emissions

The operation of geothermal plant, particularly high enthalpy resources for electricity generation will produce some carbon dioxide and methane plus other gases, which contribute to the natural green-house effect of the Earth's atmosphere. However, the mode of operation (i.e. closed circuit or use of re-injection) strongly affects the amount of Carbon Dioxide discharged to the atmosphere.

The figures used in Table 3.1.1 are based on a median value derived from a number of operational sites. However, when compared to the equivalent energy produced from fossil-fuel alternatives the amount of gas released is much lower which is evident from the comparison in Table 3.1.2 below.

Geothermal	Parameter	Value
Electrical output	Emissions during construction – CO_2 (kg/TJ)	2,527.8
	Emissions during construction – SO_2 (kg/TJ)	5.6
	Emissions during construction – NO_x (kg/TJ)	77.8
	Emissions during construction – Particulates (kg/TJ)	8.9
	Emission factor – CO_2 (kg/TJ)	19,444.4
	Emission factor – SO_2 (kg/TJ)	0.0
	Emission factor – NO_x (kg/TJ)	0.0
	Emission factor – Particulates (kg/TJ)	0.0
Thermal output	Emissions during construction – CO_2 (kg/TJ)	280.9
	Emissions during construction – SO_2 (kg/TJ)	0.6
	Emissions during construction – NO_x (kg/TJ)	8.6
	Emissions during construction – Particulates (kg/TJ)	1.0
	Emission factor – CO_2 (kg/TJ)	2,160.5
	Emission factor – SO_2 (kg/TJ)	0.0
	Emission factor – NO_x (kg/TJ)	0.0
	Emission factor – Particulates (kg/TJ)	0.0

Table 3.1.1 Emissions data for Geothermal Electricity Generation and Thermal Plant

Power generation technology Emission factor	Conventional steam cycle coal fired plant	Combined cycle gas turbine	Geothermal
CO_2 (kg/GJ)	249	112	19.4
SO_2 (g/GJ)	3326	0	0.0
NO_x (g/GJ)	977	196.5	0.0
Particulates (kg/TJ)	47	0	0.0

Table 3.1.2 Comparison of some emissions from different forms of thermal power generation

1.3 Environmental benefits

The environmental advantages outlined here are relevant to almost all possible variants of geothermal energy use:

- Continuous supply

Geothermal heat is always available when required. Biomass, geothermal energy and small hydro are the only renewable energies which are available in a stored form without the use of an intermediary form of storage such as batteries. The wide range of energy conversion techniques allows geothermal resources to be used for many different applications. Further development in this sector will make it possible to use geothermal energy practically everywhere once further technical advances have been made.

- Little operating cost

Once a geothermal heat plant is installed operating costs are minimal since water, as the energy carrier, is continuously available. Moreover, once an installed system has been fully commissioned it requires only a little auxiliary energy to drive the circulation pumps.

- Scarce emissions to atmosphere

As indicated above the level of pollutant emissions to atmosphere are very low compared to conventional energy sources for electricity and heat generation.

- Little space required

Geothermal plants occupy a comparatively small surface area. Storage facilities which are required for fossil fuels or biomass are unnecessary.

- No load traffic

No raw materials have to be transported to the geothermal plants once they become operational.

- Minimum risk of accidents

Geothermal energy is recovered in plants with conventional technical components. No hazardous material has to be handled. Energy transferred via water presents minimal risk when compared with the combustion hazards posed by the use of fossil-fuels.

2. EMPLOYMENT BENEFITS

2.1 Evaluation of the effects of the construction and operation of geothermal heating plant on the labour market.

A case study for the Federal Land of Mecklenburg - West Pomerania (Germany) is described here as an example of employment opportunities generated from the construction and operation of a geothermal heating plant.

The construction and operation of geothermal heating plants should not be exclusively confined to environmental benefits, energy policy, public heating supplies and cost - employment opportunities should be included as well.

The utilisation of geothermal energy requires capital-intensive plants - the investment needed for a geothermal heating plant is 10 times greater than for a gas-fired heating plant with the same heat output. When a geothermal heating plant is constructed, many suppliers deliver a wide range of goods and services, which can be local and can be small or medium sized enterprises. As a rule, a complete gas-fired heating plant will be delivered by one general contractor.

The supply of geothermal heat implies the replacement of natural gas or other fossil fuels by a locally available resource whose utilisation requires capital investment and, above all, permanent debt service and technical service of the equipment. The share of the cost of imported energy is low (ranging from 5 to 20 % compared to 60 to 80 % in the case of a fossil-fuel fired heating plant).

In this way, the major share of the profit gained through the sale of heat energy is used for debt service (between 40 and 60 %) as well as for services such as plant management, maintenance and repair, etc., which results in job creation in the country or region. Expenditure is not predominantly for the payment of fuel or power imports as would be the case for fossil-fuelled plant.

Based on the results obtained in the Neustadt-Glewe demonstration plant an attempt has been made to evaluate the indirect effects on employment. In this example the existence of deep wells has to be taken into consideration.

The analysis of the suppliers' contributions covers both the investment and the operating phases. While the construction of the plant and engineering work provide employment over a period of 1 - 3 years, the phase of operation - geothermal heating plants are designed for a period of at least 30 years - includes permanent employment in the field of the services listed below. The suppliers' contributions are classified according to the following characteristics:

- turnover in the project
- net output (gross proceeds = production)
- large-scale enterprises and SME.

The total investment budget in the Neustadt-Glewe demonstration plant was ECU 9.3 million, comprising:

- ECU 5.8 million for supplies
- ECU 0.8 million for architects' and engineers' work
- ECU 0.5 million for R&D and testing
- ECU 0.4 million for project management
- ECU 1.6 million for the purchase of existing units
- ECU 0.2 million for the purchase of the site.

This amounts to ECU 7.5 million of the total investment budget for supplies and services.

The turnover of local enterprises (those directly related to the project) in Mecklenburg-West Pomerania was ECU 6.05 million (65 % of the total turnover or 81 % of all supplies and services) split between ECU 3.95 million for SMEs (42 % of the total turnover or 53 % of all supplies and services or 65 % of the total domestic turnover) and ECU 2.1 million from large-size enterprises.

The value of the production from the local enterprises (directly involved in the scheme) within the overall turnover was about ECU 3.7 million (which is equal to 74 % of the total value of the production or 49 % of all supplies and services) with ECU 2.55 million attributable to SMEs (51 % of the value of the production or 34 % of all supplies and services or 42 % of the total domestic turnover) and ECU 1.15 million attributable to large-scale enterprises.

Based on the assumption that one man-year of employment is equal to a value of production of ECU 30,000, the total value of production corresponds to a one-off effect of employment of about 120 man-years (= 60 employees based on an investment period of 2 years) with 85 man-years directly related to SMEs.

Depending on the content of work / qualification it is estimated that an investment ranging from about ECU 100,000 to 1.0 million will lead to the creation of one workplace. The amount of employment becomes even clearer in the operational phase.

The annual turnover for supplies and services, for debt service and taxes is ECU 1.05 million on average. This implies a value of production of about ECU 0.3 million per year resulting in about 10 permanent jobs.

Here, however, only ECU 0.06 million /year with about 2 permanent jobs can be directly related to SMEs (the managing board is provided by the regional energy supplier WEMAG).

Summarising the above, the local employment effects are as follows:

- investment	about 120 man-years	60 jobs over a period of 2 years
- operation	about 300 man-years	10 jobs over a period of 30 years
- total	about 420 man-years	
- with	about 150 man-years attributed to SME.	

The technological part of the Neustadt-Glewe project was supported by the local government with a total of ECU 2.3 million (= 25 % of the total budget). This corresponds to a ratio of about ECU 5,500 / man-year of local employment (ECU 2.3 million : 420 man-years) and a ratio of about ECU 230,000 per permanently created local job (ECU 2.3 million : 10 permanent jobs).

These figures show the high employment benefits of politically supported energy schemes such as the construction of geothermal heating plants. The amount and ratio of the support are related to the fact that the Neustadt-Glewe plant is a demonstration scheme (extensive research programme, among others) which needs to be taken into consideration.

Annex 4.1
ECONOMY OF GEOTHERMOELECTRIC GENERATION

INDEX

1. PRESENT PROBLEMS OF GEOTHERMAL DEVELOPMENT (1997)

The pace of geothermal energy exploitation increased rapidly in the 1970's and 1980's. With the demise of the oil crisis and subsequent sharp decrease in the price of oil, geothermal energy has become less competitive with conventional energy sources.

A further reason for decrease in investments in geothermal projects, is the fact that the main International Banking Agencies (W.B., A.D.B., I.D.B. etc.) no longer consider investments in the energy sector as a priority. The privatisation of the energy sector is actually recommended by the World Bank to all Governments of developing countries.

The generation cost of geothermal energy is generally still competitive with other alternative. For instance the electrical generation cost from the oil burning power plants is about 10% higher than the average cost of a geothermal power plant of more than 50 MW.

However the lower returns make a less appealing investment for a private sector investor in comparison with other opportunities offered by a free market economy, especially when the mining or geological risk is taken into consideration, which will always exist with a geothermal project.

In this context an unusual contradiction exists. From an economical standpoint a geothermal project is usually competitive with an alternative technology as the generation cost is lower. Moreover, a geothermal resource it is at least partially renewable, this part is lost if not exploited by means of proper investments. Again it is a local, not a tradable or exportable resource, but its exploitation for many countries means a reduction in imported of fuels and in a commensurate reduction in foreign exchange.

From a financial standpoint the same project may appear unattractive mainly for two reasons:

- a higher income might not necessarily reward the mining risk.
- the rate or return of the investment, even if positive, may be lower than the opportunity rate for the investor, in comparison with an alternative offered by other investments.

From a technical viewpoint a solution to these problems may arise from an improvement in exploration techniques leading to a reduction in mining risk. However, until the economic profitability of geothermal resources is substantially increased by market conditions, investments in the improvement of geoscientific exploration techniques cannot be expected.

A possible solution to the problem of investment in geothermal generation may be found from a different approach to the organisation and implementation of projects.

2. THE INFLUENCE OF DIFFERENT MARKETS IN GEOTHERMAL ENERGY DEVELOPMENT

The development of geothermal energy for electrical generation purposes, has followed different paths according to the specific institutional and market conditions of different countries.

The different conditions can be summarised in three groups as follows:

a) Countries where indigenous know-how and financial resources existed before the beginning of the geothermal development (United States, Italy, Japan, Iceland and New Zealand). Here the geothermal exploration as well as the implementation of plants, has been mainly regulated by free market conditions, both when the investor was a state owned public utility or a private one.

b) Countries that supported the private sector and charged it with the exploration and exploitation of the geothermal resource, even when the electrical energy production, is either a state monopoly or strictly regulated by the Government. Such a policy was implemented by means of mining concession and operation contracts for the purchase of the steam or the electrical energy. In these countries the market conditions cannot be considered "free market", being only one (the state) is the final purchaser. The free market rules are applied here when the concession is offered to different investors in a competitive bid. Financial resources come mainly from private investors and partially from the state owned companies, often financed, on their side, by international banking agencies. This situation is typical in two countries where geothermal energy is a significant commercial energy, Indonesia and Philippines.

c) Countries where the state-owned public utilities developed the resources by themselves and commissioned the generation plants. This situation was prevalent in all Latin America countries until very recently. The investment capital was either from the governments or from the state-owned companies, but the international banking agencies (I.B.R.D., I.D.B., UNDP) played a fundamental role in the development of geothermal resources.

In cases a) and b) the operations may be carried out in two different ways:

1) By two operators:

- a mining company as far as the geothermal field exploitation and steam production is concerned
- a public utility which implements and operates the geothermoelectric plant

In this case the mining company get the lease or concession from the land owner, produces and sells the steam to the "public utility" which produces and sells the electric energy into the power sector market.

2) By a single operator, being the field developer, the owner and operator of the power plant is the same entity.

In case a), the decision to implement a geothermal project is determined mainly by financial considerations. In contrast the development policies in the group b) countries are regulated by economic aspects. For instance a government may accept to pay a private investor a price higher than the least cost alternative, taking into account shadow prices, for a strategic reasons to develop indigenous resources, or using the opportunity to diversify energy resources.

In case c), where the finance for a project comes from an International Banking Agency, each project has to be submitted for approval, and therefore both economical and financial aspects have to be in principle strictly observed, according to the rules of the financial institutions concerned.

In practice the implementation of schemes is more complex, especially where contracts between the state-owned enterprises and private investors are concerned. For instance, the effect of contracts signed under solicited or unsolicited proposals, or after structured or unstructured requests, strongly affects the final economical and financial results of a project.

Other parameters may strongly influence the final outcome of a project. For example a project implemented by a private investor, , generally results in a lower production cost due to the higher efficiency of a private enterprise (not bounded with strict controls like a public one). But the higher expected rate of return of the same investor may eventually result in a higher price for the energy.

There are many aspects of this kind that should be carefully analysed before issuing a final judgement on the matter.

A detailed assessment of geothermal generation cost is therefore necessary both for the general appraisal of the sector and to look for a solution of its present problems.

3. THE PRIVATISATION PROCESS AND ITS INFLUENCE ON THE DEVELOPMENT OF GEOTHERMAL ENERGY

Since the mid 1980's privatisation of infrastructure and energy supply industries has increased substantially even in the countries where the Government usually had a unique role in this matter. In the present decade this process has been especially significant in the sectors of telecommunication and electrical generation and distribution.

Such a process is the result of a general policy supported both by most governments and by the international banking agencies. These do not consider investments in the energy sector as a priority and therefore in many countries geothermal development has slowed down or even stopped for lack of investment. This phenomenon happened particularly in countries where geothermal development was conventionally carried out by State enterprises.

The reasons for a new policy in favour of privatisation can be summarised:

- the restriction of Governments' financial resources for capital intensive investments like the energy projects, because of macro economic conditions
- the decision of the international banking agencies (W.B., A.D.B., I.D.B.) to consider investments in energy projects as a low priority
- the lower efficiency of the state owned companies in comparison with the private ones, mainly due to the strict rules and controls duly applied to the state's companies because of their use of public funds and political interference.

Such a policy did not affect the pace of geothermal development in the countries where private enterprise was already active, for instance in Indonesia and Philippines. Here the development was also supported by the Governments for general economical reasons, has previously explained under the paragraph 1 of this chapter.

These economical considerations did not apply in other countries (in the most developed ones) were free market rules have restrained geothermal development because the decrease in the price of oil has made it less competitive.

Quite different condition occur in Latin American countries were an extensive unexploited geothermal potential still exists and in many cases is possibly competitive with alternative energy resources.

As stated before, in these countries the electricity supply system has been, until very recently, under full state control. Most Governments presently widely accept and support privatisation policies. The lack of specific laws, tradition and experience have, however, slowed down the privatisation process, even against the willingness of Governments and state enterprises. Today in many countries a new legislation is already in force, and in others it is a process that is in progress so that this obstacle will be overcome.

Nevertheless in many cases decisions specifically related to investment in geothermal schemes are slow because techno-economical aspects of the technology are not yet clear to the decision-makers. For example if the cost of geothermal energy is lower than an alternative one, the final price may be higher. In reality risk remuneration is a concept not widely understood. As well as the fact that the expected rate of return for a private investor is higher than the one used for planning by government agencies. Private sector investments also demand shorter repayment periods than state sector entreprises.

At present in many countries, especially in Latin America, the shortage of financial resources still affects the geothermal development. The existence in the market of a new kind of financing instrument may resolve the problem in the near future.

4. THE "PROJECT FINANCING"

The definition of "project Financing" is*: to finance a project, fully or partially, on the basis of the credit of the same project, which is wholly dependent on the incomes of the project for the sole or main source of the debt service.*

This kind of financing procedure is spreading through out in the world for public works projects. In the estimation of the I.B.R.D. within the year 2000[1] 14% of the total world investments for infrastructures schemes, will be implemented according to this procedure.

The basic difference with traditional financing procedures is that in the case of Project Financing the loan is not granted on the basis of the solvency of the investor but on the financial warrantee of the project itself. This means that in the assessment of the investments, the pay back of the loan is expected not from the financial soundness of the borrower, but from the income and profits that the project is expected to generate. This kind of financing is called "no or limited resource loans".

This procedure has only an important consequence for the investor (be it public or private): because it does not bind, (or partially binds), financial resources so that they are available for other investments.

If on the one the hand such a procedure makes the financing of a project easier, on the other hand the project's technical design, planning, scheduling, and economical and financial analysis, (the feasibility study), has to be prepared with attention to detail which is somewhat different from the traditional approach. For instance for an international banking agency, to finance an energy project, the following requirements will be necessary:

- the system needs to supply the estimated energy output
- the project offers the least cost expansion
- the investor can pay the debt service

In a Project Financing evaluation the following requirements need to be analysed:

- the market will buy the produced energy
- the price the market will pay guarantees the pay back of the loan
- the borrower has the capacity to sustain the risks involved in the project .

In other words in the first instance the project analysis has to define the production ***cost***, and provide a check that it is the least cost option. Moreover, the cost must be sustained by the economy of the country. In the second instance the analysis must assess that the ***price*** the market can pay for the energy, throughout the entire economic life of the plant, is enough to pay the operation and maintenance of the plant, the debt service, the taxes, and leaves to the owner with profits equal or higher than an alternative investment.

An important item of the preparatory study for a Project Financing assessment is risk analysis. The Bank, because of it own criteria, may not accept the risk related to the project.

[1] F.Sander, "Privatization and Foreign Investment in Developing World" 1988-1992, The World Bank.

The borrower's analysis must indicate not only the technical risks, but also the financial and political ones, clearly indicating the mitigation procedures that will be taken related to technical, financial, legal and insurance aspects of the project.

In the case of geothermal projects, generally, the land owner (the government, the state or a private, according to the local laws) grants the exploitation rights to a concessionaire. The relationship between the owner and the concessionaire are regulated by contracts that may be:

- BOO (Build, Own and Operate)
- BOOT (Build, Own, Operate, and Transfer)
- BLT (Build, Lease and Transfer).

These contracts are the basis on which the Project Financing is structured.

In countries where the privatisation process is now underway, Project Financing through BOO, BOOT or BLT contracts, offers the State owned electric companies many advantages:
- reduction of need of financial resources
- reduction of the implementation schedule in comparison with a traditional route linked to turn-key contracts and loans from international banking agencies
- the previous identification of risks and their mitigation.

It should be stressed that the implementation of a Project Financing procedure has to overcome some difficulties, especially for state owned companies which do not have a specific experience in the matter.

The following criteria are essential:
- The preparatory studies must be specifically orientated.
- The project must be attractive for many potential at investors: the lack of competition may lethal for a project.
- Bidding and negotiation in this kind of contracts requires much more care than the traditional "turn-key" contracts. The risk of stipulating contracts which in the long term may result in losses for one of the parties is high.
- The higher efficiency of private investors results in lower costs but this is not necessarily reflected in lower prices. The expected return for a private investor must pay for higher efficiency.

However, Project Financing is a mechanism that may overcome the present slow pace of geothermal development.

5. COST ELEMENTS OF A GEOTHERMAL PROJECT

As already stated in paragraph 3, the assessment of the parameters that affects the cost of geothermal energy is fundamental for any sound analysis on the matter.

The discrepancy of some investment costs in different countries and in different geothermal areas, makes it almost impossible to generalise the production cost of geothermal energy. Local market conditions, decision-making procedures, but mainly the geological features of a field, deeply affect the final production cost which it can change by a factor from one to three or more of the original cost.

It is essential therefore to define a methodology for cost assessment, rather than give figures which essential therefore related to specific parameters and conditions.

To assess the generation cost of a geothermal project, the expenditure that investors afford in each phase of the project, from preliminary reconnaissance to the operation of the plant, need to be examined in detail strictly in connection with the schedule of the project (Fig.4.1.1)

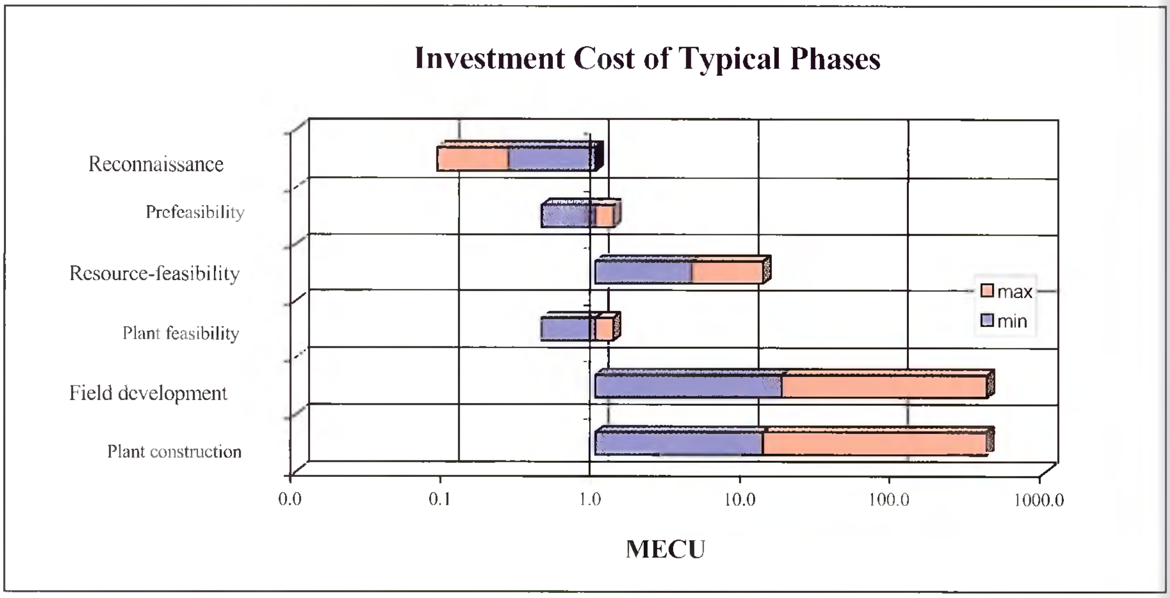

Fig. 4.1.1

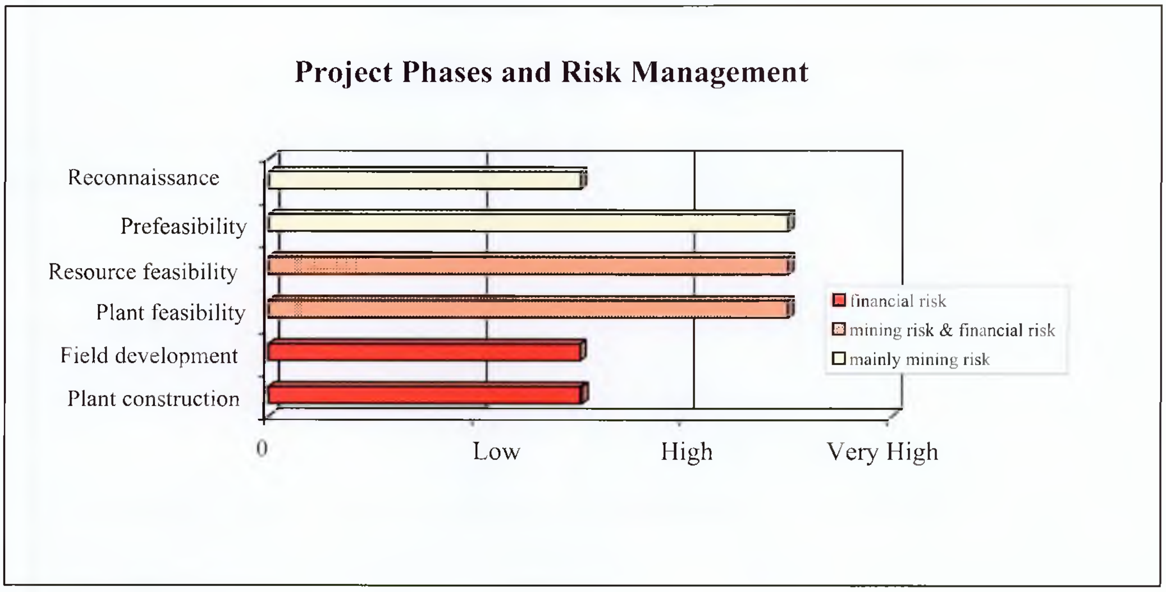

Fig. 4.1.2

A geothermal project develops (or should developed) in a sequence of phases based on established procedures:

1. Surface Exploration
   - reconnaissance
   - prefeasibility

2. Deep Exploration
   - feasibility :
     . field (deep exploratory drilling)
     . plant

3. Implementation
   - field development:
     . production and reinjection wells
     . piping and separation system
   - plant construction

4. Operation

A review of the activities and the objectives related to the different phases and their relevant cost is advisable.
The above project phases and risk management is outlined in Figure 4.1.2.

5.1 Reconnaissance

Reconnaissance is a low cost activity, in the order of hundred or two hundred thousand dollars, whose objective is to prepare an inventory of the geothermal resources areas in a nation or in a region, to establish a priority and to chose the most promising prospects.

Even if the financial cost of such an activity is negligible, the general frame of a geothermal development, (i.e. its economic value is important). A reconnaissance study reduces the risk of the following stages of the project, allows better programming and scheduling of the successive activities and eventually may result in lower production costs.

In some cases when a state owned operator has been involved, it has happened that the choice of an area for expensive deep exploration resulted a failure without preliminary reconnaissance study or delays have been caused in a general development program when better areas where initially neglected.

These incidents emphasise the importance of reconnaissance activities.

5.2 Prefeasibility

The goal of a prefeasibility study is to establish the existence of a geothermal resource on the basis of data that can be collected by means of surface exploration and locate the best sites for deep exploration wells.

The geoscientific activities performed in this phase are geology, geophysics and geochemistry. The direct cost of such activities is generally not excessive (they should be in the order of 400 thousand ECU). Costs up to the double this figure are sometime justified where complex or hidden geological features of the exploration area exist. The cost may also substantially increase if drilling of a deep slim hole results advisable at the end of the surface prospections.

It is strongly recommendable that the prefeasibility phase does not last more than a few months and no more than a year. The request for more details and further prospections are often requested which inflates the costs and delays the subsequent development with no substantial reduction in the mining risk.

An idealized function of the reduction in the mining risk with increasing investment in exploration is broadly a hyperbolic one, as may be seen in the following graph[2] (Figure 4.1.3).

The graph synthetises the concept that exploration drastically reduces the mining risk, but a residual risk will always exist, and an increase in exploration work cannot completely eliminate it.

[2] Speech of F.Barberi at the I.I.L.A. convention on Geothermics, Guatemala City(1977)

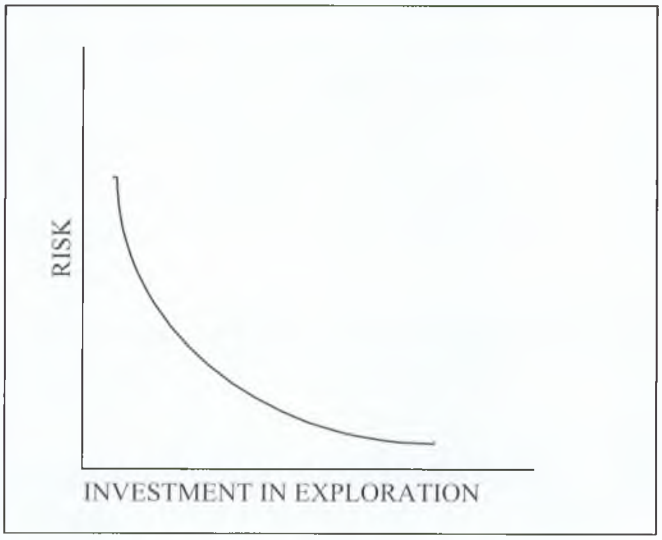

Fig. 4.1.3 Mining Risk versus Exploration Investment

If a delay in production results in a lower actualized value of the produced energy, the real cost of an inflated exploration program is much higher than its direct cost.

The outcome may be that the actualised cost of this phase could be in four or more times higher than expected.

5.3 Feasibility

It should be emphasised that the goals of a feasibility study are as follows:

- Verify if the project may be carried out from a technical standpoint
- Define the technical characteristics, selecting the best conditions after a technical and economical comparison with other alternatives
- Design plant and equipment with sufficient detail to define their functional characteristics, their cost and implementation schedule.
- Assess costs and benefits, economic and financial, compare the whole project with possible alternatives, including "non-implementation".

In a geothermal project, the feasibility study is divided in two parts for logical and operational reasons. The field is deep exploration, as well as the assessment of the available resource and its thermodynamical characteristics, is carried out prior to any definition of the equipment (class, size, thermodynamic cycle, layout etc.).

The first phase is the "Resource Feasibility" and its aim is:

- to verify the existence of a geothermal reservoir,
- to assess its size and potential
- to define the fluid's thermodynamical parameters.

This phase is the most critical one in a geothermal development: the investment in drilling is quite high, between 4.4 and 8.8 millions ECU, about 1.3 million ECU per exploration well with an average estimated depth of 1500m, including well-site, access purchase and preparation, engineering and administration. This cost (sometimes higher than the figures quoted here) is entirely submitted to the mining risk. The mining risk includes not only the existence of the resource but also its thermodynamical and chemical characteristics. These parameters may substantially affect the possibility of exploitation and its cost.

The second phase, or "Plant Feasibility", is based on the results of the first one, and its goals are:

- Choose the size of the plant and its thermal cycle,
- Compare and optimize the possible technical solutions and parameters (i.e single or double flash, inlet pressure, condensing pressure, gas extraction systems, piping and separators sizing and lay-out),
- Design plant and field surface equipment in a preliminary way,
- Analyse the whole project from an economical and financial standpoint.

As we have seen in the former paragraph, a feasibility study conceived for Project Financing must develop the last item in a special way.

The cost of a typical feasibility study is in between 0.4 and 0.9 million ECU, and its duration depends mainly from the drilling program. A schedule of 1.5 years is considered an acceptable average.

5.4 Implementation

Time, schedule, size and costs of this phase depend on the characteristics of the geothermal reservoir as ascertained during the resource feasibility stage. The field potential defines the size of the plant and therefore its specific cost. The wells' flow determines the number of wells to be drilled and therefore the development cost and schedule (Fig. 4.1.4).

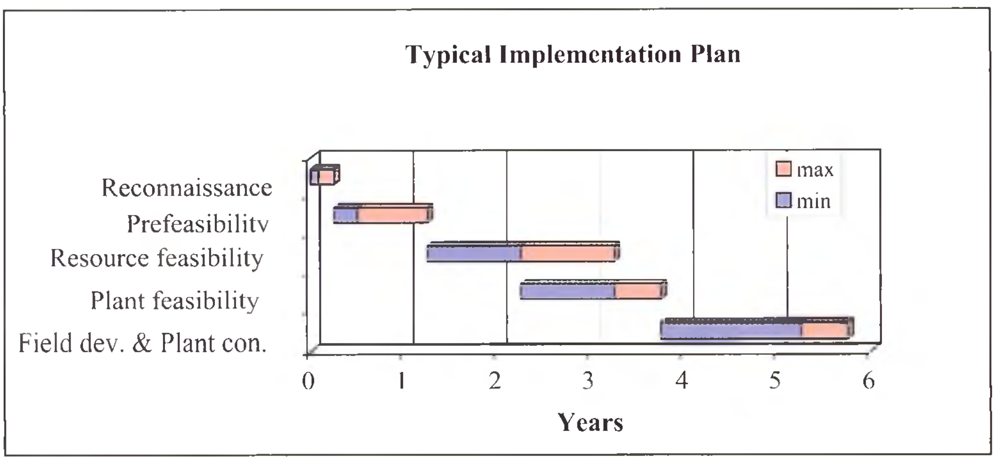

Fig. 4.1.4

In the implementation phase it is advisable to analyse separate ways to carry out field development and plant construction. The activities during the field development phase include the drilling of production and reinjection wells and the construction of the piping and separation systems.

The average cost of a development well may be estimated from an approximation of some tens of percent. Cost estimates in the order of 0.9-1.3 million ECU per well are a safe approximation in developing, but not oil-producing countries. What cannot be foreseen (before of the drilling of the exploration wells) is the average yield from wells. The world average power of productive wells (for wet steam reservoirs, measured at the beginning of production) has been estimated at 5MW. This value is presently increasing for the more recently developed fields to around 6 MW(e). This value is near the boundary that makes a geothermal project competitive with a traditional power plant with the present cost of oil. However, the variability of this value in actual wells is very high (see par. 6.2).

It is impossible to establish generically the cost of the development of a geothermal area without the results of the feasibility study of a specific field. It can be assumed that the specific cost of such development must be lower than 1750 ECU / kW installed including the power plant to make the whole project economically sound.

It is appropriate to point out that a development cost lower than 875 ECU /kW is not exceptional.

The schedule of a field development depends on the number of wells to be drilled. The schedule may be reduced to fit any plant construction program, with minor cost increases, in this phase more drilling rigs are used. This procedure can ensure that the plant construction and erection phase can be completed in time for the implementation phase.

The construction time for the power plant depends on the size and the equipment supplier. Around 24 months (for the first unit) plus minus 6 months, is the usual construction time seen in many projects over the last few years.

The definition of the cost of the power plant is much easier to determine. To a certain degree is the cost function of market conditions. The main factor influencing the specific cost is the size of the plant. At present units of 55MW have a specific cost of around 700 ECU /kW, while the small units of 10-15 MW may reach a cost almost double this per kW installed.

5.5 Operation and maintenance

The field O&M costs and those of the plant then need to be re-examined. An acceptable estimate of the O&M cost for all equipment (field and plant) is an annual expense of between 2 and 3% of the capital costs of the plant (below 55 MW).

The expense of drilling replacement wells has to be added. This cost cannot be estimated generically because it is linked to the same uncertainties described for the field development and, moreover, it depends on the rate of decline of the production wells. The cost of drilling replacement wells is roughly double the O&M expense directly related to surface plant operation.

6. VARIABILITY OF INVESTMENT COSTS

As stated at the beginning of the previous paragraph, it is impossible define in a general way the cost of geothermal energy. Nevertheless to evaluate the possible development of geothermal energy and its future market some reference costs must be defined.

To do this task, a previous analysis of the range of investments at each different phase of a project is necessary, to obtain reasonable figures and an estimate of possible errors, their reasons and variability.

This analysis is a basic requirement for choosing the parameters that, through the application of a proper mathematical model, will allow us to calculate costs and prices of geothermoelectric energy. The same model can be used to analyse the influence of the variation of each parameter on the final generation cost.

Each contributory parameters, previously described, should be examined in more detailed.

6.1 Drilling

The depth of geothermal wells in presently producing fields is in between 500 and 3000m, with an average depth of around 1500m. It is known that the specific cost (ECU /m) is not constant and increases with depth. Costs for access, well site and equipment usage are constant so that a general evaluation of well cost can be approximated.

Market conditions may also considerably affect the cost of drilling contracts.

Drilling costs are strictly dependant on the oil industry market. As the exploration and development of new oilfields grows, the availability of equipment decreases which leads on an increase in the price for the rent of rigs, especially in a secondary market like the geothermal one.

The cost is quite noticeably in countries or areas where drilling activity for oil exists. The reason is clear; rig mobilisation, and the supply of consumables, equipment and spare parts are obviously cheaper where a drilling industry is active.

All these costs are generally predictable for each project and even if they fluctuate by plus or minus 30-50% around the average of 0.9-1.1 million ECU per development well, they do not represent a critical uncertainty for geothermal projects.

It is important to recognise that exploration and development wells have different costs. In the former the drilling is slowed by uncertainty in the stratigraphy, the need to take cores and perform more in-well measurements. Moreover, contracts for exploration wells generally envisage a small number of wells, so that the influence of moving in and out is specifically higher.

For all these reasons an exploration well can cost around 20-30% more in comparison with development wells. It should be stressed that problems can arise during drilling which might push, the final cost substantially higher.

The calculations for the energy production cost, assume an average drilling price of 1.1 and 1.3 million ECU per development and exploration well, respectively. These costs include expenses for the construction of the preparation of the well site and access roads.

6.2 The influence of well productivity.

Well productivity is certainly the parameter that most affect the final cost of geothermal energy. The effect of this parameter on the proficiency of geothermal energy has been analysed by different authors.[3]

In reality production wells connected to operating power plants can have energy outputs from less than 2 to more than 30 MW(e).

If the specific cost of drilling related to the wells' potential (ECU /MWe) keeping constant the cost per well) is considered, this value may change from 1 to 15 or even more.

It is clear that such a wide variation, in comparison to the other uncertainties with variations of some tens of percent of the other costs, make this parameter the most critical one.

After the surface exploration phase, the existence of a thermal anomaly at depth, its temperature and location can only be assessed with a fair degree of approximation. The parameters that determine the productivity, that is the permeability of the reservoir, its transmissivity and recharge conditions, can only inferred. It is only after drilling and testing of the exploration wells, that the available power of the future development wells can be evaluated in relatively sound manner.

In a general assessment of geothermal generation costs is therefore advisable to manage the well productivity as a variable and analyse the final cost as a function of this parameter (see par. 8).

[3] Girelli,M. (1991) Economic proficiency of geothermal generation versus drilling costs and oil prices. *International Seminary on Geothermal Prospects in Latin America and the Caribbean*, San Salvador (C.A.) 1991.(in Spanish)

6.3 Specific cost of the plant

Market conditions may partially affect the price of equipment. Altough this influence may be high as an absolute value, it is rather low as a percentage of the project total, possibly less than 10%.

The size of the units and the total installed power is a much more important influence.

As far as the thermal cycle is concerned the geothermal turbines are of three kinds:

- back-pressure
- condensing
- organic cycle

The low cost but low efficiency of back-pressure turbines are economically justified, only in an initial stage of a geothermal development, or when the incondesable gas content of the steam is higher than 12-14%.

The organic cycle units, have a high specific cost. They are therefore, justified for exploitation of brines with temperatures under 200°C, which are regarded as marginal wells or of residual separated waters.

The main cycle to be taken into consideration are, single or double flash condensing turbines.

Even if any size of condensing unit were available (with an upper limit of 55 MW due to the maximum possible size of the turbine blades), the actual units currently available (single flash) can be grouped, for sake of simplicity, in three categories according to their size:

- 10÷15 MW
- 25÷30 MW
- 55 MW

The last figure (55 MW) represents a market standard for the upper size. From a technical standpoint turbines around 65 MW or more can now be built.

Based on the results from different bids in the last few years it is possible to methodically assess the range of specifics cost of power plants equipped with these units (within an error limited to the effect of market condition and competition).

- 10÷15 MW	1200÷1300 ECU /kW
- 25÷30 MW	875÷1050 "
- 55 MW	600÷850 "

These costs are relevant to single unit plants. Further units of the same plants may have a discount of up to 20% of the average values (Figure 4.1.5).

6.4 Plant factor

Calculations to determine the unit cost of generation assume a "plant factor" which is the average yearly percentage of time plant generates at rated power, during the whole economic lifetime. It is assumed that the electricity system can receive the entire production of the plant, as actually happens for all the existing geothermal power plants around the world. For this reason the term "plan" factor and not "load" factor is used as the latter term is generally dependant on the capability of the electricity distribution network to absorb the full capacity of the plant.

It has to be stressed that such assumptions are based on the hypothesis that the plant is sized so that the field's steam production may sustain the rated power of the plant for its lifetime.

An oversizing of the power plant (up to a certain degree) results in higher financial benefits,[4] but such cases are not considered as they do not represent a standard condition.

The unavailability of the plant is therefore related only to the scheduled yearly maintenance requirements and estimated accidental "out-of-service" incidents, both of the plant, the field and related equipment.

In reality geothermoelectric generation is typically used for base load production. From a theoretical standpoint a "storatibility" of the unexploited resource exists, but the time requested for closing and opening the wells (for technical and safety reasons), does not allow any daily modulation.

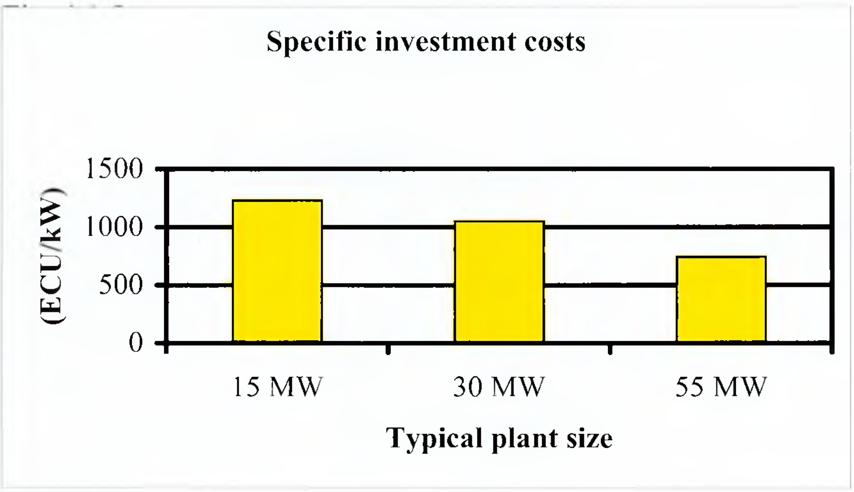

Fig. 4.1.5

[4] Girelli, M.,Parini,M, Pisani,P.."*Economic evaluation of alternative strategies of geothermal exploitation*", Proc.World Geothermal Congress, Florence, 1995, pp. 2843-2846.

7. TYPICAL COSTS OF GEOTHERMOELECTRIC GENERATION

The former assessment of the cost and the schedule of the components for a geothermal electric project, allows the cost of the energy produced to be calculated. It is therefore possible to analyse the influence of the variability of each factor on the final cost (see Figure 4.1.6).

Calculations were made by means of a mathematical model, based on the Discounted Cash Flow Method.

Before choosing a reference project to evaluate what can be termed a "typical cost" preliminary calculations were performed on different cases.

Based on the project partners professional judgement the base case is a plant of a single 55MW units, whose generation cost results are almost equivalent to a 2 x 30 MW, can be accepted as representative of a "typical project".

It should be stressed again that the results from these calculations are based on input data within accepted error limits. The eventual figures are consequently subject to error.

A Reference Typical Geothermal Project is defined by the following input data which is the basis of the mathematical model (see also tables of the Appendix to this Annex for the inputs of the Financial model).

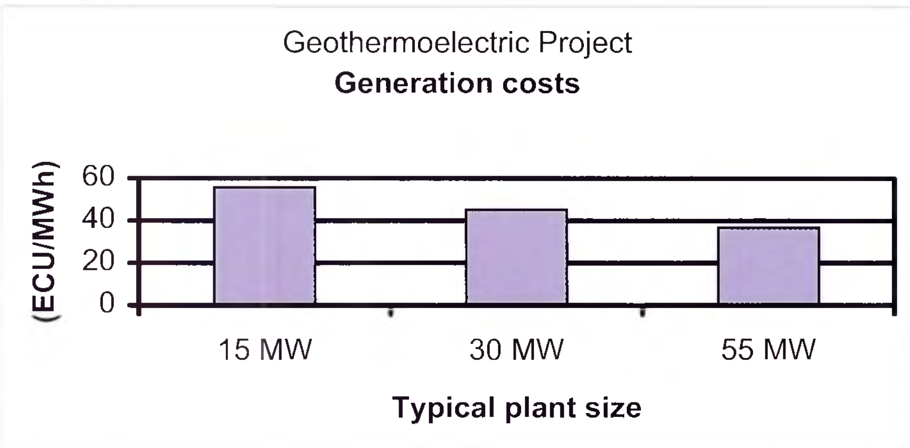

Fig. 4.1.6

EXPLORATION	
Surface prospections	
cost	0.4 MECU
term[5]	1 year
Deep exploration	
cost (wells drilling not included)	0.9 MECU
term	2 years
Exploration wells	
n° of wells	4
cost per well	1.1 MECU
success ratio	1:1 (or 50%)
% of unsuccessful wells good for reinjection	50%
average productivity of successful wells	6 MW
DEVELOPMENT [6]	
Wells	
cost per well	1.0 MECU
average productivity	6 MW
success ratio	4:1(or 80%)
ratio producing/reinjection wells	3:1
Piping and separation system	
cost per producing well	0.7 MECU
cost per reinjection well	0.5 MECU
PLANT CONSTRUCTION	
Specific cost	750 ECU /kW
Construction time[7]	3 years
Plant factor	85%
Internal consumptions	6%
OPERATION & MAINTENANCE[8]	
Field	
O&M (percentage of investment cost)	3.5% per year
production/injection decline	3% yearly
make-up wells (to keep the steam production and reinjection capacity constant for 25 years)	15
piping and separation to make up prod. wells	0.35 MECU
" " " " " reinj.wells	0.26 MECU
Plant (percentage of the investment cost)	3.5% yearly

[5] Including the time for contracting a drilling company
[6] The term for development is assumed to be the same as plant construction.
[7] Including 6 months for bidding and contracting
[8] Including Administration and Engineerig.

The following conditions were also assumed:

- The productive life of the plant is 25 years.
- An allowance for contingencies of 10% of investment cost has been applied to the whole project.
- The discount rate used in the basic calculations is 10%.
- The disbursements are evenly distributed for every year over the term of each phase.
- The delivery point is taken as at the high tension side of the plant substation. (Transmission line cost and its operation are not included).

The generation cost for a 55 MW plant results:

37 ECU /MWh[9]

of which 14.4 ECU is relevant to the field, 4.3 ECU is for the piping and separation system and 18 ECU is allowed for the plant.

Due to the variability of the input parameters attention must be paid to these figures. Their absolute value is certainly affected by errors in the order of 1÷3% but they can be treated with confidence for comparison purposes.

The discounted specific investment cost for all the project is around 1545 ECU /kW.

If same criteria area applied to a 30 MW plant the generation cost is:

47 ECU /MWh

that is 25% higher than the 55 MW plant.

This is a preliminary but meaningful indication of the variability of the generation cost as a function of the technical and economical characteristics of a project (Figure 4.1.7).

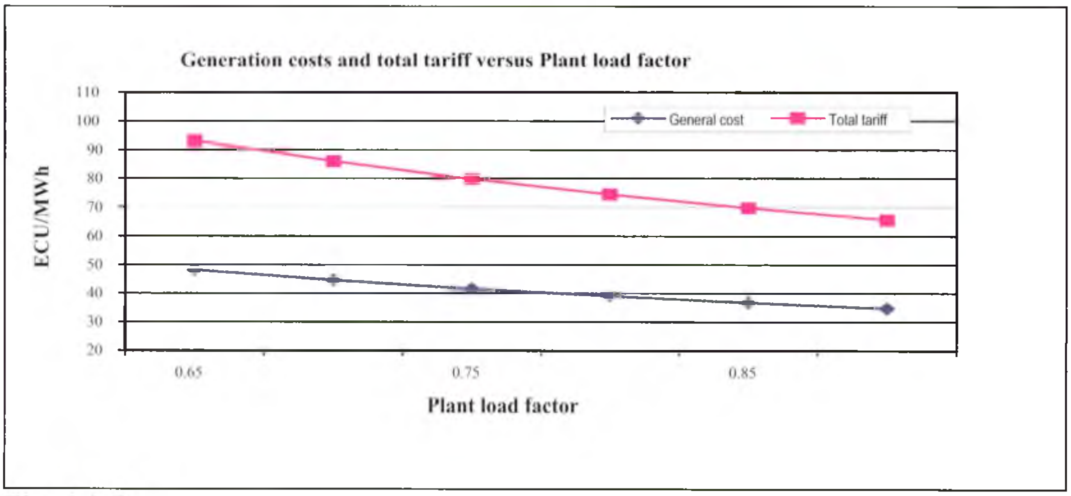

Fig. 4.1.7

[9] No taxes or royalties are included.

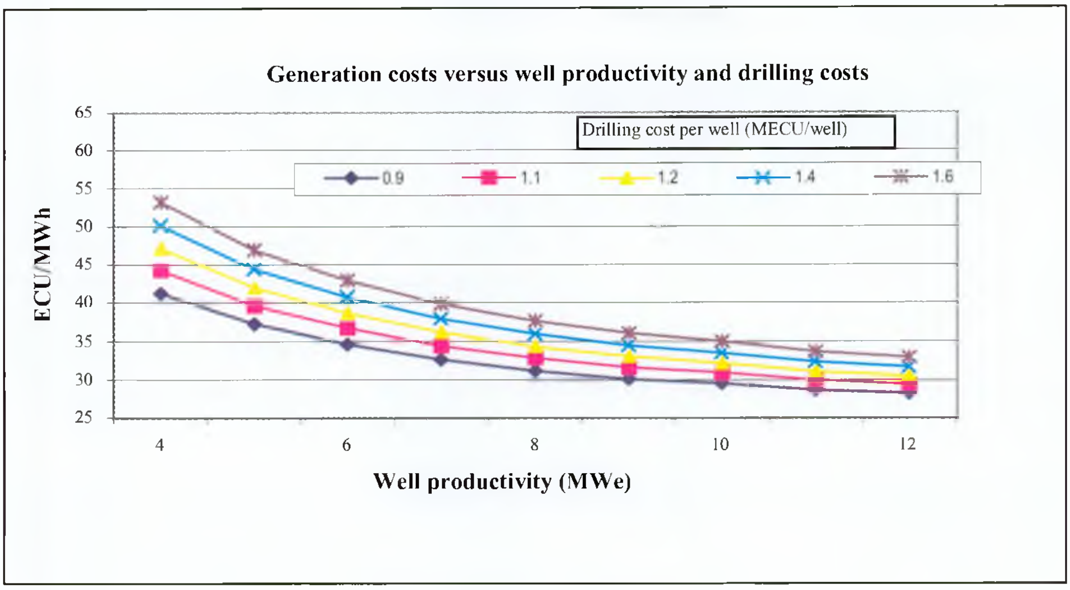

Fig. 4.1.8

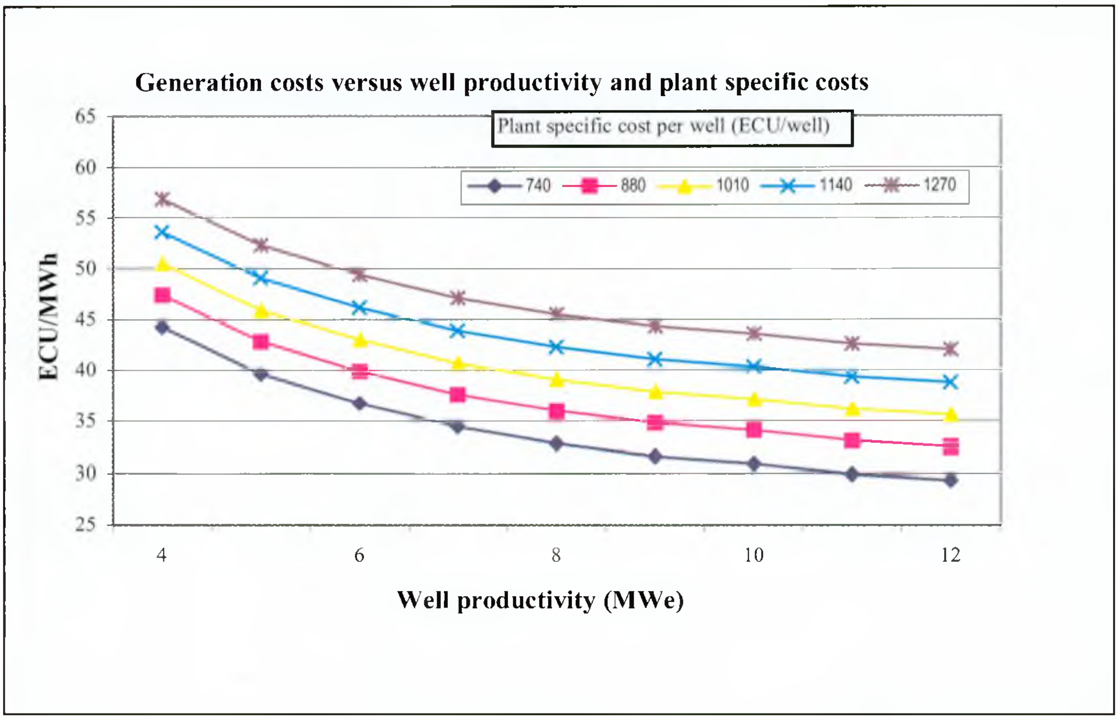

Fig. 4.1.9

8. SENSITIVITY ANALYSES

The effect of the variation of the main parameters on the generation cost are shown in Figures 4.1.8 and 4.1.9.

The first analysis was performed calculating the production cost assuming a variation of 4 to 12 MW in the potential productivity of each well and variation is the cost of each development well from 0.9 to 1.6 MECU (the cost of the exploration wells is assumed to be 25% higher).
It can be seen that the influence of a possible change of each well's productivity is much more effective on the final production cost than the probable drilling cost variation.

As stated in a previous paragraph, the specific cost of a power plant is a function of the size of the single units and of the plant as a whole. The lower cost analysed (740 ECU/kW) is that of a 1x55MW plant, the highest cost corresponds approximately to a 15 MW unit.

It appears that the influence of the cost related to the size of the plant strongly affects the production cost.

This is the reason why private investors do not normally accept development of fields with a proven or possible potential smaller than 100 MW.

The assessment of the Reference Project was performed with a discount rate of 10%. The choice of this parameter is highly subjective.

The State owned public utilities in developing countries generally adopt higher values, the international banking corporations a lower one in the order of 8%, in developed countries even as low as 6% depending upon the perception of risk.

Such a parameter strongly affects the results of the cost calculation as may be seen in Figure 4.1.10, where the energy cost, as well as the components related to the field and the plant, is calculated against a variation in the discount rate of between 6 and 12 %.

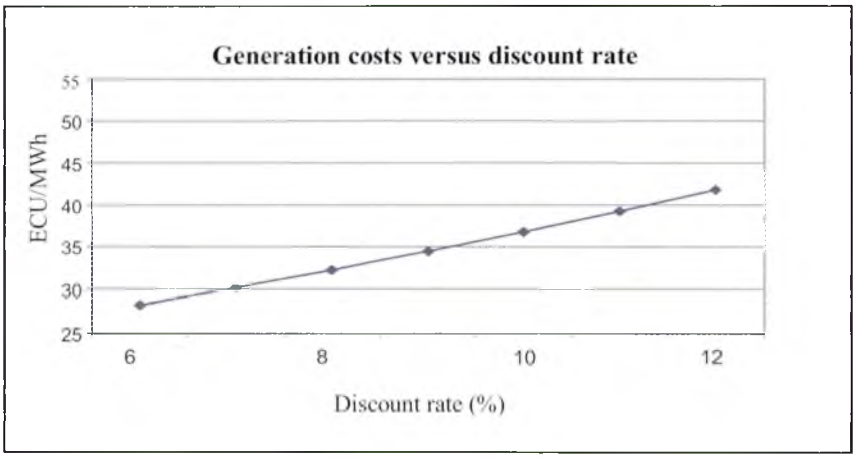

Fig. 4.1.10

9. FINANCIAL ANALYSIS AND PRICE EVALUATION

In the economic analysis the disbursements considered in the cash flow are values of the investments in the project implementation at the time they are bound. (For instance, the power plant cost are entered in the economic cash flow at the moment of the construction).

In the financial analysis the expenses are divided between equity and loan. The share related to the equity, as in the economic analysis, is charged to the cash flow at the time they are engaged. The disbursement related to the loan are distributed according to the conditions of the debt service, that is IDC (Interest During Construction), loan's interests, and capital recovery and they entered, in the cash flow at the time of the actual payment.

In the methodology used in this study the Financial Analysis is performed using a Discounted Cash Flow Method based on a cash flow of costs distributed according to the concepts explained above.

The analysis has been performed on the basis of the data shown in paragraph 7, which includes:

- Share between equity and loan
- Loan interest and term

On the basis of the same analysis the prices have been calculated taking into consideration:

- Opportunity rate of the investor
- Taxation
- Amortisation term and rules
- Shares and royalties, if any.

The opportunity rate, which measures the profit expected by the investor as a yearly interest rate on the total investment, may be expressed as the I.R.R. (Internal Rate of Return) of the Project.

In present market conditions, the expected I.R.R. of a private investor is 20% for the field and 15% for the plant and equipment calculated on the total investment regardless of the share between loan and equity.

The assumed term of the loan was 10 years. Due to the effect of actualization an extension of this term to 20 or 25 years has a negligible effect on the Net Present Value of the cash flow and therefore on the eventual calculated price, if taxation is not taken into consideration.

Assuming an interest rate over the loan of 8%, and disregarding the effect of a possible inflation, the price ***without taxes*** is:

57.2 ECU /MWh

and the average IRR 17.15%.

This figure is more than 50% higher than the cost, which clearly shows that the high opportunity rate for a private investor in comparison with the one for a state company (generally equal to the assumed discount rate) which inflates the energy price.

Nevertheless some qualification is necessary to place this analysis into perspective.

First of all, in the calculated cost, the mining risk and its relevant cost is not included. Even if it was assessed it would increase the IRR by 3% of the calculated cost for the reference project which results in a price around 41 ECU /MWh instead of 37 (figure 4.1.11).

Moreover, the cost has been calculated assuming a tight schedule of project implementation and a high efficiency for the investor.

Generally, the comparison between prices and cost is made when a private investor as opposed to a state company is involved. The controls applied to a state company, often make it necessarily less efficient and therefore the eventual cost of a project managed by a state utility, is higher than the example calculated here.

For instance if the terms generally necessary for a State owned company to get the authorisation to contract a loan from an International Banking Agency are considered, the loan negotiation and bidding time, the bidding for drilling and turn-key construction contacts, the terms of the project schedule must be extended by at least three years.

Under these conditions the reference cost grows by up to almost 39 ECU /MWh, just because of the delay in the implementation schedule.

Part of the difference between cost and price can be regarded therefore as a type of remuneration for the efficiency of the private investor.

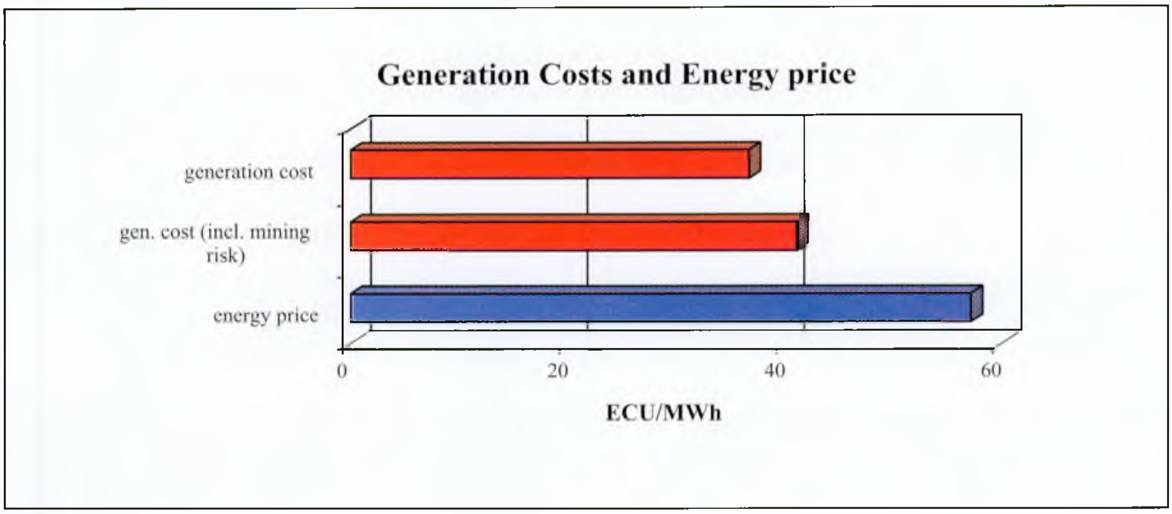

Fig. 4.1.11

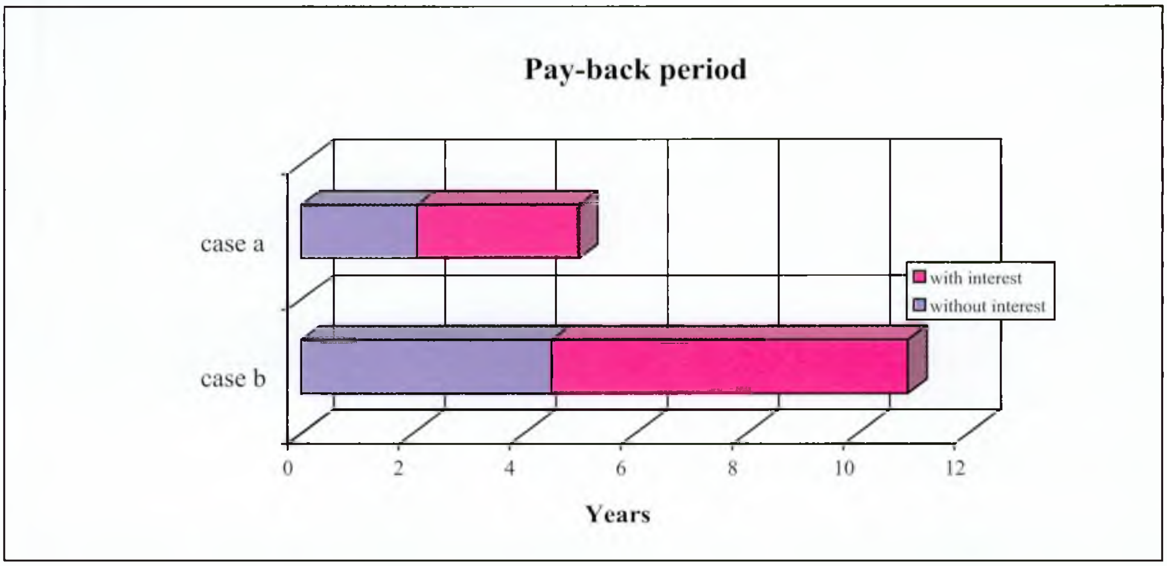

Fig. 4.1.12

10. PAY-BACK PERIOD

The pay-back period is defined as the time between the beginning of the production and the moment when the cumulated cash flow becomes positive. This condition obviously depends on the actual price paid for the energy produced and it therefore differs for equal projects in different market conditions.

For this reason the pay-back period is a useful means of describing a geothermal investments generally. To became meaningful it should be related to a specific project.

Nevertheless a review of some figures can be useful for comparison purposes.

It should be stressed that the pay-back period for investments in geothermoelectric generation is quite short if a project is correctly implemented and the mining results or quality of the resource are favourable.

According to the parameters and data of the Reference Project described in paragraph 7, the pay-back period has been calculated in different ways according to different cash flows (Figure 4.1.12).

a) the cash flow of a project implemented by a private investor whose equity is 20% of the investment, and the price of the energy is the one that allows an expected I.R.R. of 15% for the equipment and plant, and 20% for the investment in the field,
b) the cash flow of a project, whose price of energy is that one related to an expected IRR of 12% and the equity corresponds to the whole investment. Such an example could represent one implemented by a state owned public utility.

Both cases were analysed with and without the disbursements related to the payment of interests at a rate of 8% yearly over the negative values of the cumulated cash-flow. Taxes were excluded.

Case a) 25 months without interests and 35 with the interest.

Case b) 4 years and 6 months without interests, 6 years and 5 months with the interests

Such values must be regarded as an indication, not as exact figures, as they depend on many subjective parameters.

Such values are apparently very short in comparison with other projects in the field of alternative energy, fit with the values expected by private investors in any investment involving a certain degree of risk, as such as any mining project.

11. PRICING CRITERIA

The prices shown in the previous paragraph are basically related only to a financial analysis related to the expected IRR of the investor and the interest rate of the loan.

Some additional comments on factors influencing the eventual price of geothermoelectric energy are appropriate here.

11.1 Mining Risk evaluation

The higher expected IRR for the field (5% or more) is justified by the mining risk related to the investment in the field. The “cost” of the mining risk may be expressed by the amount of the investment in exploration divided by the percentage of the risk of failure. Statistically such a risk , from the phase of surface exploration to that of deep exploration drilling, may be around 50%.

A quantitative evaluation of the risk may therefore be calculated doubling the cost of the exploration phases. The higher cost calculated corresponds to an increase 3% of the opportunity rate related to the field. Therefore if the expected IRR of 15% for the investments in equipment, the expected IRR of 18% for the field is justified.

A success ratio of 50% is subjective even if based on past experience. A change in this parameter strongly affects the increase of IRR expected to compensate for the risk.

Moreover, the contingencies over the whole project have been assumed to be 10% of the investment cost. Such a value is considered fair for the equipment, plant and unit costs but may be regarded as low for drilling the well. Experience has shown that unforeseen and unexpected technical problems have resulted in drilling costs for some wells, more than two or even three times higher than the average cost assumed in these calculations.

This possibility can be included in the mining risk evaluation which causes a commensurate increase in the calculated value of 3% up to 5%.

11.2 Effect of tax system

Taxation can be applied as royalties on the mining resource, as share of the gross income, or tax on the net profit.

The tax system in each country is different and may be applied to one on more of the above factors. It is therefore impossible to assess the generic effect of the taxation system on the prices.

Nevertheless it is advisable to calculate the tax effect under some typical conditions, and analyse what effects a taxation system has on the final price of energy.

For sake of simplicity the effect of a complex taxation system can be summarised by means of only one of the factors listed above. For example as a tax expressed on a percentage of the net profit.

The net profit according to the laws of each country, may be calculated in different ways. For instance deducible amortisations may be limited in time or quantity. Interest on the equity may deduced from the income or included in the profit, as well as, in some countries, the interest on the loan.

If a taxation rate of 30% is applied on the net profit, the Reference Project, the price will increase to:

65 ECU /MWh

if the amortisation is deducible in equal rates in 10 years, as well as the interest on the loan. With this price the IRR on the equity (supposed 20% of the investment, being 80% borrowed) is 31%.

Figure 4.1.14 shows the effect of a different taxation rate on the price of electricity.

Usually the taxes are calculated on the yearly net revenue: an important factor affecting the evaluation of the net revenue, and therefore the requested price of energy, is the possibility of deducing the loan's interest rate. Generally such a deduction is allowed on the actual interest paid to the bank but not as interest over the equity.

In pratice the price usually requested by the investor treat the whole investment as equity. The difference to the resulting price is sensible, and produces a much more favourable IRR on equity.

The price without the deduction of the interest of the loan results

68.6 ECU /MWh

and the return on equity 33.5%.

Another factor that may affect the price of energy in many contracts is the inflation index. If inflation is enter into a pricing formula, it applies to the whole price (capacity and energy) and results in an unjustified price increase.
Usually operation costs are linked to inflation, whereas the investment costs are not, as the interest rate over the loans are generally not varied with inflation.

A solution to this problem is the partition of the price in a constant Capacity price related to the investment, and an Energy price which can be varied with the inflation rate.

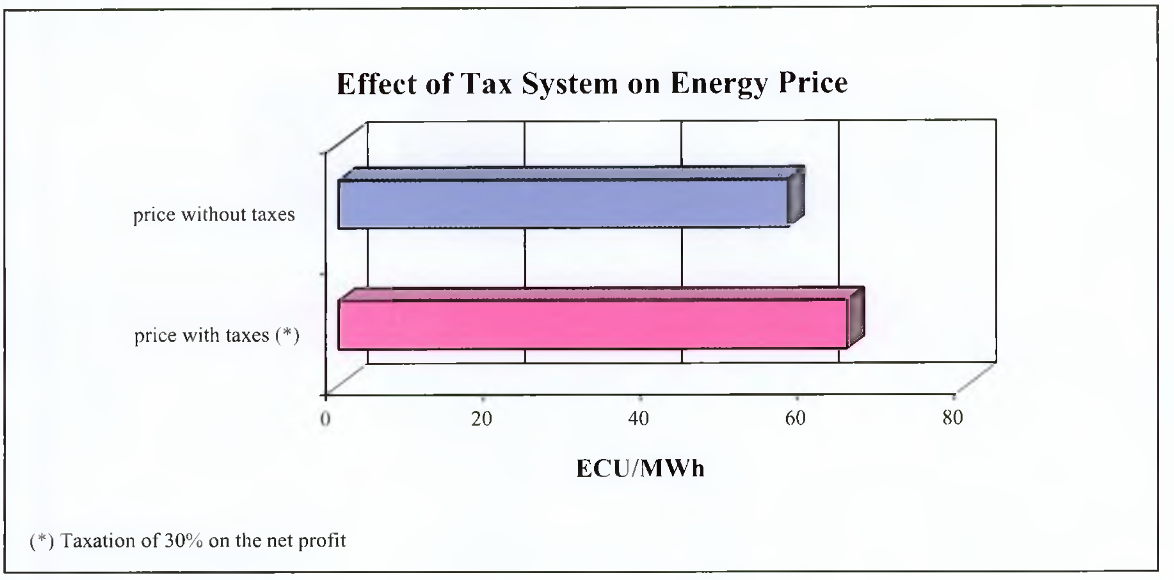

Fig. 4.1.13

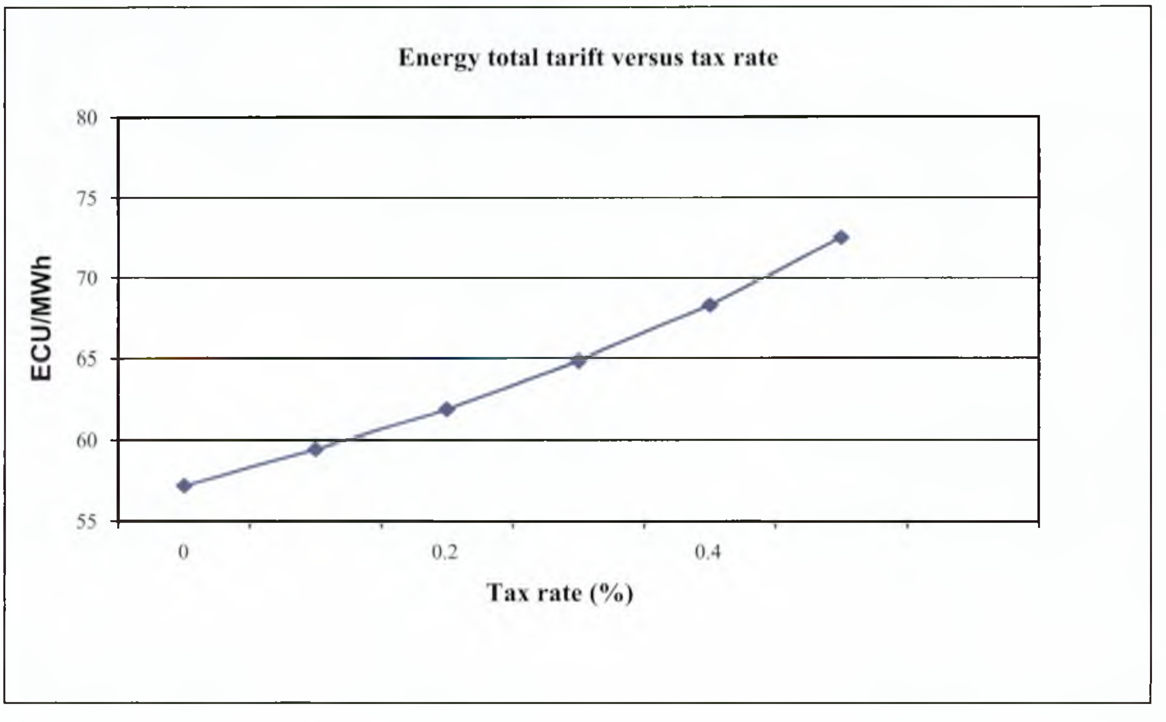

Fig. 4.1.14

Appendix to Annex 4.1

INPUT OF THE FINANCIAL MODEL

Table 1

Amortisation scheme/Investment incentives

	Investment Subdivision (*)
Field	100.0%
Gathering System	100.0%
Plant	100.0%
Transmission Line	100.0%

Year	Amortisation
1	10.0%
2	10.0%
3	10.0%
4	10.0%
5	10.0%
6	10.0%
7	10.0%
8	10.0%
9	10.0%
10	10.0%

Note: (*) contingencies included

Table 2

Field Characteristics

Exploration Wells

Total	4	wells			
Good for Production	2	"	Average Productivity	6	MW
Good for Reinjection	1	"	Average Absorption	100.0%	%
			(in % of general average)		
Sterile Exploration Wells	1	"			

Development and Make-up Wells

Production			**Reinjection**		
Average Initial Production	6	MW	Initial Ratio Prod./Reinjection	3:1	
Type:			Type:		
Average Production Decline	3.0%	wells	Average Absorption Decline	3.0%	%/year
Reserve Production Cap.	10.0%	%	Reserve Absorption Cap.	10.0%	%
Ratio Good/Sterile Wells	4:1		Ratio Good/Sterile Wells	4:1	

Table 3

Field: Drilling Mode

Drilling Performance

Max. Number Exploration Wells/year	4	wells/year
Max. Number Development Wells/year	8	wells/year

Wells Distribution in Time

Exploration:	Anticipated
Development:	Homogeneous Distr., rest anticipated
Partial Capacity:	Posticipated
Make-up:	Posticipated

Make-up Wells Grouping	2 wells

Capacity Advance

Year	Project Status	Capacity (MW)	Advance (%)
7	Tot. Cap.	55	

Year	Project Status	Deep Expl.	Development	Part. Cap.	
		4	12	0	**<-- Required Wells**
1					0
2	Deep Exploration				0
3	Deep Exploration				4
4	Development				0
5	Development				0
6	Development				12

Table 4

Economic and financial parameters

Public

Discount Rate	10.0%

Private

Opportunity Rates		**Financial Parameters**		
- Field	20.0%	Risk Capital	20.0%	% of total investment
- Gathering System	15.0%	Financed Capital	80.0%	% of total investment
- Power Plant	15.0%	Interest Rate	8.00%	%
- Transmission Line	15.0%	Amortisation	10	years
		Constant Payment		
		Risk Covering Fund	5.0%	% of income

Fiscal and "Sharing" Data

	Total
Tax Rate	30.0%
"Share" on Gross Income	0.0%
Tax-free Portion	0.0%
"Share" on Net Income	0.0%
Max. Deduction of Passive Interest	100.0%

Table 5

Geothermal plant

Technical Data

Plant Factor	85.0%	
Internal Consumption	6.0%	of gross capacity

Costs

Construction		
Global Definition		
Specific Cost	744	ECU/kW (-->Distr. %, 1)
Global Cost	41\	MECU
Specific Cost (calculated)	744	ECU/kW
Erection	0.0%	% of yearly investment
Adm. & Engineering	10.0%	% of yearly investment
Contingencies	0.0%	% of yearly investment
Operation		
O & M	2.5%	% of total investment
Adm. & Engineering	1.0%	% of total investment

Table 6

General

Project Identification

Field	Typical Project
Case	1 x 55

Project Characteristics

Costs Assignment and Contract Type

	Public	Private	Contract (BOO,BOT,BLT)	*Duration (year)*	*Residual Value (% of investment)*
Field			BOO		
-Surface Exploration		X			
-Deep Exploration		X			
-Development		X			
-Operation		X			
Gathering System		X	BOO		
Plant		X	BOO		
Transmission Line	X				

Energy Sale Point:	Plant

Table 7

Project Size and Chronogram

Exploration:	Duration		Year		
-Surface	1	years	1	1998	Start Year
-Deep	2	"	2	1999	"
Field Development	3	"	4	2001	"
Operation and Maintenance					
-Partial Capacity	0	"	7	2004	"
-Total Capacity	25	"	7	2004	"
-Declining Capacity	0	"	32	2029	"
Total	25	"			
Project Duration:	31	"	31	2028	End Year

Total Capacity	55	MW	Year:	7

Table 8

Field: Cost Data

Surface Exploration			
Investigation and Studies	0.4	MECU	(--> Distr.%, 1)
Adm. & Engineering	10.0%	% of yearly investment	
Deep Exploration			
Investigation and Studies	1.3	MECU	(--> Distr. %, 2)
Land and Access	0	MECU	(--> Distr. %, 3)
Drilling Costs	1.3	MECU	* 4 wells
Adm. & Engineering	10.0%	% of yearly investment	
Contingencies	10.0%	% of yearly investment	
Field Development			
Investigation and Studies	1.7	MECU	(--> Distr. %, 4)
Land and Access	0.9	MECU	(--> Distr. %, 5)
Drilling Costs			
-production	1.05	MECU	* 9 wells
-reinjection	1.05	MECU	* 3 wells
Average Well Cost	1.05	MECU	
Adm. & Engineering	10.0%	% of yearly investment	
Contingencies	10.0%	% of yearly investment	

Operation and Maintenance			
Make-up Drilling Costs			
-production	1.05	MECU	* 10 wells
-reinjection	1.05	MECU	* 4 wells
Average Well Cost	1.05	MECU	
O&M	2.0%	% of total investment	
Adm. & Engineering			
	1.5%	% of total investment	
+	10.0%	% of yearly investment	

		1	2	3	4	5	
1	Surface Exploration	100.0%					%
2	Deep Exploration		50.0%	50.0%			
3	Deep Exploration		50.0%	50.0%			
4	Development				33.3%	33.3%	
5	Development				33.3%	33.3%	
6	Development				33.3%	33.3%	

Table 9

Gathering System

Field Development

Materials			
Fixed Cost	0	MECU	
Variable Cost:			
-per Production Well	0.7	MECU	* 11 wells
-per Reinjection Well	0.35	MECU	* 4 wells
Total Investment	9.1	MECU	(--> Distr.%, 1)
Erection	0.0%	% of yearly investment	
Adm. & Engineering	10.0%	% of yearly investment	
Contingencies	10.0%	% of yearly investment	

Operation

Materials for Make-up Wells			
Variable Cost:			
-per Production Well	0,3	MECU	* 10 wells
-per Reinjection Well	0.26	MECU	* 4 wells
Average	0.32	MECU	
O&M	2.0%	% of total investment	
Adm. and Engineering	1.5%	% of total investment	

		MW	Wells	%
1	Total Capacity		0	
2			0	
3			0	
4	Development		0	33.3%
5	Development		0	33.3%
6	Development		0	33.3%
7	Total Capacity	55	0	

Annex 4.2

COMPARISON WITH OTHER ENERGY SOURCES

INDEX

1. ASSUMPTIONS AND APPROACH USED FOR COMPARISON OF GEOTHERMAL ENERGY WITH OTHER ENERGY RESOURCES.

1.1 Geothermal versus other RE

A general comparison of geothermal versus other RE for electricity generation in EU and in the world is given in attached Table 4.2.1. The purpose of providing a range for each technology is to demonstrate that a number of variables determine the unit cost of generation. Capital cost estimates have been taken from in-house knowledge of these technologies. Costs presented are largely based on UK or western European data.

The unit cost of generation has been calculated using a conventional economic analysis, which discounts the cash flow over the technical life of the project. No allowance is made for inflation. A profile of capital costs and operational and maintenance costs for each year of the project's anticipated life are discounted to the first year of the project.

The income stream assumes that the unit cost of generation will remain constant over the technical life of the project. Income for most technologies is entirely derived from the amount of electricity generated per year. For waste incineration some additional income is derived from a disposal tariff. The income for each year of operation is also discounted to the year the project was initiated.

The unit cost of generation for each technology has been calculated an at arbitrary 8% discount rate, which was the standard public sector discount rate in the UK prior to privatisation of the country's utility companies. The unit cost of generation represents the value of each unit generated which would be necessary for the project to break even.

Listed below are some qualifying remarks for each technology which explain the range in values.

1.1.1. Small hydro

The wide range of capital costs shown demonstrates that costs are highly site-specific. One noticeable factor is that capital cost/kW installed capacity tend to decrease with increasing capacity (because manufacturing overheads are less significant for larger turbines) and with increasing head (because cheaper, less complex turbines can be used at higher heads, and speed increasers are not needed).
Hence the worst case above - capital cost 3000ECU/kW, operating cost 25ECU/kW and load factor 15%, would represent a very small turbine (say 50kW) on a small stream with long low flow periods.

Whereas the best case - capital cost 800ECU/kW, operating cost 15ECU/kW, load factor 95% would represent a large machine (say 5MW) operating with a large, constant flow and head (allowing a simple turbine and automatic controls) with minimal civil works required (e.g. installed on the compensation flow outlet of a water supply reservoir).
Operating and maintenance costs are low, and likely to remain so with increasing plant automation and remote control (even of multiple sites).

1.1.2. Onshore wind

The load factor range presented reflects the variation in different wind regimes across Western Europe. Development costs vary according to proximity to the electricity distribution network and the necessity for new access roads, particularly in remote locations.

1.1.3. Wave

Cost information for the prototype OSPREY II is commercially confidential and is not available to this study. The predicted costs for 2010 are based on successful development of the technology. These costs include the device and its associated transmission system.

1.1.4. Tidal barrage

The size of 240 MW is based on the only tidal barrage project which was built for commercial demonstration at La Rance in Brittany, northern France. The construction time refers to La Rance project. Cost estimates presented here are from more recent work on site-specific feasibility studies in the UK in the absence of data on the Rance barrage. The UK programme on tidal energy revealed that there are no significant economies of scale despite differences in scale of potential barrages of over two orders of magnitude.

1.1.5. Municipal Solid Waste

Costs are based on the newer municipal solid waste incineration plant which now requires flue gas scrubbing equipment. The fuel cost is negative as this is effectively the waste disposal fee. The waste disposal fee in the early years was relatively low, about 5 - 20 ECU(1990)/t, but is now in the range 10 - 90 ECU(1990)/t.
In future waste disposal fees could rise further as land fill options become more

restricted. Since the unit cost of generation is highly dependent on disposal fees, local or national policies on waste disposal options are of critical importance to the competitiveness of the technology and its likely location.

1.1.6. Photovoltaic

1 - 100 kWp is regarded as a typical unit size for individual system sizes in Europe. In the developing world typical solar home systems are often only 40 - 100 Wp.

Load Factor: This is the equivalent time which a system would have to produce power at the nominal level to provide the same total energy in a year. i.e. load factor = annual energy production (kWh/kWp) / number of hours in a year. The lower values are for remote professional systems where reliability is paramount. Consequently the systems are typically oversized and may only be used for part of the year. When the batteries are full any remaining energy produced is lost - usually as heat in the modules. Such systems therefore have a very low load factor although they usually meet the energy demand in a cost effective fashion.

The costs of energy quoted are the minimum costs achievable. For current and future figures these will apply to grid connected systems in southern Europe. In northern Europe it will be important to use PV modules to displace conventional cladding materials in building facades in order to save on other building costs and effectively reduce the costs allocated to the PV generation system.

1.1.7. Anaerobic Digestion (agricultural waste)

The 1995 data is based on Danish information as Denmark was the main country developing centralised AD. This is an emerging technology which is likely to be affected by different policies to agricultural waste in different countries. Overall there likely to be a reduction in electricity costs as capital costs are reduced and markets are developed for digestate.

	Geothermal	Small Hydro	Wind (onshore)	Urban Solid Waste Combustion	Land Fill Gas	Anaerobic Digestion (agricultural waste)	Photo Voltaics	Tidal Barrage	Wave (near-shore)
Typical unit size (MWe)	10-55	0.001-10	0.41	10-27	1	1	1-100 kW	240	2
Availability factor %	95	>95	98	90	90	90	70-99	90	94
Load Factor (%) (Time plant generates at rated power)	65-85	15-95	18%-35% (24%)	90	80	27	3-15	26	25
Construction time (years)	1-3	1-2	0.25	2-3	1	1	10-180 days	7	< 1
Economic lifetime (years)	25	40	15	20	15	20	15-25	>40	30
Investment cost (ECU/kW)	2,300-1,400	970-3,600	850-1,100	5,000-6,400	1,200	7,260-8,470	24,200-5,500	2,100-2,800	
Fixed operating and maintenance cost (ECU/kW)	49-46	18-30	24-36	379-429	67-202	600-726	Negligible	109-145	
Generation cost for energy (ECU/MWh)	55 – 30	22 - 140	36 - 84	24 – 160	42	120 – 160	1,250-620	120 – 160	110
EU installed capacity (MWe)	834*	9,000	3,500	1,437	298	150	60	240	0
World installed capacity (MWe)	7,679	27,900	4,821	3,069	1,385	5,300-6,300	376	261	0

Table 4.2.1 Electricity generation: comparison between geothermal and other RE resources.
For geothermal data:* include Iceland, generation cost derived using 10% discount rate
For other RE resources data: published information; EU figures exclude Iceland; generation cost derived using 8% discount rate
Cost values at 1995.

	Chevilly la Rue/l'Hay les Roses		Meaux-Beauval		Alfortville		Fresnes		Villeneuve-St. George	
	M.FF	Million. ECU	FF	Million.ECU	FF	Million.ECU	FF	Million.ECU	Milion.ECU	FF
Wells	67,00	10,31			18,00	2,77	17,00	2,62	19,80	3,05
Geothermal plant					21,00	3,23	37,50	5,77	60,70	9,34
Heating network	148,00	22,77			3,80	0,58				
Total	215,00	33,08	124,00	19,08	42,8	6,58	54,5	8,38	80,50	12,38

	Chevilly la Rue/l'Hay les Roses		Meaux-Beauval		Alfortville		Fresnes		Villeneuve-St. George	
Dwellings connected	12 800		8500		4750		3900		3940	
N° of production wells	2		2		1		1		1	
Geothermal Heat distributed (MWh/y)	112000		103000		490000		400000		55000	
Ratio Geothermal Heat/Total Heat	84%		66%		85%		80%		80%	
Total capacity, heat network (MW)		75		96						
Geothermal capacity (MW)	34%	26	28%	27		9		8,7		12
Ratio Total invest/N° of dwelling	2.641		2.245		1.385		2.149		3.142	

Notes:
The five cases presented are in the Paris Basin
Doublet scheme operation = always 1 injection well associated with 1 production well
The well are between 1800 to 2000 m depth (Price for one doublet from 2,6 to 3 Million ECU)
Geothermal capacity is calculated with the exploited flow rate and the actual inlet and outlet temperature
The final cost of each operation depend on whether a former network exist or not.
The % of Geothermal heat distributed is higher than the % of geothermal capacity installed (due to the type of installation chosen for economical reasons in France)

Table 4.2.2. Investments costs for main geothermal district heating systems in France

1.2 Geothermal versus other conventional energy sources

Comparison of geothermal versus other conventional energy sources for electricity generation in EU and in the world is given in the Table 4.2.3. This type of analysis is purely for economic comparison to provide a broad comparison between geothermal energy and a range of different technologies or different schemes.

	Geothermal	Coal	Natural gas	Fuel oil	Nuclear
Average unit size (MWe)	10-55	600	225	600	2,000
Availability factor (%)	95	90	80	95	95
Load Factor (%) (Time plant generates at rated power)	65-85	85	80	85	75
Construction time (years)	1 - 3	4	2.5	3	3
Economic lifetime (years)	25	35	30	40	30
Investment cost average (ECU / kW)	2,300 – 1,400	950	550	900	3,080
Fixed operating and maintenance cost (ECU / KW / yr))	46 - 49	48	33	27	92
Fuel cost (ECU cents / kWh)	0	1.53	1.65	2.02	0.05
Unit generation cost (ECU/MWh)	55 – 30	37	30	39	74
EU installed capacity (MWe)	834*		315,000		120,000

Table 4.2.3: Electricity generation: comparison between geothermal and conventional energy sources *(1997 including Iceland)

All costs above are updated up to 1997-1998 and they have been assumed as constant for all the period of analysis. In particular:

Coal and fuel-oil: medium-large new conventional power plants have been performed for the costing.
Installed capacity: 600 Mwe. They have an standard profile without relevant expenses to reduce the environmental impacts. Large-Coal plant does not include flue gas scrubbing to remove SO_2 or No_x. Average efficiency : 43-40 % respectively.
Operating and maintenance costs: 5 - 3%/yr of the investment cost, respectively.
Coal cost[1]: $45 /ton (5,700 kcal/kg) – Average Unit Value CIF.
Oil cost: $13/bbll – Average Unit Value CIF

Natural gas plants: a 225 MWe CHP plant has been selected to be used in the above comparison. Operating and maintenance costs: 6% of the investment costs.
Average efficiency: 48%. Gas cost: $ 80 /th m^3.

Nuclear power plant: PWR type.
Operating and maintenance costs: 3%/yr of the investment cost.

The method for the estimates of the unit generation cost is the annuity approach . For such approach a discount rate of 10% has been applied .Note that the fuel cost has been undertaken in constant terms over all the economic life time of the plant. Thus, no growth rate in real terms is foreseen in the analysis.

[1] Source: CESEN study based on Energy Prices & Taxes (IEA-1998).

Annex 5.1

THE SHARE OF GEOTHERMAL ENERGY: AN ANALYSIS OF THE PRESENT SITUATION AND EXPECTED FUTURE DEVELOPMENT FOR THE ELECTRICITY GENERATION

INDEX

1. INTRODUCTION

In this annex only the present situation of geothermal supply dedicated to the electricity generation is considered in order to estimate a realistic size of this market and to foresee the potentialities together with the future developments.

Considering that a geothermal market can exist only if there is the availability of the natural resource the market analysis covers the countries where exploitable resources exist.

The analysis focused attention on 30 countries (see Figure 5.1.1) selected as "interesting" because of their endowment of high enthalpy geothermal resources for electricity generation and grouped according the areas considered by this study:

1. EUROPEAN UNION
2. E.E.A. AND OTHER EUROPEAN COUNTRIES
3. NORTH AMERICA
4. CENTRAL AMERICA
5. SOUTH AMERICA
6. ASIA
7. OCEANIA
8. AFRICA

2. METHODOLOGY

The statistical and economical analysis has required the organisation of a reliable database. Since every Organisation has its own way to collect and select data, inconsistencies in output data could occur.

Therefore only reference data coming from direct investigation (questionnaires sent to national institutions energy agencies), energy balance sheets, national planning documents (especially for geothermal energy data), and, in addition, official publications, coming from ONU, OECD and Economist Intelligence Unit) were used [1].

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[1] The reference data for the analysis of energy and electricity supply come mainly from:

- *"Energy balances an statistics of NON- OECD countries" (IEA)*
- *"Energy balances and statistics of OECD countries" (IEA)*
- *"Statistic Yearbook 1995" (ONU)*

When possible, the time series considered 1995 but sometimes the most recent data are 1994 or even 1993. It is possible to have data for the year 1996 only very rarely. Starting from all these available data, the study presents the projections of geothermal installed capacity for electric energy generation for the following periods:

1995/2000; 2000/2005; 2005/2010

In addition, the installed capacity (expressed in MWe) is translated, through the national average load factor, into the “annual electricity output” which is expressed in GWh.

The analysis of the geothermal market takes account of the present and the past situation, from a general background of the average tendency of energy and electricity production (1990-1994), and then considers the tendency for “geothermal energy supply” both from the point of view of *installed capacity* (MWe) and *annual energy production* (GWh). The distinction between installed capacity and annual production is important because it allows the relative importance of geothermal energy for the production of electricity as a function of the total supply to be recognised (Table 5.1.1).

Considering the present availability of all types of geothermal resources in terms of installed capacity, it is also possible to make hypotheses about future developments both for the installed capacity and for the effective geothermal energy production for each country.

The report is organised by summarising each nation in the form of “country sheet”, which includes the last available energy balance (generally 1995), taking account, where possible, of the time series (see “energy statistics”) for the last 4/5 years, in order to consider the energy supply situation of that nation as accurately as possible and to appreciate the effective role played by geothermal energy. In this case the main reference data come also from direct investigation forms (institutional questionnaires) especially for the data about geothermal sector.

3. FORECAST AND SCENARIOS

The present availability of geothermal resources has been distinguished as a function of their situation with regard to exploitation (see Table 5.1.2 and note 1).

Figures on “Plants in operation”, “Plant planned or under construction”, and “Proven resources and Probable/Possible resources” are derived mainly from data directly achieved by means of questionnaires compiled by official national institutions and other official publications such as the Proceedings of WGC and generally refer to 1995.

Progress of exploitation		code
Exploited	Plant in operation	A
Unexploited	Plant planned or under construction	B
Unexploited	Proven resources	C
Unexploited	Probable and possible resources	D

Table 5.1.1 Classification of geothermal sources[(1)]

This analysis has been extended to look at the possibilities and forecasts for increasing the present geothermal supply. Some reference scenarios have been constructed, each of them based a specific starting hypotheses.
The scenarios considered for the three periods, 1995-2000, 2000-2005 and 2005-2010 as follows:

a) "REFERENCE" SCENARIO
b) "TENDENCY" SCENARIO
c) "MEDIUM PROFILE" SCENARIO
d) "LOW PROFILE" SCENARIO
e) "HIGH PROFILE" SCENARIO

The first and second scenarios can be considered as "base case scenarios" developed without any specific simulations.

In the third, fourth and fifth cases, the possibilities are analysed which could exploit the available reserves through a dedicated action plan.

The inclusion of the data for annual electricity production (GWh/y), calculated through the load factor in 1994/1995, is for easier comparison of the geothermal sector with total electricity supply, in order to check the potential supply from geothermal cources indicated by the different scenarios.
The criteria and parameters assumed by each scenario are summarized in table 5.1.3; the level of exploitation and reference code refer to those of Table 5.1.2.

In Figures from 5.1.1. to 5.1.8 are summarized and shown the geothermal energy scenarios for each area considered by this study.

[(1)] The market analysis has required a simplification of the traditional definitions of resources and reserves (White and Williams 1975; Muffler and Cataldi 1978; Haelel 1983) which have been synthesised in 4 categories:

- Exploited resources: plant in operation
- Unexploited resources: plant under construction or planned
- Unexploited resources proven resources
- Unexploited probable and possible resources

Proven resources have been considered those evaluated through wells, even exploratory, while probable and possible resources have been considered those evaluated through surface surveys (geochemistry, geophysics etc. ...) or through simple recoinnassance studies such as geological evidences.

SCENARIO	1995	1995/2000	2000/2005	2005/2010
REFERENCE	A	A+0,35 B	A+0,70 B	A+B
TENDENCY	A	$A(1+\% \text{ var.}A)^{5}$	$A(1+\% \text{ var.}A)^{10}$	$A(1+\% \text{ var.}A)^{15}$
MEDIUM PROFILE	A	A+0,90B	A+B+0,35 C A+B+0,65 C	A+B+C
LOW PROFILE	A	A+0,70 B	A+B	A+B+0,40C
HIGH PROFILE	A	A+B	A+B+0,50 C	A+B+C+0,20D

Table 5.1.2 Synthesis of the criteria and parameters assumed by each scenario

3.1 "Reference" Scenario – (Table 5.1.4)

In this first scenario, the future size of the market is showed, as communicated by the national institutional organisations, adding the MWe already installed (group A) with the MWe which will come from the plants under construction or planned (group B).

For group B the progress of the "under construction and planned plants" is not exactly known and considering that 3-4 years are sufficient to have a plant in operation, the hypothesis is of a linear growth. In other words it is assumed that the planned capacity will increase by 35% of the resource planned by the year 2000, by another 35% by the year 2005 and will complete by the year 2010.

3.2 "Tendency" Scenario - (Table 5.1.5)

This second scenario is based on a past tendency assuming a linear projection of the past trend of the geothermal supply development to the future. This kind of analysis is possible only for those countries which have already resources under exploitation. Therefore the limit of this scenario is the underestimate from new countries which could start geothermal exploitation.

The application of the past production trend to the future increase of geothermal installed capacity could appear "forced" but the aim of this scenario is just to "make valid" the official forecast presented by the national (Reference scenario). These official forecasts have been checked by a comparison between what has already done in the past, and the potential level simply calculated as the projection of annual average variation.

The final result is a distinction between the selected countries, into three groups:

- "= A+B" – Countries where the final result is equal to the sum of MW installed (A) and under construction or planned (B);
- "< A+B" – Countries where the final result is lower;
- "> A+B" – Countries where the final result is higher;

In the first group (=A+B) it should appear as a validation of the official forecast (reference scenario).

In the second group (<A+B) this scenario seems to reveal a potential optimistic official plan (since the linear projection has given a lower result).

In the third group (>A+B) the official plans appear be to prudential, compared to the previous tendency.

3.3 "Medium profile" Scenario - (Table 5.1.6)

Considering the possibility of an action plan, the hypotheses are:

-) for the year 2000 nearly all of what was planned should be realised;
-) for the year 2010 also the amount of proven resources could be even exploited (that generally required 4-6 years of work), (i.e. A+B+C).
-) for the intermediate year of 2005 two possible scenarios have been considered for the exploitation of proven resources (35%) and (70%). This depends on many factors that will change between countries.

3.4 "Low profile" Scenario - (Table 5.1.7)

The base hypothesis has the objective to further develop plants planned or already constructed, but with the presence of some obstacles. First of all technical lags, organisation deficiencies, a low interest by the institutional organisations, lack of money, etc.). The final result is generally a little worse than the medium profile scenario (input only by the year 2005 all the plants planned should be constructed), and by the year 2010 only a little part of the proven resources (group C) could be exploited.

3.5 "High profile" Scenario - (Table 5.1.8)

This last scenario should show a theoretical possible maximum if the action plans to improve geothermal energy supply are good. That is it nothing goes wrong, and if the country has a favourable context to develop and exploit this kind of energy.

In this scenario, a "strong" action plan could lead to the complete use of geothermal proven resources, and further it should be even possible to exploit some (about 20%) of the probable and possible resources (group D). Only in this case, it would be possible to exploit these last resources, because the time required extends beyond the period considered in this analysis.

		(1-2)	(3) GEOTHERMAL ELECTRICITY GENERATION DATA (1995)					
			PLANT IN OPERATION					
AREA	COUNTRY	ELECTRICITY PRODUCTION 1994	ENERGY PRODUCTION	INSTALLED CAPACITY		Unexploited Plant planned or under construction	Unexploited Proven resources	Unexploited Probale and Possible resources
				A	Load factor	B	C	D
		GWh	GWh/yr	MWe	%	MWe	MWe	MWe
EU	France*	n.a.	24	4.2	65.2	n.a.	n.a.	n.a.
	Greece	40,623	-	-	-	10	200	n.a.
	Italy	231,804	3,762	742.2	57.9	227.5	n.a.	n.a.
	Portugal	31,380	52	9	66	n.a.	n.a.	n.a.
EEA & Other European Countries	Iceland	4,780	284	49.9	65	120.0	n.a.	4,000
	Russia**	875,910	25	11	25.9	130	80	380-550
	Turkey	78,322	71.1	20.9	38.8	258.0	100	200-300
NORTH AMERICA	Canada	554,227	-	-	-	70	n.a.	2,500
	Usa	3,473,616	17,386.8	2.970.0	66.8	130	n.a.	30,000
	Mexico	147,926	5,682.0	753.0	86.1	435	n.a.	6,000
CENTRAL AMERICA	Costa Rica	4,770	447	60	85	137.5	780-950	1,700-1,800
	El Salvador	3,170	908.6	118	87.9	28	150	200
	Guatemala	3,160	-	-	-	94	70	n.a.
	Nicaragua	1,690	310	40	88.5	465	n.a.	2,500
SOUTH AMERICA	Argentina	61,590	3.4	0.7	57.1	n.a.	30	n.a.
	Bolivia	2,820	-	-	-	n.a.	36-40	350
	Chile	25,280	-	-	-	28	72	n.a.
	Ecuador	8,260	-	-	-	n.a.	534	768
ASIA	China	928,080	109.6	32.2	38.9	n.a.	n.a.	1,840
	India	385,560	-	-	-	21	n.a.	2,000-10,000
	Indonesia	53,410	1,051.4	309	38.8	992	1,057	8,000
	Japan	964,328	1,738.4	300	66.1	230	2,800	n.a.
	Philippines	27,060	7,520	1,445	59.4	455.0	1,000	2,000
	Thailand	71,180	2.3	0.3	87.9	n.a.	5	n.a.
OCEANIA	Australia	167,155	1.2	1	14.1	-	50	1,200
	New Zeland	35,135	2,193	286	87.5	157	n.a.	n.a.
	Papua-New Gui.	1,392	-	-	-	n.a.	300	300
AFRICA	Ethiopia	1,290	53.9	7	87.9	n.a.	15	20
	Kenia	3,540	348.0	45	88.3	64	450	600
	Mozambique	490	-.	-	-	n.a.	25	50

(*) Guadelupe
(**) Kamchatka

Table 5.1.3 Energy Present Situation

1 "1993-94-Energy Balances of NON OECD countries" IEA/Paris 1996
2 "1993-94-Energy Balances of OECD countries" IEA/Paris 1996
3 Data given by COUNTRY QUESTIONNAIRES and WGC 1995 (modified); refers mainly to 1995 situation updated to 1997 for some countries
n.a. Data not available

	2000 MWe	2005 MWe	2010 MWe
France	4	4	4
Greece	4	7	10
Italy	822	901	970
Portugal	9	9	9
Total EU	839	922	993
Iceland	92	134	170
Russia	57	102	141
Turkey	111	202	279
Total EUROPE	1,099	1,359	1,583
Canada	25	49	70
Usa	3,016	3,061	3,100
Mexico	905	1,058	1,188
North America	3,945	4,168	4,358
Costa Rica	108	156	198
El Salvador	128	138	146
Guatemala	33	66	94
Nicaragua	203	366	505
Central America	472	725	943
Argentina	1	1	1
Bolivia	-	-	-
Chile	10	20	28
Ecuador	-	-	-
South America	10	20	29
China	32	32	32
India	7	15	21
Indonesia	656	1,003	1,301
Japan	381	461	530
Philippines	1,604	1,764	1,900
Thailand	-	-	-
Asia	2,681	3,275	3,785
Australia	1	1	1
New Zeland	341	396	443
Papua-New Gui.	-	-	-
Oceania	342	397	444
Ethiopia	7	7	7
Kenia	67	90	109
Mozambique	0	0	0
Africa	74	97	116

Table 5.1.4 "Reference" Scenario (MWe)
(Official forecast from national institutions)

	2000 MWe	2005 MWe	2010 MWe
France	6	9	13
Greece	-	-	-
Italy	881	1,046	1,241
Portugal	48	259	1,390
Total EU	935	1,314	2,644
Iceland	36	26	19
Russia	15	21	29
Turkey	13	8	5
Total EUROPE	1,000	1,369	2,697
Canada	-	-	-
Usa	3,829	4,937	6,365
Mexico	1,034	1,419	1,947
North America	4,863	6,356	8,313
Costa Rica	86	123	175
El Salvador	76	49	31
Guatemala	-	-	-
Nicaragua	47	56	67
Central America	209	228	273
Argentina	1	1	2
Bolivia	-	-	-
Chile	-	-	-
Ecuador	-	-	-
South America	1	1	2
China	47	69	102
India	-	-	-
Indonesia	214	148	103
Japan	363	440	533
Philippines	2,133	3,149	4,649
Thailand	-	1	1
Asia	2,758	3,807	5,387
Australia	1	1	2
New Zeland	210	154	113
Papua-New Gui.	-	-	-
Oceania	211	155	115
Ethiopia	7	7	7
Kenia	39	33	29
Mozambique	-	-	-
Africa	46	40	36

Table 5.1.5 "Tendency" Scenario (MWe)
(Linear projection of the past trend)

	2000 MWe	2005 MWe		2010 MWe	
France	4	4	4	4	4
Greece	9	80	140	210	210
Italy	947	970	970	970	970
Portugal	9	9	9	9	9
Total EU	969	1,063	1,123	1,193	1,193
Iceland	158	170	170	170	170
Russia	128	169	193	221	221
Turkey	253	314	344	379	379
Total EUROPE	1,508	1,716	1,830	1,963	1,963
Canada	63	70	70	70	70
Usa	3,087	3,100	3,100	3,100	3,100
Mexico	1,145	1,188	1,188	1,188	1,188
North America	4,295	4,358	4,358	4,358	4,358
Costa Rica	184	471	705	978	1,148
El Salvador	143	199	244	296	296
Guatemala	85	119	140	164	164
Nicaragua	459	505	505	505	505
Central America	870	1,293	1,593	1,943	2,113
Argentina	1	11	20	31	31
Bolivia	-	13	23	36	40
Chile	25	53	75	100	100
Ecuador	-	187	347	534	534
South America	26	264	466	701	705
China	32	32	32	32	32
India	19	21	21	21	21
Indonesia	1,202	1,671	1,988	2,358	2,358
Japan	507	1,510	2,350	3,330	3,330
Philippines	1,855	2,250	2,550	2,900	2,900
Thailand	-	2	4	5	5
Asia	3,615	5,486	6,892	8,593	8,647
Australia	1	18	33	51	51
New Zeland	427	443	443	443	443
Papua-New Gui.	-	105	195	300	300
Oceania	428	566	671	794	794
Ethiopia	7	12	17	22	22
Kenia	103	267	402	559	559
Mozambique	0	9	16	25	25
Africa	110	288	435	606	606

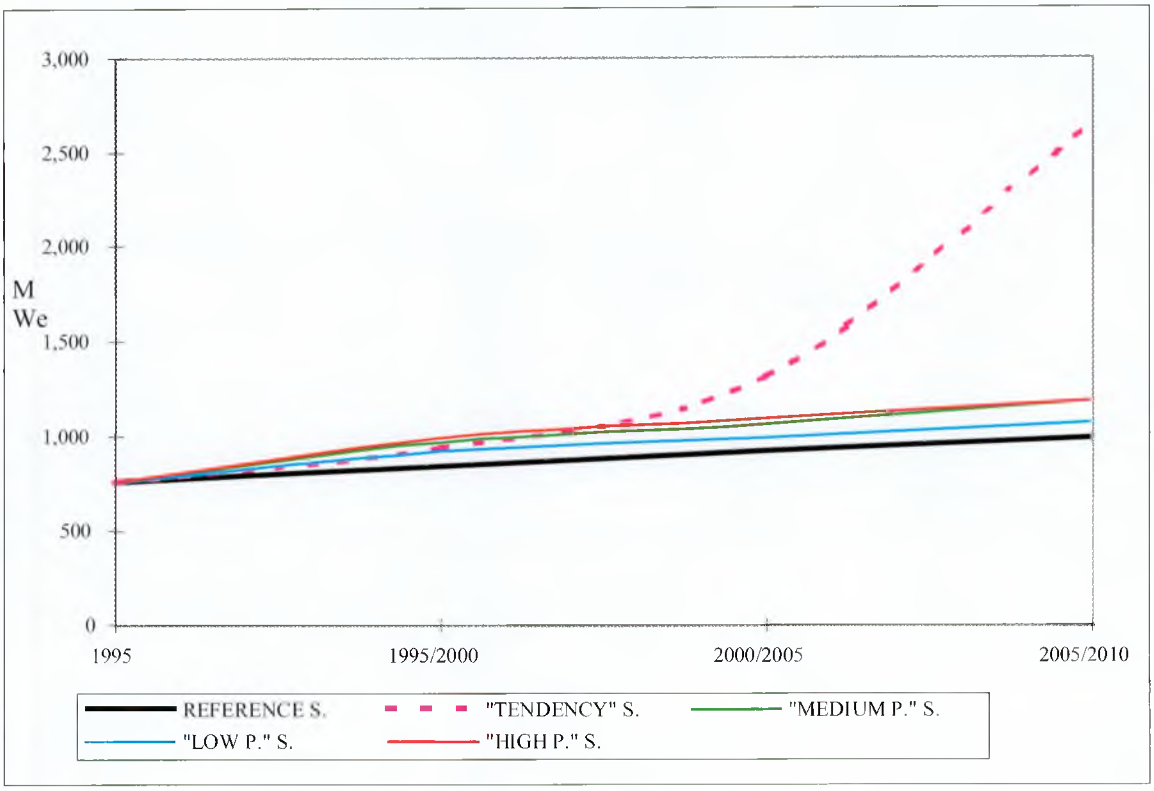
Table 5.1.6 "Medium Profile" Scenario (MWe)
(Planned plants and proven resources)

	2000 MWe	2005 MWe	2010 MWe
France	4	4	4
Greece	7	10	90
Italy	902	970	970
Portugal	9	9	9
Total EU	922	993	1,073
Iceland	134	170	170
Russia	102	141	173
Turkey	202	279	319
Total EUROPE	1,359	1,583	1,735
Canada	49	70	70
Usa	3,061	3,100	3,100
Mexico	1,058	1,188	1,188
North America	4,168	4,358	4,358
Costa Rica	156	198	510
El Salvador	138	146	206
Guatemala	66	94	122
Nicaragua	366	505	505
Central America	725	943	1,343
Argentina	1	1	13
Bolivia	-	-	14
Chile	20	28	57
Ecuador	-	-	214
South America	20	29	298
China	32	32	32
India	15	21	21
Indonesia	1,003	1,301	1,724
Japan	461	530	1,650
Philippines	1,764	1,900	2,300
Thailand	-	0	2
Asia	3,275	3,785	5,729
Australia	1	1	21
New Zeland	396	443	443
Papua-New Gui.	-	-	120
	397	444	584
Ethiopia	7	7	13
Kenia	90	109	289
Mozambique	-	-	10
Africa	97	116	312

Table 5.1.7 "Low Profile" Scenario (MWe)
(Planned plants and part of proven resources)

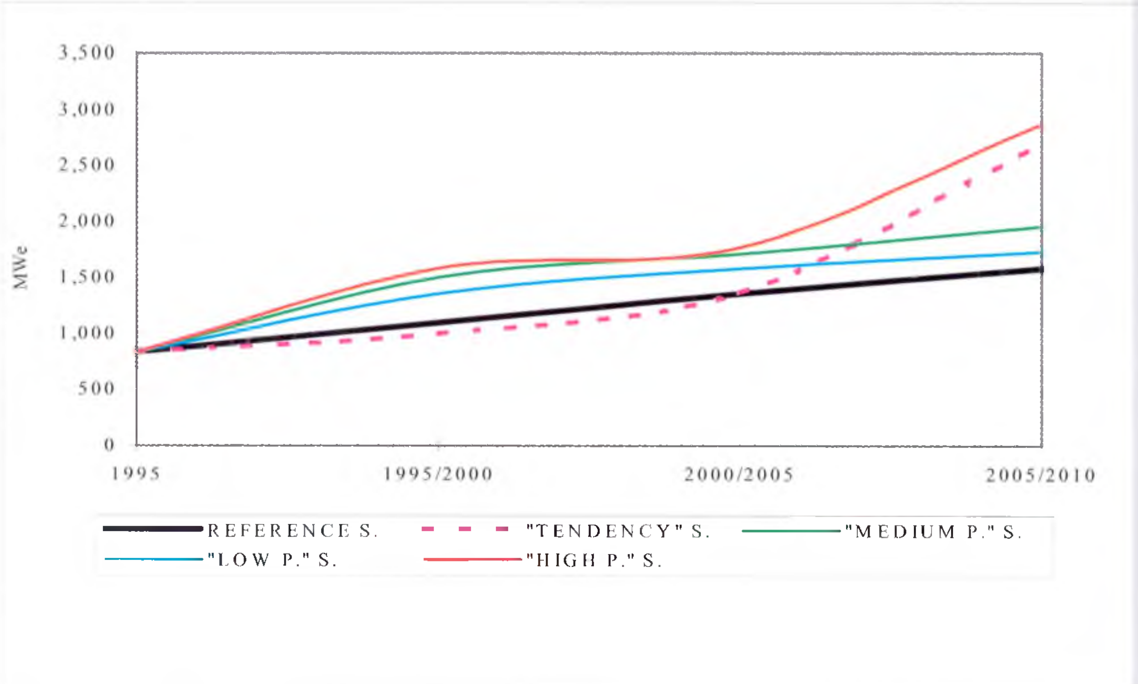
	2000 MWe	2005 MWe	2010 MWe
France	4	4	4
Greece	10	110	210
Italy	970	970	970
Portugal	9	9	9
Total EU	993	1,093	1,193
Iceland	170	170	970
Russia	141	181	297
Turkey	279	329	419
Total EUROPE	1,583	1,773	2,879
Canada	70	70	570
Usa	3,100	3,100	9,100
Mexico	1,188	1,188	2,388
North America	4,358	4,358	12,058
Costa Rica	198	588	1,318
El Salvador	146	221	336
Guatemala	94	129	164
Nicaragua	505	505	1,005
Central America	943	1,443	2,823
Argentina	1	16	31
Bolivia	-	18	106
Chile	28	64	100
Ecuador	-	267	688
South America	29	365	924
China	32	32	400
India	21	21	421
Indonesia	1,301	1,830	3,958
Japan	530	1,930	3,330
Philippines	1,900	2,400	3,300
Thailand	-	3	5
Asia	3,785	6,216	11,415
Australia	1	26	291
New Zeland	443	443	443
Papua-New Gui.	-	150	360
Oceania	444	619	1,094
Ethiopia	7	15	26
Kenia	109	334	679
Mozambique	0	13	35
Africa	116	361	740

Table 5.1.8 "High Profile" Scenario (MWe)
(Planned plants, proven resources and part of the probable/possible ones)



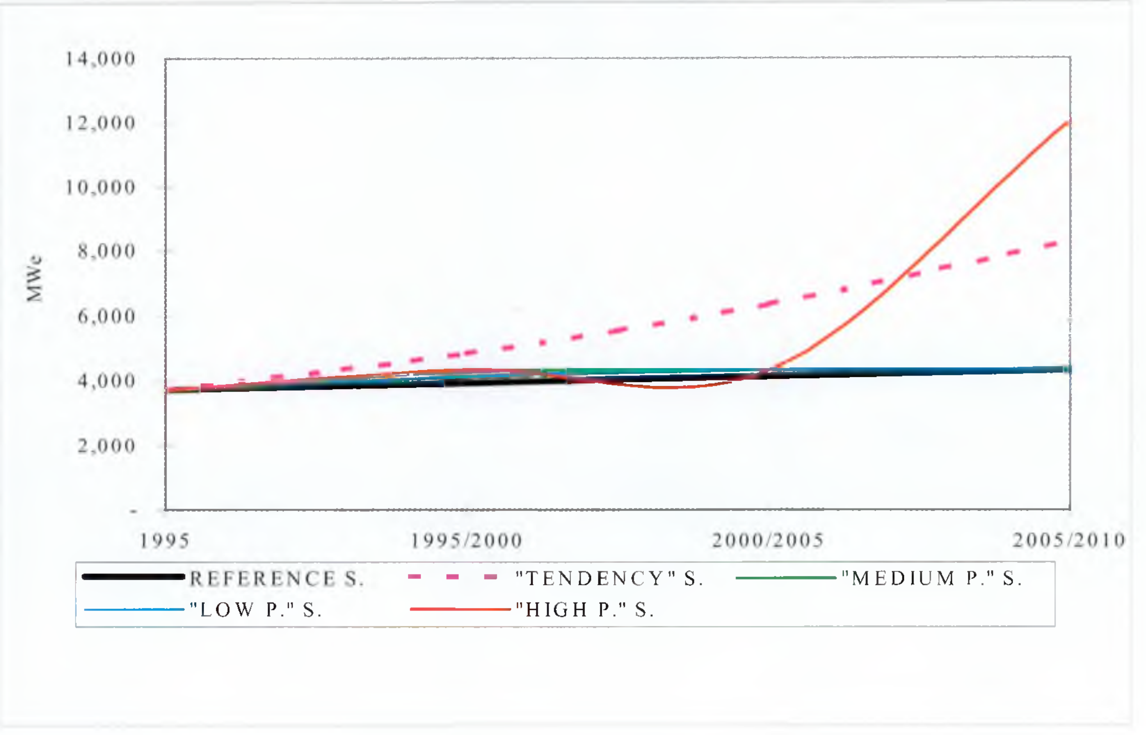
EU	1995	1995/2000	2000/2005	2005/2010
REFERENCE S.	755	839	922	993
"TENDENCY" S.		935	1,314	2,644
"MEDIUM P." S.		969	1,063	1,193
"LOW P." S.		922	993	1,073
"HIGH P." S.		993	1,093	1,193

Fig. 5.1.1 **EUROPEAN UNION** - Geothermal Energy Forecast (MWe capacity)



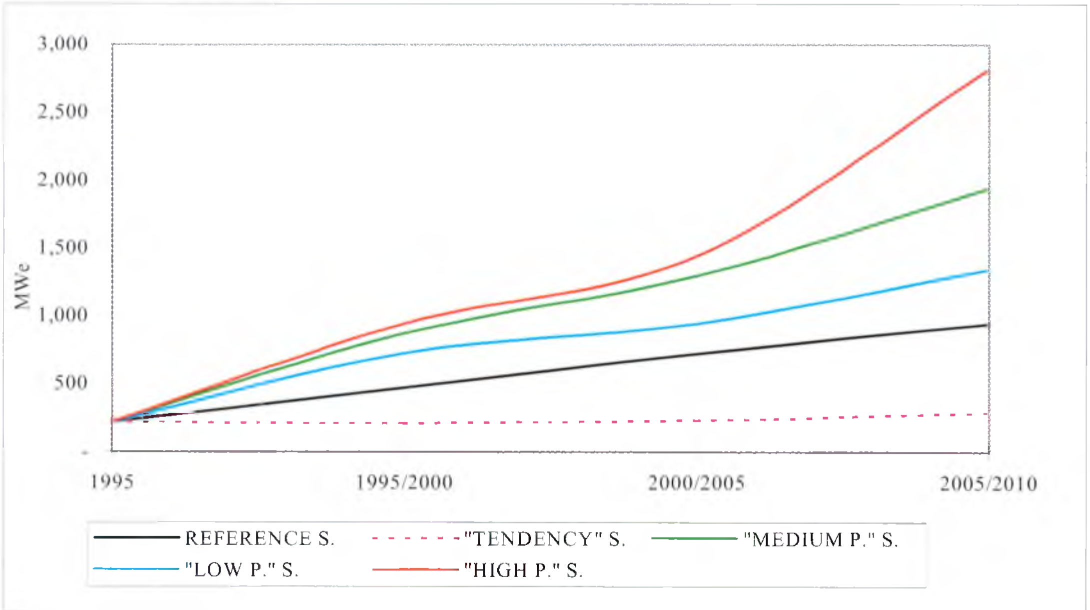
TOTAL EUROPE	1995	1995/2000	2000/2005	2005/2010
REFERENCE S.	837	1,099	1,359	1,583
"TENDENCY" S.		1,000	1,369	2,697
"MEDIUM P." S.		1,508	1,716	1,963
"LOW P." S.		1,359	1,583	1,735
"HIGH P." S.		1,583	1,773	2,879

Fig. 5.1.2 **EUROPE** - Geothermal Energy Forecast (MWe capacity)



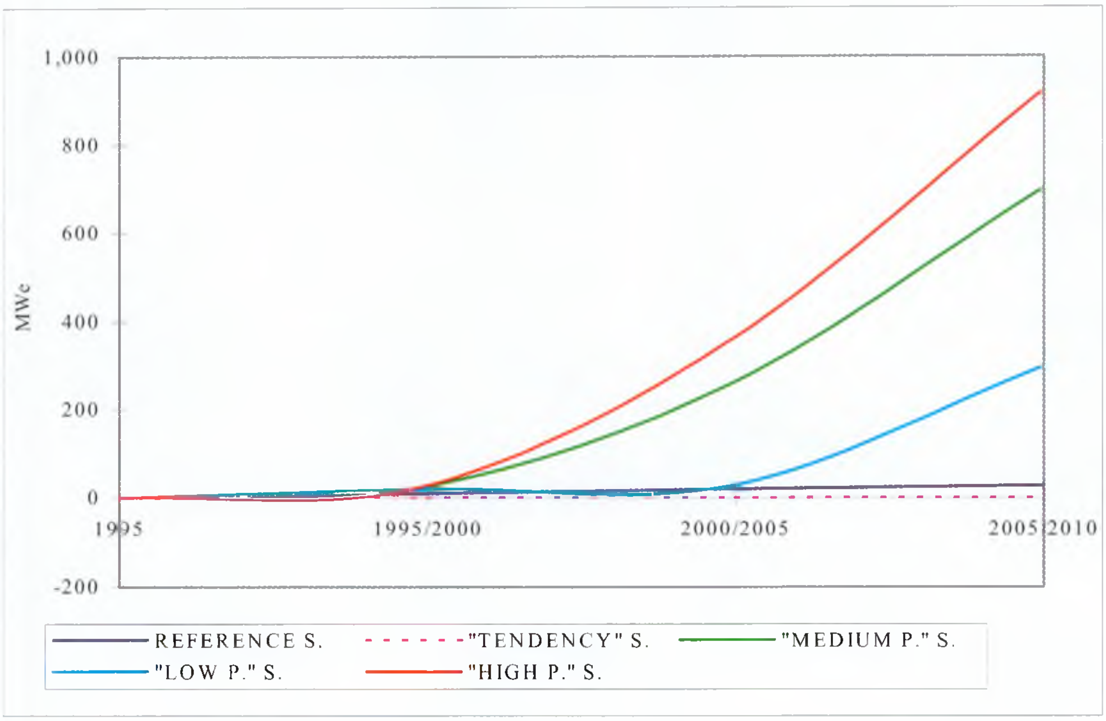
NORTH AMERICA	1995	1995/2000	2000/2005	2005/2010
REFERENCE S.	3,723	3,945	4,168	4,358
"TENDENCY" S.		4,863	6,356	8,313
"MEDIUM P." S.		4,295	4,358	4,358
"LOW P." S.		4,168	4,358	4,358
"HIGH P." S.		4,358	4,358	12,058

Fig. 5.1.3 **NORTH AMERICA** - Geothermal Energy Forecast (MWe capacity)



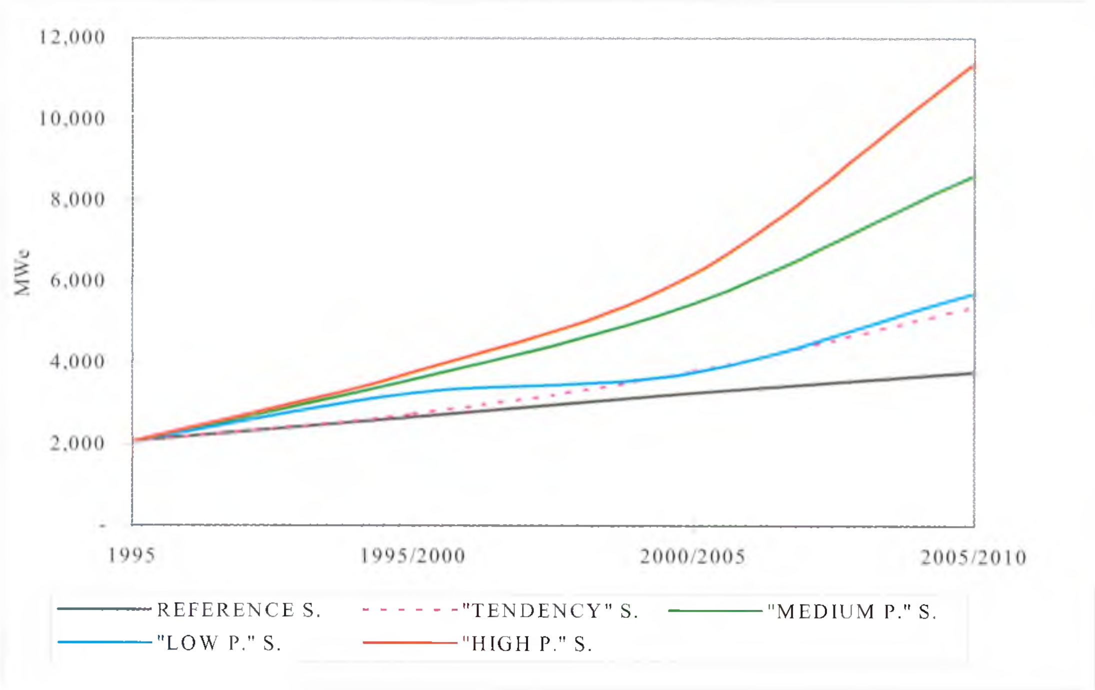
CENTRAL AMERICA	1995	1995/2000	2000/2005	2005/2010
REFERENCE S.	218	472	725	943
"TENDENCY" S.		209	228	273
"MEDIUM P." S.		870	1,293	1,943
"LOW P." S.		725	943	1,343
"HIGH P." S.		943	1,443	2,823

Fig. 5.1.4 **CENTRAL AMERICA** - Geothermal Energy Forecast (MWe capacity)



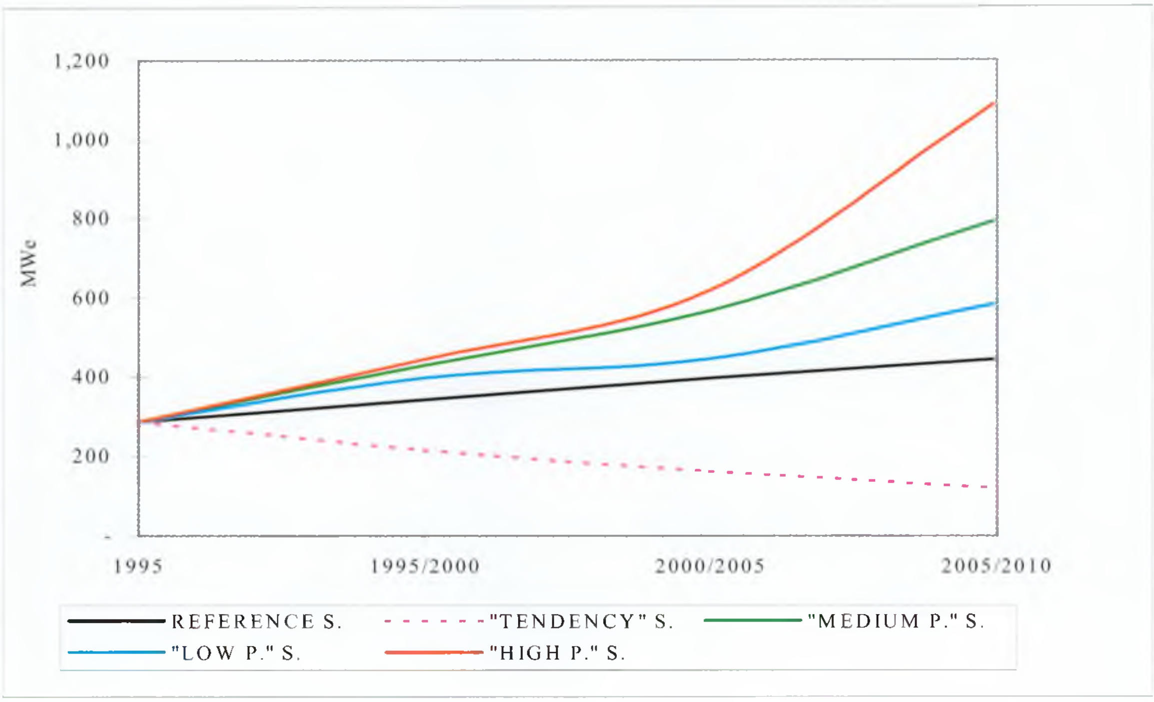
	1995	1995/2000	2000/2005	2005/2010
REFERENCE S.	1	10	20	29
"TENDENCY" S.		1	1	2
"MEDIUM P." S.		26	264	701
"LOW P." S.		20	29	298
"HIGH P." S.		29	365	924

Fig. 5.1.5 **SOUTH AMERICA** - Geothermal Energy Forecast (MWe capacity)



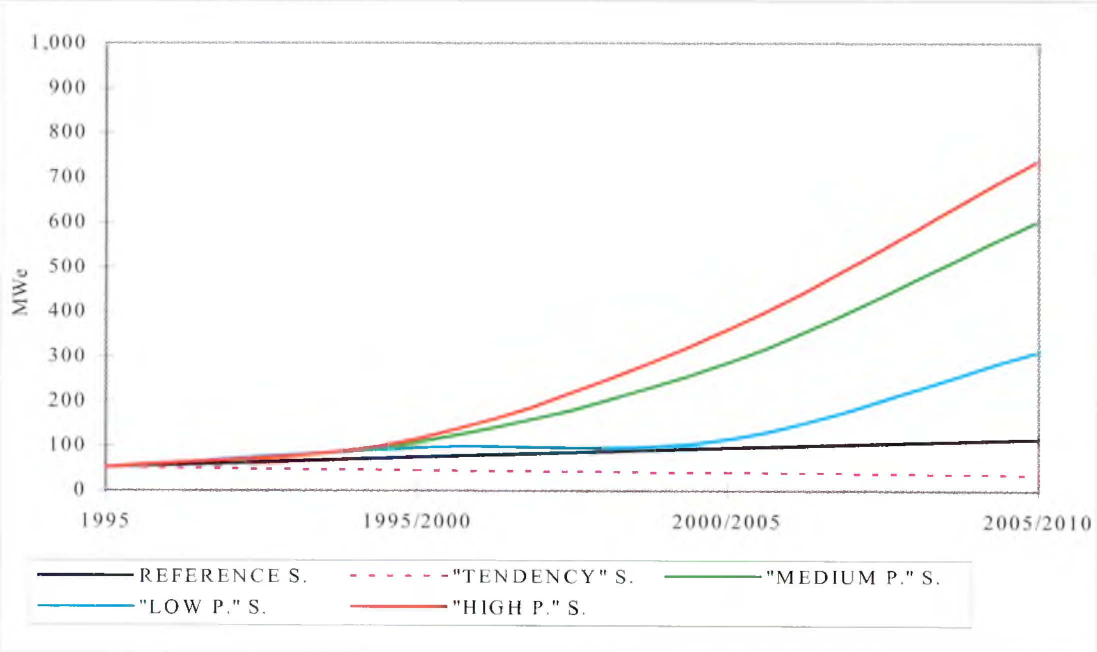
ASIA	1995	1995/2000	2000/2005	2005/2010
REFERENCE S.	2,087	2,681	3,275	3,785
"TENDENCY" S.		2,758	3,807	5,387
"MEDIUM P." S.		3,615	5,486	8,563
"LOW P." S.		3,275	3,785	5,729
"HIGH P." S.		3,785	6,216	11,415

Fig. 5.1.6 **ASIA** - Geothermal Energy Forecast (MWe capacity)



OCEANIA	1995	1995/2000	2000/2005	2005/2010
REFERENCE S.	287	342	397	444
"TENDENCY" S.		211	155	115
"MEDIUM P." S.		428	566	794
"LOW P." S.		397	444	584
"HIGH P." S.		444	619	1.094

Fig. 5.1.7 **OCEANIA** - Geothermal Energy Forecast (MWe capacity)



AFRICA	1995	1995/2000	2000/2005	2005/2010
REFERENCE S.	52	74	97	116
"TENDENCY" S.		46	40	36
"MEDIUM P." S.		110	287	606
"LOW P." S.		97	116	312
"HIGH P." S.		116	361	740

Fig. 5.1.8 **AFRICA** - Geothermal Energy Forecast (MWe capacity)

*FRANCE**

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

(*) Guadeloupe

MAIN ENERGY DATA ***(thousand toe)***

	1990	*1991*	*1992*	*1993*
PRIMARY ENERGY PRODUCTION				
coal				
oil				
natural gas				
electricity				
total	0	0	0	0
% variation				
ENERGY DEMAND				
solids				
liquids	389	408	430	441
gas				
electricity				
total	*389*	*408*	*430*	*441*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	*1991*	*1992*	*1993*
thermal	*selfproducers*	747	824	901	960
	public				
hydro	*selfproducers*				
	public				
nuclear	*selfproducers*				
	public				
geothermal	*selfproducers*				
	public				
	total	747	824	901	960
% variation	0.087				
Geothermal production share		-	-	-	-
% variation					

GREECE

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

	1990	*1991*	*1992*	*1993*
PRIMARY ENERGY PRODUCTION				
coal	7,115	6,898	6,848	7,519
oil	834	840	690	564
natural gas	153	150	138	102
electricity	172	273	206	223
total	8,274	8,161	7,882	8,408
% variation 0.005	-1.37	-3.42	6.67	
ENERGY DEMAND				
solids	8,063	7,763	8,033	8,524
liquids	13,413	14,326	14,669	14,704
gas	153	150	138	102
electricity	233	328	258	292
total	*21,862*	*22,567*	*23,098*	*23,622*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	*1991*	*1992*	*1993*
thermal	*selfproducers*	875	934	929	845
	public	32,129	31,708	34,086	34,962
hydro	*selfproducers*				
	public	1,997	3,171	2,389	2,541
nuclear	*selfproducers*				
	public				
geothermal	*selfproducers*				2
	public	0	0	6	46
	total	35,001	35,813	37,410	38,396
% variation 0.031					
Geothermal production share		0.00000	0.00000	0.016	0.125
% variation 679.456					

ITALY

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA *(thousand toe)*

	1990	1991	1992	1993
PRIMARY ENERGY PRODUCTION				
coal	1,270	1,340	1,450	1,320
oil	4,668	4,330	4,500	4,640
natural gas	14,040	14,130	14,740	15,770
electricity	8,426	10,730	10,830	10,590
total	28,404	30,530	31,520	32,320
% variation 0.044	7.48	3.24	2.54	
ENERGY DEMAND				
solids	6,072	6,180	6,410	5,990
liquids	64,330	63,900	64,500	63,070
gas	30,650	33,390	32,710	33,260
electricity	18,450	18860	19,220	19,290
total	*119,502*	*122,330*	*122,840*	*121,610*

PRODUCTION OF ELECTRICITY *(million KWh)*

		1990	1991	1992	1993
thermal	*selfproducers*	20,817	22,543	24,601	27,562
	public	157,773	150,710	152,396	147,076
hydro	*selfproducers*	5,747	6,901	7,506	7,400
	public	29,332	38,705	38,280	37,082
nuclear	*selfproducers*				
	public				
geothermal	*selfproducers*	0	0	0	0
	public	3,222	3,182	3,460	3,668
	total	216,891	222,041	226,243	222,788
% variation 0.009					
Geothermal production share		1.49	1.43	1.53	1.65
% variation 0.035					

PORTUGAL

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

	1990	*1991*	*1992*	*1993*
PRIMARY ENERGY PRODUCTION				
coal	115	111	91	81
oil	0	0	0	0
natural gas	0	0	0	0
electricity	803	793	441	756
total	918	904	532	837
% variation -0.030	-1.53	-41.15	57.33	
ENERGY DEMAND				
solids	2,773	2,710	2,862	3,133
liquids	9,868	10021	11,160	10,491
gas	0	0	0	0
electricity	807	801	556	771
total	*13,448*	*13,532*	*14,578*	*14,395*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	*1991*	*1992*	*1993*
thermal	*selfproducers*	1,408	1,608	1,792	2,133
	public	17,784	19,081	23,212	20,320
hydro	*selfproducers*	29	36	20	24
	public	9,274	9,140	5,054	8,713
nuclear	*selfproducers*		0		
	public	0	0	0	0
geothermal	*selfproducers*				
	public	5	6	9	15
	total	28,500	29,871	30,087	31,205
% variation 0.031					
Geothermal production share		0.02	0.02	0.03	0.05
% variation 0.399					

ICELAND

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

		1990	*1991*	*1992*	*1993*
PRIMARY ENERGY PRODUCTION					
coal					
oil					
natural gas					
electricity		619	604	568	605
	total	*619*	*604*	*568*	*605*
% variation	-0.008	-2.42	-5.96	6.51	
ENERGY DEMAND					
solids		60	61	43	45
liquids		578	503	521	648
gas					
electricity		619	604	568	605
	total	*1,257*	*1,168*	*1,132*	*1,298*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	*1991*	*1992*	*1993*
thermal	*selfproducers*	1	1	1	1
	public	6	6	4	4
hydro	*selfproducers*	4	4	4	2
	public	4,200	4,200	4,302	4,462
nuclear	*selfproducers*				
	public				
geothermal	*selfproducers*	-	-	-	4
	public	300	283	230	254
	total	*4,511*	*4,494*	*4,541*	*4,727*
% variation	0.016				
Geothermal production share		6.65	6.30	5.06	5.46
% variation	-0.064				

RUSSIA

("1995 -Energy Statistics Yearbook" ONU/ New York 1997)

MAIN ENERGY DATA ***(thousand toe)***

		1992	1993
PRIMARY ENERGY PRODUCTION			
coal		169,311	154,236
oil		399,270	351,437
natural gas		492,572	484,336
electricity		45,974	46,081
	total	*1,107.127*	*1,036.090*
% variation	-0.036		
ENERGY DEMAND			
solids		168,841	151,885
liquids		165,965	162,872
gas		339,543	337,984
electricity		44,578	44,470
	total	*718,927*	*697,211*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1992	1993
thermal	*selfproducers*	47,257	41,658
	public	668,944	619,656
hydro	*selfproducers*	751	890
	public	171,843	174,284
nuclear	*selfproducers*		
	public	119,626	119,186
geothermal	*selfproducers*		
	public	29	28
	total	*1,008.450*	*955,702*
% variation	-0.052		
Geothermal production share		0.0029	0.0029
% variation	0.07		

TURKEY

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

	1990	1991	1992	1993
PRIMARY ENERGY PRODUCTION				
coal	11,773	11,818	10,938	11,571
oil	3,711	4,363	4,275	3,891
natural gas	194	186	163	165
electricity	2,059	2,028	2,345	2,986
total	*17,737*	*18,395*	*17,721*	*18,613*
% variation 0.016	3.71	-3.66	5.03	
ENERGY DEMAND				
solids	15,793	16,994	15,420	16,233
liquids	20,194	19,072	20,740	23,839
gas	3,173	3,876	3,819	4,244
electricity	1,996	2,049	2,334	2,954
total	*41,156*	*41,991*	*42,313*	*47,270*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	1991	1992	1993
thermal	*selfproducers*	3,352	3,365	3,715	4,156
	public	30,964	34,117	36,989	35,623
hydro	*selfproducers*	10	5	12	16
	public	23,138	22,769	26,556	33,935
nuclear	*selfproducers*				
	public				
geothermal	*selfproducers*				
	public	80	81	70	78
	total	*57,544*	*60,337*	*67,342*	*73,808*
% variation	0.087				
Geothermal production share		0.139	0.134	0.104	0.106
% variation	-0.087				

CANADA

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

	1990	1991	1992	1993
PRIMARY ENERGY PRODUCTION				
coal	36,944	38,706	34,428	37,519
oil	90,957	91,212	94,652	99,419
natural gas	98,259	103,763	113,852	125,715
electricity	44,487	48,613	48,170	52,494
	9,98	11,80	12,81	13,73
% variation 0.112	18.24	8.56	7.18	
ENERGY DEMAND				
solids	23,508	24,694	25,263	24,060
liquids	75,698	72,218	74,226	76,612
gas	60,664	61,369	64,545	68,882
electricity	44,448	47028	46,016	50,136
total	*204,318*	*205,309*	*210,050*	*219,690*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	1991	1992	1993
thermal	*selfproducers*	10,550	10,929	10,842	11,096
	public	101,644	103,544	112,918	97,679
hydro	*selfproducers*	31,398	33,933	30,618	33,368
	public	265,531	274,546	285,866	290,322
nuclear	*selfproducers*				
	public	72,886	84,929	80,580	94,823
geothermal	*selfproducers*				
	public	26	32	33	28
	total	482,035	507,913	520,857	527,316
% variation	0.030				
Geothermal production share		0.0054	0.0063	0.0063	0.0053
% variation	-0.005				

USA

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

	1990	*1991*	*1992*	*1993*
PRIMARY ENERGY PRODUCTION				
coal	540,307	522,653	522,712	482,897
oil	425,422	431,786	422,020	405,841
natural gas	462,709	459,184	462,870	477,885
electricity	187,822	196,966	196,427	198,940
total	1,616.260	1,610.589	1,604.029	1,565.563
% variation -0.011	-0.35	-0.41	-2.40	
ENERGY DEMAND				
solids	467,679	463,398	465,815	450,525
liquids	738,169	727070	735,864	766,525
gas	486,968	503,921	517,203	534,117
electricity	187,992	198,881	198,864	201,412
total	*1,880.808*	*1,893.270*	*1,917.746*	*1,952.579*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	*1991*	*1992*	*1993*
thermal	*selfproducers*	187,948	215,972	256,292	238,783
	public	1,942.779	1,928.848	1,930.776	1,997.605
hydro	*selfproducers*	6,173	6,181	9,353	11,400
	public	279,926	275,519	239,559	265,063
nuclear	*selfproducers*	109	75	63	74
	public	576,862	612,565	618,776	610,291
geothermal	*selfproducers*	9,368	10,569	11,578	13,107
	public	8,584	8,090	8,107	9,569
	total	3,011.749	3,057.819	3,074.504	3,145.892
% variation	0.015				
Geothermal production share		0.60	0.61	0.64	0.72
% variation	0.065				

MEXICO

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA *(thousand toe)*

	1990	*1991*	*1992*	*1993*
PRIMARY ENERGY PRODUCTION				
coal	3,895	3,546	3,361	3,815
oil	149,463	156,330	156,202	156,400
natural gas	22,813	22,645	22,337	23,335
electricity	7,187	7,656	8,263	9,132
total	183,358	190,177	190,163	192,682
% variation 0.017	3.72	-0.01	1.32	
ENERGY DEMAND				
solids	4,003	3,790	3,846	3,873
liquids	76,171	79350	79,365	80,732
gas	23,248	24,173	24,807	24,373
electricity	7,069	7,535	8,173	9,037
total	*110,491*	*114,848*	*116,191*	*118,015*

PRODUCTION OF ELECTRICITY *(million KWh)*

		1990	*1991*	*1992*	*1993*
thermal	*selfproducers*	7,995	8,240	8,240	8,245
	public	82,849	86,943	85,835	89,284
hydro	*selfproducers*	205	210	210	215
	public	23,338	21,737	26,095	25,799
nuclear	*selfproducers*				
	public	2,937	4,242	3,919	4,806
geothermal	*selfproducers*				
	public	5,124	5,435	5,804	6,576
	total	122,448	126,807	130,103	134,925
% variation	0.033				
Geothermal production share		4.18	4.29	4.461	4.874
% variation	0.052				

COSTA RICA

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

	1990	*1991*	*1992*	*1993*
PRIMARY ENERGY PRODUCTION				
coal				
oil				
natural gas				
electricity	301	312	306	341
	9,98	11,80	12,81	13,73
% variation 0.112	18.24	8.56	7.18	
ENERGY DEMAND				
solids				
liquids	885	952	1.118	1,155
gas				
electricity	315	314	301	340
total	*1,200*	*1,266*	*1,419*	*1,495*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	*1991*	*1992*	*1993*
thermal	*selfproducers*	0	0	5	2
	public	47	178	580	423
hydro	*selfproducers*	1	10	17	24
	public	3,496	3,620	3,542	3,937
nuclear	*selfproducers*				
	public				
geothermal	*selfproducers*				
	public				
	total	3,544	3,808	4,144	4,386
% variation	0.074	7.45	8.82	5.84	
Geothermal production share		-	-	-	-
% variation					

EL SALVADOR

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

	1990	1991	1992	1993
PRIMARY ENERGY PRODUCTION				
coal				
oil				
natural gas				
electricity	504	476	460	498
total	504	476	460	498
% variation -0.004	-5.56	-3.36	8.26	
ENERGY DEMAND				
solids				
liquids	734	936	1,047	1,221
gas				
electricity	504	477	464	505
total	*1,238*	*1,413*	*1,511*	*1,726*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	1991	1992	1993
thermal	*selfproducers*	53	41	44	50
	public	151	604	576	608
hydro	*selfproducers*				
	public	1,673	1,294	1,446	1,800
nuclear	*selfproducers*				
	public				
geothermal	*selfproducers*				
	public	419	425	391	400
	total	2,296	2,364	2,457	2,858
% variation	0.076	2.96	3.93	16.32	
Geothermal production share		18.25	17.98	15.91	14.00
% variation	-0.085	-1.49	-11.48	-12.05	

GUATEMALA

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

	1990	1991	1992	1993
PRIMARY ENERGY PRODUCTION				
coal				
oil	215	202	306	352
natural gas	8	8	8	9
electricity	185	185	182	165
total	408	395	496	526
% variation 0.088	-3.19	25.57	6.05	
ENERGY DEMAND				
solids				
liquids	1,398	1,376	1,654	1,546
gas	8	8	8	9
electricity	185	185	182	165
total	*1,591*	*1,569*	*1,844*	*1,720*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	1991	1992	1993
thermal	*selfproducers*	88	98	111	122
	public	95	248	598	1,040
hydro	*selfproducers*	0	0	0	0
	public	2,147	2,147	2,113	1,922
nuclear	*selfproducers*				
	public				
geothermal	*selfproducers*				
	public				
	total	2,330	2,493	2,822	3,084
% variation	0.098	7.00	13.20	9.28	
Geothermal production share		-	-	-	-
% variation					

NICARAGUA

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

	1990	*1991*	*1992*	*1993*
PRIMARY ENERGY PRODUCTION				
coal				
oil				
natural gas				
electricity	367	423	425	469
total	367	423	425	469
% variation 0.085	15.26	0.47	10.35	
ENERGY DEMAND				
solids				
liquids	639	614	729	783
gas				
electricity	372	428	428	469
total	*1,011*	*1,042*	*1,157*	*1,252*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	*1991*	*1992*	*1993*
thermal	*selfproducers*	65	65	50	50
	public	536	600	803	810
hydro	*selfproducers*	8	8	8	8
	public	403	337	257	300
nuclear	*selfproducers*				
	public				
geothermal	*selfproducers*				
	public	386	458	468	515
	total	1,398	1,468	1,586	1,683
% variation	0.064	5.01	8.04	6.12	
Geothermal production share		27.61	31.20	29.51	30.60
% variation	0.035	13.00	-5.42	3.70	

ARGENTINA

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

	1990	*1991*	*1992*	*1993*
PRIMARY ENERGY PRODUCTION				
coal	159	172	127	99
oil	25,989	26,471	29,764	31,311
natural gas	18,945	21,154	21,476	22,089
electricity	3,453	3,434	3,524	4,092
total	48,546	51,231	54,891	57,591
% variation 0.059	5.53	7.14	4.92	
ENERGY DEMAND				
solids	810	709	776	623
liquids	17,561	18,336	18,836	19,661
gas	20,982	22,958	23,452	23,739
electricity	3,524	3,509	3,747	4,199
total	*42,877*	*45,512*	*46,811*	*48,222*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	*1991*	*1992*	*1993*
thermal	*selfproducers*	3,827	3,850	3,929	4,008
	public	21,666	25,996	25,692	27,132
hydro	*selfproducers*	73	70	71	72
	public	18,060	16,361	19,500	24,076
nuclear	*selfproducers*				
	public	7,281	7,771	7,081	7,750
geothermal	*selfproducers*				
	public				
	total	50,907	54,048	56,273	63,038
% variation	0.074	6.17	4.12	12.02	
Geothermal production share		-	-	-	-
% variation					

BOLIVIA

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

	1990	*1991*	*1992*	*1993*
PRIMARY ENERGY PRODUCTION				
coal				
oil	1,232	1,303	1,311	1,245
natural gas	2,405	2,386	2,577	2,556
electricity	108	119	116	118
total	3,745	3,808	4,004	3,919
% variation 0.015	1.68	5.15	-2.12	
ENERGY DEMAND				
solids				
liquids	1,181	1,223	1,209	1,307
gas	450	446	599	619
electricity	109	120	117	119
total	*1,740*	*1,789*	*1,925*	*2,045*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	*1991*	*1992*	*1993*
thermal	*selfproducers*	113	113	118	120
	public	767	777	944	950
hydro	*selfproducers*	128	124	125	125
	public	1,125	1,261	1,225	1,250
nuclear	*selfproducers*				
	public				
geothermal	*selfproducers*				
	public				
	total	2,133	2,275	2,412	2,445
% variation	0.047	6.66	6.02	1.37	
Geothermal production share		-	-	-	-
% variation					

CHILE

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

	1990	1991	1992	1993
PRIMARY ENERGY PRODUCTION				
coal	1,805	1,825	1,357	1,127
oil	1,301	1,174	1,056	1,047
natural gas	1,655	1,464	1,666	1,604
electricity	1,029	1,129	1,440	1,515
total	5,790	5,592	5,519	5,293
% variation -0.029	-3.42	-1.31	-4.09	
ENERGY DEMAND				
solids	3,088	2,479	2,202	2,219
liquids	6,506	6,617	7,346	7,583
gas	1,624	1,422	1,637	1,556
electricity	1,029	1,129	1,440	1,515
total	*12,247*	*11,647*	*12,625*	*12,873*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	1991	1992	1993
thermal	*selfproducers*	1,400	1,533	1,400	1,500
	public	5,000	5,300	4,220	4,880
hydro	*selfproducers*	650	650	700	724
	public	11,322	12,478	16,042	16,900
nuclear	*selfproducers*				
	public				
geothermal	*selfproducers*				
	public				
total		18,372	19,961	22,362	24,004
% variation	0.093	8.65	12.03	7.34	
Geothermal production share		-	-	-	-
% variation					

ECUADOR

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

		1990	1991	1992	1993
PRIMARY ENERGY PRODUCTION					
coal					
oil		15,055	15,803	16,901	18,112
natural gas		116	116	116	116
electricity		428	435	426	505
	total	15,599	16,354	17,443	18,733
% variation	0.063	4.84	6.66	7.40	
ENERGY DEMAND					
solids					
liquids		4,834	5,171	5,414	5,241
gas		116	116	116	116
electricity		428	435	426	505
	total	*5,378*	*5,722*	*5,956*	*5,862*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	1991	1992	1993
thermal	*selfproducers*				
	public	1,355	1,891	2,214	1,576
hydro	*selfproducers*				
	public	4,972	5,061	4,951	5,871
nuclear	*selfproducers*				
	public				
geothermal	*selfproducers*				
	public				
	total	6,327	6,952	7,165	7,447
% variation	0.056	9.88	3.06	3.94	
Geothermal production share		-	-	-	-
% variation					

CHINA

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

	1990	*1991*	*1992*	*1993*
PRIMARY ENERGY PRODUCTION				
coal	539,402	543,159	557,626	574,298
oil	138,283	140,968	142,073	145.213
natural gas	14,227	14,943	14,682	15,781
electricity	10,896	10,756	11,520	13,703
total	702,808.00	709,826.00	725,901.00	748,995.00
% variation 2.15	1.00	2.26	3.18	
ENERGY DEMAND				
solids	509,349	527,861	544,535	562,244
liquids	90,775	99309	109,826	116,700
gas	14,227	14,943	14,682	15,781
electricity	11,054	11,001	11,949	14,150
total	*625,405*	*653,114*	*680,992*	*708,875*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	*1991*	*1992*	*1993*
thermal	*selfproducers*				
	public	494,480	552,460	621,470	685,153
hydro	*selfproducers*				
	public	126,720	125,090	132,470	151,800
nuclear	*selfproducers*				
	public			500	2,500
geothermal	*selfproducers*				
	public				
	total	621,200	677,550	754,440	839,453
	% variation 0.106	9.07	11.35	11.27	
Geothermal production share		-	-	-	-
	% variation				

INDIA

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

	1990	1991	1992	1993
PRIMARY ENERGY PRODUCTION				
coal	120,530	135,103	139,396	146,667
oil	34,179	32,016	29,104	27,665
natural gas	9,284	10,469	10,886	10,987
electricity	7,761	7,697	7,763	7,849
total	171,754	185,285	187,149	193,168
% variation 4.03	7.88	1.01	3.22	
ENERGY DEMAND				
solids	125,564	135,471	142,109	150,025
liquids	45,721	48,949	52,044	54,067
gas	9,284	10,469	10,886	10,987
electricity	7,879	7,822	7,866	7,956
total	*188,448*	*202,711*	*212,905*	*223,035*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	1991	1992	1993
thermal	*selfproducers*	25,096	28,584	31,332	33,000
	public	186,514	208,709	224,717	246,000
hydro	*selfproducers*	15	18	17	17
	public	71,641	72,757	69,869	70,650
nuclear	*selfproducers*				
	public	6,141	5,524	6,726	6,800
geothermal	*selfproducers*			2	2
	public	32	39	50	50
	total	289,439	315,631	332,713	356,519
% variation	0.072	9.05	5.41	7.16	
Geothermal production share		0.01	0.01	0.02	0.01
% variation	0.097	11.76	26.49	-6.68	

INDONESIA

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

	1990	1991	1992	1993
PRIMARY ENERGY PRODUCTION				
coal	5,131	9,600	14,803	19,309
oil	92,894	102,903	100,023	100,127
natural gas	56,018	45,347	47,510	49,249
electricity	1,846	1,817	1,978	1,972
total	155,889	159,667	164,314	170,657
% variation 3.06	2.42	2.91	3.86	
ENERGY DEMAND				
solids	2,069	4,025	3,732	6,336
liquids	30,179	33,346	34,659	35,547
gas	30,012	13,301	17,202	19,620
electricity	1,846	1,817	1,978	1,972
total	*64,106*	*52,489*	*57,571*	*63,475*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	1991	1992	1993
thermal	*selfproducers*	10,100	10,200	10,300	10,400
	public	27,432	30,026	30,843	35,316
hydro	*selfproducers*	4,350	4,150	4,200	4,250
	public	5,890	5,974	8,572	7,835
nuclear	*selfproducers*				
	public				
geothermal	*selfproducers*				
	public	1,125	1,102	1,025	1,087
	total	48,897	51,452	54,940	58,888
% variation	0.064	5.23	6.78	7.19	
Geothermal production share		2	2	2	2
% variation	-0.071				

JAPAN

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

	1990	*1991*	*1992*	*1993*
PRIMARY ENERGY PRODUCTION				
coal	5,087	4,959	4,679	4,445
oil	553	751	834	758
natural gas	2,003	2,092	2,115	2,159
electricity	62,336	66,112	67,300	75,415
total	69,979	73,914	74,928	82,777
% variation 5.82	5.62	1.37	10.48	
ENERGY DEMAND				
solids	80,337	83,761	82,786	84,671
liquids	204,137	207,661	209,921	204,915
gas	48,082	51,693	52,530	53,104
electricity	62336	66,112	67,300	75415
total	*394,892*	*409,227*	*412,537*	*418,105*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	*1991*	*1992*	*1993*
thermal	*selfproducers*	91,466	91,615	98,902	102,048
	public				
hydro	*selfproducers*	7,087	7,989	6,872	7,588
	public				
nuclear	*selfproducers*	869	1,118	953	1,040
	public				
geothermal	*selfproducers*	257	255	275	321
	public				
	total	99,679	100,977	107,002	110,997
% variation	0.036	1.30	5.97	3.73	
Geothermal production share		0.26	0.25	0.26	0.29
% variation	0.039	-2.05	1.77	12.53	

PHILIPPINES

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA *(thousand toe)*

	1990	1991	1992	1993
PRIMARY ENERGY PRODUCTION				
coal	588	597	786	792
oil	245	165	418	500
natural gas				
electricity	5,213	5,384	5,259	5,294
total	6,046	6,146	6,463	6,586
% variation 2.90	1.65	5.16	1.90	
ENERGY DEMAND				
solids	1,511	1,642	1,344	1,384
liquids	10,666	11,046	11,839	12,120
gas				
electricity	5,213	5,384	5,259	5,294
total	*17,390*	*18,072*	*18,442*	*18,798*

PRODUCTION OF ELECTRICITY *(million KWh)*

		1990	1991	1992	1993
thermal	*selfproducers*	1,062	900	975	980
	public	13,738	10,952	10,848	10,900
hydro	*selfproducers*	16	15	15	15
	public	6,045	5,130	4,237	4,250
nuclear	*selfproducers*				
	public				
geothermal	*selfproducers*				
	public	5,466	5,757	5,700	5,740
	total	26,327	22,754	21,775	21,885
% variation	-0.060	-13.57	-4.30	0.51	
Geothermal production share		21	25	26	26
% variation	0.081				

THAILAND

("1993 -Energy Statistics Yearbook" ONU/ New York 1995)

MAIN ENERGY DATA ***(thousand toe)***

	1990	*1991*	*1992*	*1993*
PRIMARY ENERGY PRODUCTION				
coal	3,242	3,834	4,018	4,065
oil	2,820	3,269	3,592	3,696
natural gas	5,400	6,706	7,188	8,105
electricity	428	394	34	318
total	11,890	14,203	14,832	16,184
% variation 11.00	19.45	4.43	9.12	
ENERGY DEMAND				
solids	3,406	4,045	4,128	4,177
liquids	19,977	21125	23,045	26,237
gas	5,400	6,706	7,188	8,105
electricity	481	442	402	369
total	*29,264*	*32,318*	*34,763*	*38,888*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1990	*1991*	*1992*	*1993*
thermal	*selfproducers*	2,000	2,300	2,600	2,900
	public	39,199	45,599	52,859	59,705
hydro	*selfproducers*				
	public	4,976	4,587	4,239	3,700
nuclear	*selfproducers*				
	public				
geothermal	*selfproducers*				
	public				
	total	46,175	52,486	59,698	66,305
% variation	0.128	13.67	13.74	11.07	
Geothermal production share		-	-	-	-
% variation					

AUSTRALIA

("1995 -Energy Statistics Yearbook" ONU/ New York 1997)

MAIN ENERGY DATA (thousand toe)

	1992	1993
PRIMARY ENERGY PRODUCTION		
coal	110,022	110,921
oil	24,380	24,026
natural gas	19,403	20,879
electricity	1,355	1,467
total	*155,160*	*157,293*
% variation 0.010		
ENERGY DEMAND		
solids	40,650	39,634
liquids	33,053	36,575
gas	14,342	14,933
electricity	1,355	1,467
total	*89,400*	*92,609*

PRODUCTION OF ELECTRICITY *(million KWh)*

		1992	1993
thermal	*selfproducers*	11,612	11,693
	public	132,382	134,990
hydro	*selfproducers*	50	59
	public	16,210	16,590
nuclear	*selfproducers*		
	public		
geothermal	*selfproducers*		
	public		
	total	*160,254*	*163,332*
% variation 0.026			
Geothermal production share		-	-
% variation			

NEW ZEALAND

("1995 -Energy Statistics Yearbook" ONU/ New York 1997)

MAIN ENERGY DATA (thousand toe)

	1992	*1993*
PRIMARY ENERGY PRODUCTION		
coal	1,669	1,758
oil	1,908	2,040
natural gas	4,976	4,841
electricity	3,724	3,863
total	*12,277*	*12,502*
% variation 0.036		
ENERGY DEMAND		
solids	1,380	1,276
liquids	4,345	4,200
gas	4,976	4,841
electricity	3,724	3,863
total	*14,425*	*14,180*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1992	*1993*
thermal	*selfproducers*		
	public	8,368	7,705
hydro	*selfproducers*		
	public	20,631	23,368
nuclear	*selfproducers*		
	public		
geothermal	*selfproducers*		
	public	2,272	2,159
	total	*31,271*	*33,232*
% variation 0.032			
Geothermal production share		7.27	6.50
% variation -0.06			

PAPUA NEW GUINEA

("1995 -Energy Statistics Yearbook" ONU/ New York 1997)

MAIN ENERGY DATA (thousand toe)

	1992	1993
PRIMARY ENERGY PRODUCTION		
coal		
oil	5,299	5,399
natural gas	72	74
electricity	40	40
total	*5,411*	*5,513*
% variation 0.024399807		
ENERGY DEMAND		
solids	1	1
liquids	754	751
gas	72	74
electricity	40	40
total	*867*	*866*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1992	1993
thermal	*selfproducers*	1,210	1,210
	public	120	120
hydro	*selfproducers*	45	45
	public	415	415
nuclear	*selfproducers*		
	public		
geothermal	*selfproducers*		
	public		
	total	*1,790*	*1,790*
% variation			
Geothermal production share **% variation**		-	-

ETHIOPIA

("1995 -Energy Statistics Yearbook" ONU/ New York 1997)

MAIN ENERGY DATA (thousand toe)

	1992	1993
PRIMARY ENERGY PRODUCTION		
coal		
oil		
natural gas		
electricity	154	166
total	*154*	*166*
% variation 0.011		
ENERGY DEMAND		
solids	-	-
liquids	849	848
gas		
electricity	154	166
total	*1,003*	*1,014*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1992	1993
thermal	*selfproducers*	53	53
	public	20	27
hydro	*selfproducers*		
	public	1,127	1,251
nuclear	*selfproducers*		
	public		
geothermal	*selfproducers*	67	68
	public		
	total	*1,267*	*1,399*
% variation 0.016			
Geothermal production share		5.29	4.86
% variation -0.001			

KENYA

("1995 -Energy Statistics Yearbook" ONU/ New York 1997)

MAIN ENERGY DATA (thousand toe)

		1992	*1993*
PRIMARY ENERGY PRODUCTION			
coal			
oil			
natural gas			
electricity		474	491
	total	*474*	*491*
% variation	0.029		
ENERGY DEMAND			
solids		111	92
liquids		1,423	1,541
gas			
electricity		495	514
	total	*2,029*	*2,147*

PRODUCTION OF ELECTRICITY ***(million KWh)***

		1992	*1993*
thermal	*selfproducers*	50	50
	public	97	81
hydro	*selfproducers*	20	20
	public	2,776	2,973
nuclear	*selfproducers*		
	public		
geothermal	*selfproducers*		
	public	272	272
	total	*3,215*	*3,396*
% variation	0.052		
Geothermal production share		8.46	8.01
% variation	-0.03		

MOZAMBIQUE

("1995 -Energy Statistics Yearbook" ONU/ New York 1997)

MAIN ENERGY DATA (thousand toe)

	1992	1993
PRIMARY ENERGY PRODUCTION		
coal	28	28
oil		
natural gas		
electricity	4	4
total	*32*	*32*
% variation -		
ENERGY DEMAND		
solids	42	42
liquids	273	270
gas		
electricity	32	32
total	*347*	*344*

PRODUCTION OF ELECTRICITY *(million KWh)*

		1992	1993
thermal	*selfproducers*	150	150
	public	290	290
hydro	*selfproducers*	-	-
	public	50	50
nuclear	*selfproducers*		
	public		
geothermal	*selfproducers*		
	public		
	total	*490*	*490*
% variation	0.047		
Geothermal production share		-	-
% variation			

Annex 5.2

GEOTHERMAL OPERATORS

INDEX

1. FACTS ON GEOTHERMAL OPERATORS

The geothermal sector is both a natural phenomenon and an economic resource of the planet which has provoked the interest and intervention of man from different perspectives.

The geothermal sector involves a scientific interest which has continued to developed the knowledge of geothermal processes and their effects. Scientists, technicians, and researchers around the world strive towards this aim by means of theoretical and applied research, laboratory and field analyses, interpretation from surveys.

From a scientific viewpoint, the geothermal sector, is not a mono-thematic discipline limited only to the study on the origin of Earth's heat; other disciplines are also involved (volcanology, structural geology, hydro-geology, geophysics, geochemistry, etc. etc.).

The economic interest is aimed at the extraction and exploition of energy from the Earth for human needs (heat, electricity, curative) as described in the previous chapters.

Both scientific and economic aspects are strictly connected and interrelated. In fact, the economic interest of geothermal resources is a strong incentive for the continuous improvement of scientific and technological knowledge and consequent theoretical and applied research.

The aim of this study defines geothermal operators as those strictly and directly involved with the economic exploitation for energy production.

In this context the geothermal operators include:

- Consulting and engineering operators, who are mainly related to the "intellectual activity" during the field exploration phase, evaluation of field, reservoir and production, engineering, project management during the plant installation, field evaluation monitoring during exploitation, specialised studies and surveys etc.

  This category is very large and not easy to define and classify because it includes a number of operators from large companies, to the medium size, and very small ones, individuals, sectors of Universities and research centres, parts of firms also involved in other geological sectors which occasionally treat the geothermal one.

  In general, the world situation shows a stationary and often weakening status of the sector, due to the corresponding low development of projects in new areas. The European operators are strongly present in this category from many years especially in Italy for electricity generation and in Iceland, France and Germany for direct uses. The strong individual capabilities and firm's experience often do not show a corresponding strength in the world market due mainly to the fragmentation in small, medium entities and weak cooperation.

The situation appears even more stationary due also to the competition from non-EU operators, especially in the USA, Japan, and New Zealand, who are strongly represented in the more dynamic areas from geothermal development such as Indonesia and Philippines

- Drilling operators, who are those involved in well drilling and related activities. For this category, it is difficult to define the behaviour for the sector as most are not specifically or exclusively involved in geothermal drilling but are also involved in hydrocarbons and water markets.

  A general impression has become evident from the activities of big companies operating at continental and/or world level with established equipment. Another factor is the entry of firms from Central Eastern Countries sometimes directly, sometimes as subcontractors to the main western contractors. This last process is favoured because of the relatively good technical expertise of such drillers and their highly competitive prices.

  Drilling activity (exploration, exploitation, reinjection wells) is presently (1990-96) mainly concentrated in Indonesia, Philippines, Japan, USA, Mexico, Iceland, Italy. Data from the inventory indicate about 1,100 as total number of geothermal wells drilled in the world in 1990-96. This number can be assumed as lower limit considering the lack of data from some countries.

  European drilling operators have a good reputation from a technical point of view; they could also be active participants with new companies from Central Eastern European operators in the process of market penetration.

- Service operators, are those companies involved in specialistic activities related to all phases of the geothermal development such as geochemical/geophysical surveys, lab analyses, well logging, measurement/testing equipment (construction, installation) services related to plant operation. This category is wide and covers a lot of specialist activities traditionally subcontracted by the geothermal field developers. Many of these services are also performed by consulting engineering companies. Their activity is largely proportional to the plant behaviour.

- Plant manufacturers. This category includes different kind of operators (geothermoelectric power plants, direct uses plants, components, etc.).

  As far as geothermal electric plants are concerned, a more detailed survey is provided here.

2. MAIN MANUFACTURES MARKET SHARE: GENERAL CONSIDERATIONS

The world geothermal electricity generation capacity installed between the period 1971 - 1997 (including the under construction plants) is 7,282 MWe and 7,855 MWe including the plants scheduled for commissioning up to 2000, as presented Table 5.2.1 and Table 5.2.3.

In Table 5.2.2 the world installed capacity for all geothermal power plants manufacturers is given and amounts to about 9,700 MWe. For the same above period about 8,377 MWe (~90%) is plant manufactured by the present five world leaders of geothermal turbines and generators manufacturers: Ansaldo, Fuji, Mitsubishi, Ormat and Toshiba. The remaining 10% is divided between two other worldwide companies, Elliot Ge and GEC Alsthom (7%) and several companies with any national relevance.

The market is dominated by the five companies mentioned above which during the period 1971 - 1995 installed about 6,532 MW (73% of the worldwide total from table 5.2.2), in five continents, as shown in Table 5.2.3.
The European presence in the world market is represented by Ansaldo (20%) and GEC Alsthom (3%). Ansaldo products are distributed in different countries Indonesia, USA, Philippines, and the remainder in the Italian market. Both companies act at international level with a presence diffused across all the geothermal markets.

The Japanese share is dominant in the world market and represents more than 70% of the global market with conventional cycle power plants installed all over the world.
Ormat is the world leader of binary cycle type geothermal power plants.
Presently power plants utilising Ansaldo, Fuji, and Toshiba technology are under construction or are being commissioned in the world, amount for a total of about 1,260 in the period up to 2000. The Philippines represent the actual main market for the Japanese manufacturers, while Indonesia, Central America and Italy is the destination for the European leader, Ansaldo. The world market for this company in the period 1971- 1997 represents about 40% of its total installed capacity (Table 5.2.4).

A short company description for each of the above four main manufacturers of conventional cycle power plant (Ansaldo, Toshiba, Mitsubishi, Fuji) and for the main binary cycle plant producer, Ormat, and a summary of the supplied units are given with indication of the customer and the country where plants have been installed.

This census has been limited to the companies which have supplied reliable and complete historical data.

	MW installed	
Greece	2.0	
Iceland	75.0	
Italy	816.8	
Portugal	14.6	
Turkey	17.8	
Europe	926.2	**12%**
Kenya	45.0	**1%**
China	4.5	
Indonesia	420.0	
Japan	423.0	
New Zealand	97.3	
Philippines	1,449.7	
Thailand	0.2	
Asia	2,394.7	**33%**
Costarica	115.0	
El Salvador	95.0	
Mexico	813.0	
Nicaragua	70.0	
C. America	1,093.0	**15%**
USA	2,823.0	**39%**
TOTAL	7,282.0	

Tab. 5.2.1 Distribution of geothermal power (MWe) installed by countries and continents by the five world leader turbine and generator manufacturers (1971-1997).

Manufacturer	Geothermal power installed - MWe				
	up to 1971	1971-1985	1986-1995	1996-2000	Total
Toshiba		2,057	535.1	232	2,824.1
Ansaldo	655	163.3	810	571.3	2,199.6
Mitsubishi	10	950.8	846.9	60.0	1,867.7
Fuji		334.8	880.9	486.5	1,707.2
Ormat		1.7	190.8	63.6	256.1
Elliot Ge		410			410
Gec Alsthom		248			248
ND		81			81
Ben Holt Rotoflow		74			74
Nei Parson		25			25
Chinese companies		21			21
Russian companies		21			21
Mafi Trench		13			13
Aeg-Kanis		2			2
Turboden/Sowit			1.5		1.5
TOTAL	665	4,402.6	3,265.2	1,413.4	9,746.2

Table 5.2.2 - Geothermal power plants (Mw_e) installed in the world up to 1995 and 2000.

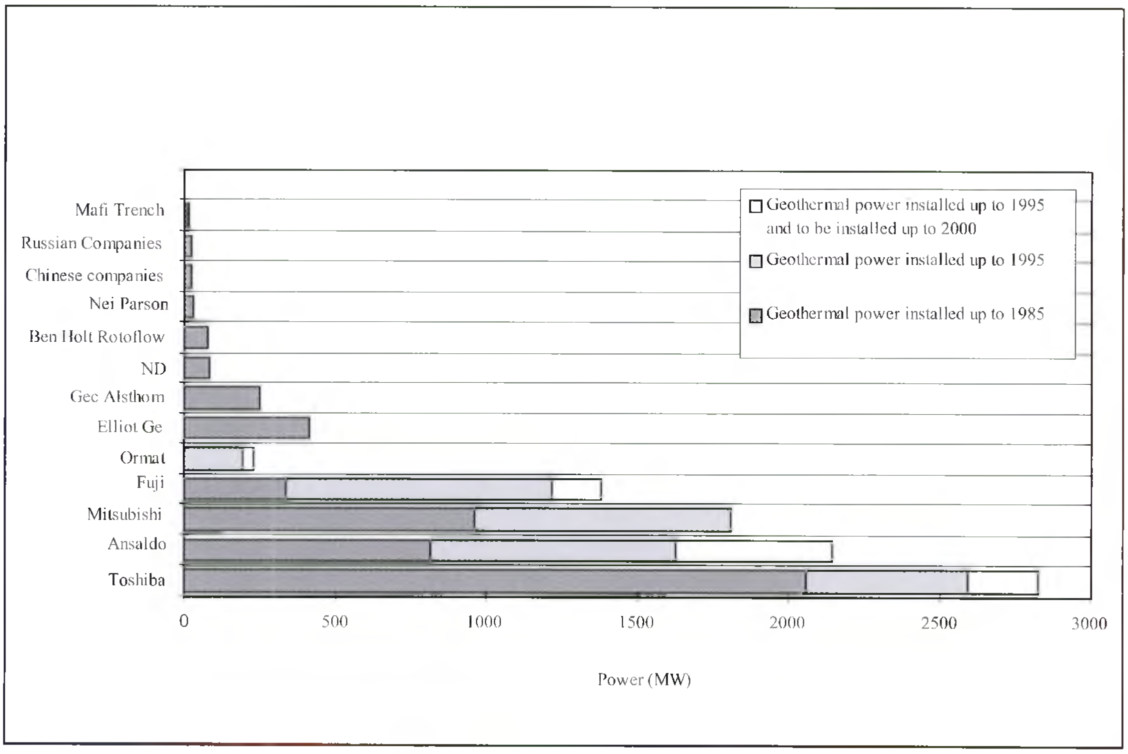


Fig. 5.2.1 Main manufacturers' market share

Period	*Turbine/Generator Manufacturer / MW installed*						America						Europa					Asia					Oceania	Africa
	Ansaldo	*Fuji*	*Mitsubishi*	*Ormat*	*Toshiba*	*Total*	USA	MEX	CR	GUA	El S.	NIC	GR	I	IS	P	TR	China	RI	J	T	RP	N.Z.	EAK
under commissioning	*60*	*224*	*-*	*57*	*232*	*573*			60	25	50											438		
under construction	511.3	262.5	60.0	6.6	-	840								396.3	90	6.6			115			232.5		
1991-1995	460	80.2	260.2	83	177.5	1,061	70	38	115					150	4.5	4.5			165	203		310		
1986-1990	350	568.2	586.7	101.7	357.6	1,964	1.133	350				35	2	160	4.5			1.3	110	55.5	0.2	15	97.3	
1981-1985	83.8	290.8	494	1.7	973	1,843	946	275				35		31			17.8	3.2	30	53.1		407.5		45
1976-1980	46	44	415.7	0	679	1,185	344	75			65			46	66	3				101		484.7		
1971-1975	33.5	0	40	0	405	479	330	75			30			33.5						10				
TOTAL	**1,484**	**1,246**	**1,857**	**193**	**2,592**	**7,372**	2,823	813	115	0	95	70	2	817	165	14.6	17.8	4.5	420	423	0.2	1,450	97.3	45
	20%	17%	25%	3%	36%		38%	11%	2%	0.5%	2%	1%	0%	11%	1%	0.2%	0.2%	0.1%	6%	6%	0%	20%	1%	1%
GRAN TOTAL	*1,544*	*1,470*	*1,857*	*250*	*2,824*	*7,945*			*175*	*25*	*145*											*1,888*		

Table 5.2.3 Country distribution of geothermal power plants installed (MWe) by the five leader manufacturers up to 1995, under construction (1997) and under commissioning.

under commissioning = 2x30 MW Costarica – Miravalles 3
1x25 Guatemala – Zumil
The Philippines:
180 MW (Leyte-Mahanagdong): 52 MW(Mindanao – Matingao)
18 MW (Leyte-Mahanagdong): 14 MW (Leyte – Tongonan 1)
154 MW (Leyte – S. Sambalouan); 20 MW (Bac Man, Botong)
2x25 El Salvador – Berlin 2

Country	**Turbine/Generator Manufacturer/MW installed (1971-1997)**					
	Ansaldo	Fuji	Mitsubishi	*Ormat*	Toshiba	*Total*
Costarica	55		5		55	115.0
China		3.2		1.3		4.5
El Salvador		35	60.9			95
Greece			2			2.0
Iceland		6	60	9		75.0
Indonesia	225		195			420.0
Italy	816.8					816.8
Japan		0.645	199.9		222.5	423.0
Kenya			45			45.0
Mexico	80	80	55	3	595	813.0
New Zealand			93.8	3.5		97.3
Nicaragua	70					70.0
Philippines	110	428	566.7	15	330	1,449.7
Portugal			3	1.6		14.6
Thailand				0.2		0.2
Turkey	17.8					17.8
USA	110	662.9	511.5	148.9	1,389.6	2,822.9
TOTAL	**1,485**	**1,216**	**1,797**	**193**	**2,592**	**7,282**

Table 5.2.4 Distribution of geothermal power (MWe) installed by countries and by the five leader turbine and generator manufacturers (1971-1997)

* Generators (only) installed in Indonesia (1x55 MW), in New Zealand (2x50 MW) and in Japan (1x25 MW)

ANSALDO ENERGIA S.P.A.

VIA NICOLA LORENZI, 8 - 16152 GENOA - ITALY
TEL. ++39 10 6551 FAX ++39 10 6556209

Ansaldo Energia is an Ansaldo Company - Finmeccanica Iri Group - and combines all manufacturing, engineering, contracting and service activities in the power generation field.
Ansaldo Energia designs and builds all kinds of power stations: steam fossil fired, gas turbine and combined cycle, hydroelectric, geothermal, nuclear, photovoltaic, fuel cell, as well as desalination plants: it can supply turn-key contract equipment , in separate lots, or components.

Ansaldo Energia is the result of a merger between Ansaldo Componenti, Ansaldo Gie and Franco Tosi in 1986; it also draws upon the manufacturing potential of different subsidiaries of Ansaldo: Coemsa Ansaldo (Brazil), Ganz Ansaldo (Hungary), Ansaldo Volund (Denmark).
The company is based in Genoa and Milan and has manufacturing facilities in Legnano, Genoa and Gioia del Colle (Italy), Canoas (Brazil), Budapest, Obuda, Szolnok, Baya and Gyula (Hungary).
Representatives abroad are spreaded all around Europe (Denmark, France, Germany, Greece, Hungary, Ireland, Luxembourg, Monaco, The Nederlands, Romania, Spain, Sweden, United Kingdom) Asia (Middle East: Emirates, Iran, Kuwait, Lebanon, Qatar, Saudi Arabia, Turkey, C.S.I.; Pacific: China, Hong Kong, India, Indonesia, Japan, Korea, Malaysia, Pakistan, Philippines, Singapore, Thailand) Africa (Algeria, Egypt, Morocco, Tunisia) and America (Southern: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Peru, Uruguay; Central: Costa Rica, Cuba, Republica Dominicana, Panama; Northern: USA).

The company's turnover is more than 10,000MECU (2,036.546 billion italian liras in 1994; 3,309.688 billion in 1995) and about 7,160 permanent employees (2,800 engineering, 3,060 manufacturing).Ansaldo Energia has installed over 131,000MW throughout the world of which 93,000MW is for thermal power plants.

Ansaldo Energia provides technical pre-sale services as well as financial, including project financing or equity participation in BOT / BOO projects.

Ansaldo has supplied 60 units - about 1400MW - in 8 countries between 1971-1997:

Country	NO. of Units	MW
Costa Rica	1	55
Indonesia	4	225
Italy	40	816.8
Mexico	10	80
Nicaragua	2	70
Philippines	2	110
Turkey	1	17.8
USA	2	110
total	**60**	**1484.6**

Ansaldo geothermal power plants installed in the world:

STARTUP DATE	NO. UNITS / MW	CUSTOMER	COUNTRY
	2×60	ENEL	Italy
	10×20	ENEL	Italy
UNDER	1×18.9	ENEL	Italy
CONSTRUCTION	3×15	ENEL	Italy
	1×12.4	ENEL	Italy
	1X60	CAL. ENERGY	Indonesia (Dieng)
	1×55	PLN	Indonesia (Salak 3)
	TOTAL 511.3MW		
	2×60	ENEL	Italy
	2×15	ENEL	Italy
1991-1995	2×55	NAPCOR	Philippines
	2×55	PLN	Indonesia
	1×55	ICE MIRAVALLES II	Costa Rica
	7×5	CFE	Mexico
	TOTAL 460MW		
	2×20	ENEL	Italy
	5×18	ENEL	Italy
1986-1990	2×15	ENEL	Italy
	3×15	CFE	Mexico
	1×35	INE	Nicaragua
	2×55	NCPA	USA
	TOTAL 350MW		
	1×35	INE	Nicaragua
1981-1985	1×17.8	TEK	Turkey
	1×15	ENEL	Italy
	2×8	ENEL	Italy
	TOTAL 83.8MW		
1976-1980	2×15	ENEL	Italy
	2×8	ENEL	Italy
	TOTAL 46MW		
	2×15	ENEL	Italy
1971-1975	1×3.5	ENEL	Italy
	TOTAL 33.5MW		
	632.9	ENEL	Italy
1926-1970	20.3	BORACIFERA LARDERELLO	Italy
	1.8	CFE	Mexico
	TOTAL 655MW		
From 1926 to date:	GRAND TOTAL 2,139.6MW	installed in the world.	

FUJI ELECTRIC CO., LTD.

12 - 1 YURAKUCHO 1 - CHOME, CHIYODA-KU, TOKIO, 100 JAPAN
TEL. ++81 3 3211 - 7111 FAX ++81 3 211 - 7988

Fuji Electric supplied 43 units in the world and operates in 9 countries.
The company produces a wide variety of turbines, single flash and double flash cycles, with capacity range from 100kW - 150,000 kW.
Fuji main market area for geothermal turbines during 1981-89 was the USA (660MW installed), presently Philippines and Mexico represent the only large market.
The company installed mainly generators in Indonesia (1994) and New Zealand (1986); its market share in Japan is very low, latest installations were made in 1989-91 for only 245 kW.

Fuji Electric co. has supplied 43 units, for about 1,200 MW installed in the following countries during the period 1975 - 1996:

Country	NO.of Units	MW	Notes
China	1	3.2	
El Salvador	1	35	
Iceland	1	6	
Indonesia	(1)	(55)	generator only
Japan	4+(1)	0.645+(25)	no.1 generator only
Mexico	4	80	
New Zealand	(2)	(100)	generator only
Philippines	12	428	
U.S.A.	19	662.9	
total	**43**	**1215.7**	

Fuji electric geothermal power plant installed in the world 1975-1996:

STARTUP DATE	NO. UNITS / MW	CUSTOMER	COUNTRY
1991 - 1995			
1991	1×0.2	BEPPU REHAB. CENTER	Japan
1993	1×20	NPC / PALIMPINON	Philippines
1994	3×20	NPC / PALIMPINON	Philippines
1996/97	3×77.5	NPC / MALITBOG	Philippines
	TOTAL 312.7		
1986 - 1990			
1986	1×55	DEPT. WATER RESOURCES	USA
1987	4×20	CERRO PRIETO CFE	Mexico
1988	1×60.5	OXBOW GEOTH . CORP.	USA
1988	2×35.8	MAGMA POWER CO.	USA
1988	2×30	COSO GEOTH. CO.	USA
1988	0.3	NEDO NIPPON STEEL CORP.	Japan
1989	6×30	COSO GEOTH. CO.	USA
1989	1×35.8	MAGMA POWER CO.	USA
1989	2×12.5	MISSION POWER ENG. CO.	USA
1989	1×0.045	TAKENAKA KOUMUNTEN CO.	Japan
	TOTAL: 568.2		
1981 - 1985			
1981	1×55	NORTHERN CALIF. POWER AGENCY	USA
1981	1×10	SOUTHERN CALIF. EDISON CO.	USA
1982	1×55	NORTHERN CALIF. POWER AGENCY	USA
1983	3×37.5	NPC / PALIMPINON	Philippines
1983	1×0.1	DAIWABOO KANKOO CO.	Japan
1985	1×55	DEPART. WATER RESOURCES	USA
1985	1×3.2	NAT. TECH. IMPORT CORP.	China
	TOTAL: 290.8		
1975 - 1980			
1980	2×1.5	NPC / PILOT PLANT OKOY	Philippines
1980	1×35	CEL / RIO LEMPA	El Salvador
1980	1×6	SUDURNES REG. HEATING	Iceland
	TOTAL: 44		
From 1975 to 1996	GRAND TOTAL 1,215.7MW	installed in the world.	

MITSUBISHI HEAVY INDUSTRIES, LTD

POWER SYSTEM HEADQUARTERS
5-1, MARUNOUCHI 2-CHOME, CHIYODA-KU, TOKYO, JAPAN
TEL. ++81 3 3212 - 2111 FAX ++81 3 3212 - 9841

Mitsubishi is one of the largest supplier companies with 69 units installed in the world and operates in 12 countries. The company produces a wide variety of unit types, with capacity range from 100kW - 150,000 kW, modular skid mounted turbines and three plant cycles: single flash, double flash and binary.
Mitsubishi has total engineering capabilities: design, system engineering and equipment (from well head to transmission line) for full turnkey geothermal power plants.

The company is based in Tokyo and has manufacturing facilities in Nagasaki and a Power System Division in USA and representatives all over the world.

Mitsubishi has supplied 69 units, for about 1,800 MW installed in the following countries during the period 1967-1995:

Country	NO. of Units	MW
Costarica	1	5.0
El Salvador	3	61.1
Greece	1	2.0
Iceland	2	60.0
Indonesia	4	195.0
Japan	11	209.9
Kenya	3	45.0
Mexico	6	55.0
New Zealand	2	93.8
Philippines	17	566.7
Portugal	1	3.0
U.S.A.	18	511.5
TOTAL	**69**	**1808.0**

Mitsubishi Heavy Industries geothermal power plant installed in the world, 1967-1995:

STARTUP DATE	NO. UNITS / MW	CUSTOMER	COUNTRY
1991 - 1995			
1995	1×30	KYUSHU ELEC. POWER CO.	Japan
1995	1×50	TOUHOKU ELEC. POWER CO.	Japan
1994/95	2×20	NPC/BACON MANITO	Philippines
1995	4×20	NPC / MAK - BAN	Philippines
	1×5	MIRAVALLES	Costa Rica
1994	1×55	DARAJAT / PLN	Indonesia
1991	1×0.2	HIROSE SHOUJI	Japan
	TOTAL 260.2MW		
1986 - 1990			
1987	2×55	KAMOJANG / PLN	Indonesia
1987	1×2	GREECE PPC	Greece
1987	1×25	AMJV / COSO	USA
1988/89	2×11	FREEPORT GEOT.RES. CO.	USA
1988	2×46.9	NZE	New Zealand
1988	1×0.2	NIPPON STEEL CORP.	Japan
1988	1×54	DESERT POWER CO.	USA
1989	2×14.4	FREEPORT MCMORAN RES. CO.	USA
1989	2×18.5	GEO. EAST MESA	USA
1989	2×1.9	GEO EAST MESA	USA
1989	1×150.9	PG&E THE GEYSERS	USA
1990	1×4.2	UNOCAL SALTON SEA	USA
1990	1×55	KYUSHU ELEC. POWER CO.	Japan
	TOTAL 586.7MW		
1981 - 1985			
1981	1×3	SUGINOI GEO. POWER PLANT	Japan
1981	1×15	KENYA KPC	Kenya
1981	1×30	CERRO PRIETO CFE	Mexico
1982	5×5	AZUFRES CFE	Mexico
1982	1×15	KENYA KPC	Kenya
1983	1×70.7	SMUD	USA
1983	1×30	KAMOJANG PLN	Indonesia
1982/83	2×37.5	TONGONAN LEYTE NPC	Philippines
1984	2×55	MALIKING BANAHAW NPC	Philippines
1985	1×15	KENYA KPC	Kenya
1985	hp+lp 36.6	MAGMA	USA
1985	1×52	HEBER GEOTHERMAL. CO.	USA
1985	1×16.7	CHEVRON GEOTHERMAL CO.	USA
	TOTAL 494MW		
1976 - 1980			
1976	1×30	AHUACHAPAN CEL	El Salvador
1977	1×1	JAPANESE GOVERNMENT	Japan
1977	1×50	KYUSHU ELEC. POWER CO.	Japan
1977	1×37.5	TONGONAN LEYTE NPC	Philippines
1977	1×3	TONGONAN LEYTE NPC	Philippines
1978	2×30	KRAFLA	Iceland
1979	1×1.2	MAKILING BANAHAW NPC	Philippines
1979	2×55	MAKILING BANAHAW NPC	Philippines
1980	2×55	MAKILING BANAHAW NPC	Philippines
1980	1×10	UNOCAL SALTON SEA	USA
1980	1×3	AZORES SRCI	Portugal
	TOTAL 415.7MW		
1967 - 1975			
1967	1×10	KYUSHU ELEC. POWER CO.	Japan
1973	1×10	MITSUBISHI METAL CO.	Japan
1975	1×30	AHUACHAPAN CEL	El Salvador
1975	1×1.1	AHUACHAPAN CEL	El Salvador
	TOTAL 51.1MW		
From 1967 to 1995	GRAND TOTAL 1,807.7MW	installed in the world.	

ORMAT INDUTRIES LTD

980 GREG ST. , SPARKS, NEVADA 89431- 6039
USA
TEL. ++ 1 702 356 9029 FAX ++1 702 356 9039

P.O. BOX 68 – YAVNE 81100 ISRAEL
TEL. ++ 972-8-94337351 FAX ++972–8 -9439901

The Israeli company ORMAT, with its U.S. subsidiary, is the world' s largest Organic Rankine Cycle technology manufacturer.
Since 1965, some four thousand ORMAT Energy Converters (OEC) based on ORC technology have been supplied and are operating in over 55 countries. Among them more than 200 OECs, for about 300 MW, which operate on geothermal sources in the USA, Mexico, the Philippines, New Zealand, Portugal, Iceland, Thailand , China and Italy.

Ormat modular power plants , utilizing Geothermal Combined Cycle and Binary Technologies are designed and tailored to the resource, to optimize efficiency and cost-effectiveness of electrical generation.
The modular power plants, ranging from 200 KW to over 120 MW, efficiently match the power plant to the geothermal resource characteristics, steam quality and brine chemistry.
Binary technologies are water cooled, air cooled and two phase types with geothermal fluid temperature from 95°C to 315°C.
Ormat developed the Geothermal Combined Cycle Units (GCCU) to generate power from high pressure geothermal steam resources at up to 315°C

ORMAT OECs are modular, self-contained units, comprising factory tested, skid mounted components which include heat exchangers, turbine, generator, control system, low and high voltage swithgear, valves, safety circuits and piping. Isopentane is generally used as working fluid.
Ormat has experience on developing geothermal power plants projects under a Total Project Management concept that includes design, engineering, manufacturing, financing, construction and operation. The company can take responsability for equipment supply only or assume total project responsability under BOO, BOOT, and BTO arrangements.

The main market areas for Ormat remain the USA with up to 149 MW installed and the Philippines were about 32 MW have been commissioned in 1997 and where construction has just started.
The main Ormat application of OECs units during the period 1984-1997 are:

Country	**MW**
China	1.3
Iceland	9.0
Mexico	3.0
New Zealand	3.5
Philippines	15
Portugal	11.6
Thailand	0.2
U.S.A.	148.9
Total	**192.5**

Ormat OECs plants installed in the world 1984-1997:

STARTUP DATE	NO. UNITS / MW	CUSTOMER	COUNTRY
On Commissioning			
1997	14	LEYTE, TONGONAN 1 NPC	Philippines
1997	18	LEYTE, MAHANAGDONG, NPC	Philippines
?	?	BAC-MAN- BOTONG	Philippines
	TOTAL 32MW		
1991 - 1995			
1992	4.5	SUDURNES REG. HEAT. CO.,SVARTSENGI	Iceland
1992	30	PUNA GEOTH. POWER, HAWAII	USA
1993	40	HEBER S. GEOTH. IMPERIAL,CALIFORNIA	USA
1993	3	LOS AZUFRES, CFE	Mexico
1994	2×2.5+3×2.2	RIBEIRA GRANDE, SOGEO, AZORES	Portugal
	TOTAL 89.1MW		
1986 - 1990			
1986	5.2	STEAMBOAT, NEVADA	USA
1986	30	ORMESA, EAST MESA, CALIFORNIA	USA
1987	15	NPC / MAK BAN	Philippines
1989	42	ORMESA, EAST MESA, CALIFORNIA	USA
1989	3.5	TARAWERA, KAWERAU	New Zealand
1989	1.3	NAGQU, TIBET	China
1989	0.2	EGAT, FANG	Thailand
1989	4.5	SUDURNES REG. HEAT. CO.,SVARTSENGI	Iceland
	TOTAL 101.7MW		
1981 - 1985			
1984	1.7	TAD'S ENTERPRISES, WABUSKA , NEVADA	USA
	TOTAL 1.7MW		
From 1984 to 1997	GRAND TOTAL 224.5MW	installed in the world.	

TOSHIBA CO., LTD.

POWER SYSTEMS DIVISION, 1-6 UCHISAIWAI-CHO
I-CHOME, CHIYODA-KU, TOKIO 100, JAPAN
TEL. ++ 81 3 597 2338 FAX ++ 81 3 597 2501

Toshiba supplied 39 units in the world and operates in 5 countries.
The company produces condensing type turbines, single flash and double flash cycles, with capacity range from 20,000 kW - 124,000 kW.
Toshiba main market area for geothermal turbines during eighties and seventies was USA (1389,6 MW installed), Philippines and Mexico. Since 1994 the market is limited to Japan.

Toshiba has supplied 38 units, for about 2600 MW installed in the following countries during the period 1971 - 1996:

Country	NO.of Units	MW
Costa Rica	1	55
Japan	5	222.5
Mexico	9	595
Philippines	6	330
U.S.A.	17	1389.6
total	**38**	**2592.1**

Toshiba geothermal power plant installed in the world 1975-1996:

STARTUP DATE	NO. UNITS / MW	CUSTOMER	COUNTRY
1991 - 1995			
1992	1×55	Miravalles 1, ICE	Costa Rica
1994	1×27.5	Tohoku Electric Power	Japan
1995	1×65	Tohoku Electric Power	Japan
1996	1×30	Tohoku Electric Power	Japan
	TOTAL 177.5MW		
1986 - 1990			
1986	1x110	Cerro Prieto, CFE	Mexico
1987	1×110	Crieto Prieto, CFE	Mexico
1987	1×5	Instituto Invest. Electrical	Mexico
1988	2×66.3	Central Calif. Power Co.	USA
	TOTAL 357.6MW		
1981 - 1985			
1985	2×110	Cerro Pietro, CFE	Mexico
1985	1×124	Pacific Gas & Elec. Co., Geysers	USA
1984	2×48.5	Occidental Geothermal Inc.	USA
1983	2×124	Pacific Gas & Elec. Co., Geysers	USA
1982	1×124	Pacific Gas & Elec. Co., Geysers	USA
1982	2×55	NPC	Philippines
1982	1×50	Hokkaido Electric Power Co.	Japan
	TOTAL 973MW		
1975 - 1980			
1980	1×114	Pacific Gas & Elec. Co., Geysers	USA
1980	2×55	NPC	Philippines
1979	2×37.5	Cerro Prieto, CFE	Mexico
1979	2×55	NPC	Philippines
1978	1×50	Tohoku Electric Power	Japan
1975	2×110	Pacific Gas & Elec. Co., Geysers	USA
	TOTAL 679MW		
1971 - 1974			
1973	2×55	Pacific Gas & Elec. Co., Geysers	USA
1973	2×37.5	Cerro Prieto, CFE	Mexico
1972	2×55	Pacific Gas & Elec. Co., Geysers	USA
1971	2×55	Pacific Gas & Elec. Co., Geysers	USA
	TOTAL 405MW		
From 1971 to 1996	GRAND TOTAL 2,592.1MW	installed in the world.	

Annex 5.3

CENSUS OF EU AND NON-EU FINANCING AGENCIES TO GEOTHERMAL SECTOR

INDEX

1. OVERWIEW ON MAIN INTERNATIONAL FINANCING AGENCIES

A list of the main international agencies and some of the national ones that financed the geothermal sector is presented.
These EU and non EU agencies have been, and are presently active, in supporting geothermal projects in all its activities and phases: exploration, drilling, plant installation.
Identified funds are distributed by years and divided according to the type of use for the geothermal resources: electric generation, direct use of heat , combined use of heat. Funds committed to support project only in research and tecnology including reconnaissance, pre- and feasibility studies, training courses and technical assistance are also indicated.

The EU General Directorates analysed are : DG I, DG XII, DG XVII with their relevant programmes. Other European agencies are : European Investment Bank (EIB), the European Bank for the Reconstruction and Development (EBRD), the Nordic Finance Group (NFG), based in Finland and the Directorate for Development and Cooperation (DGCS) of the Italian Foreign Ministry (MAE). Between the main international agencies the census includes the Inter-American Development Bank (IADB), the Asian Development Bank (ADB) and the World Bank (WB) with all its five main lending organizations.

List does not included private interest groups and some national or regional cooperation agencies whose data were not available such the Overseas Economic Cooperation Fund (OECF), the Japanese co-operation agency which actively operates in the Far East area in supporting geothermal activities.

The period considered is from 1978 to 1997 - 2000. In Table 5.3.1 are summarized the funds committed during the above period with indications of the geographical area where projects were implemented.

The total funds (loans and grants) amount to about 2,446 MECU of which 86% to support worldwide activities in Central and Southern America, The Philippines, Indonesia, Eastern Africa, while only the 14% in European countries with an increasing trend for international financing agencies as EBRD and WB to support geothermal projects in countries such Russia and CIS countries (see Figures 5.3.1, 5.3.2).
The total funds, as loans and grants by each financing agency are shown in Figure 5.3.3.

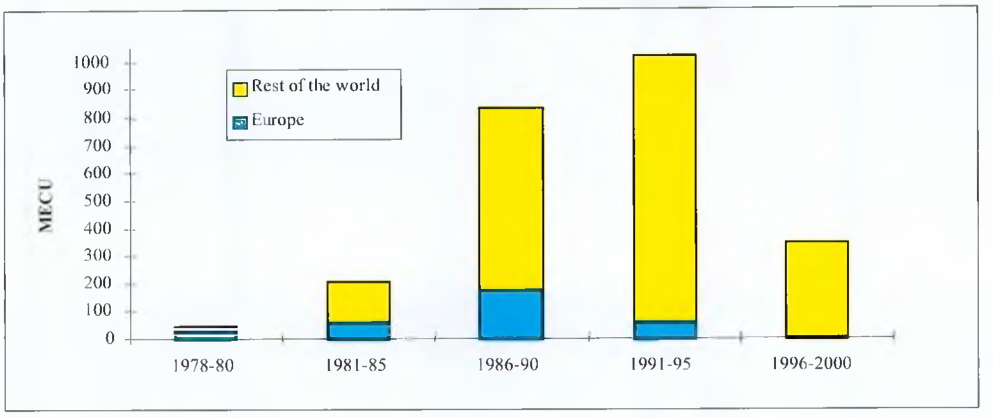


Fig. 5.3.1 Total Funds committed from 1978 to 2000

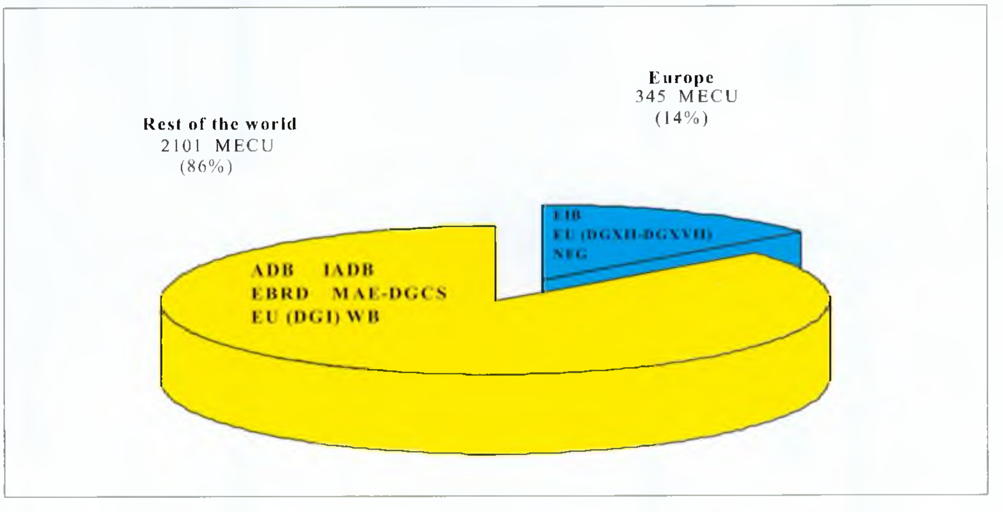


Fig. 5.3.2 International Financing Agencies, and destination area of the support (1978-2000)

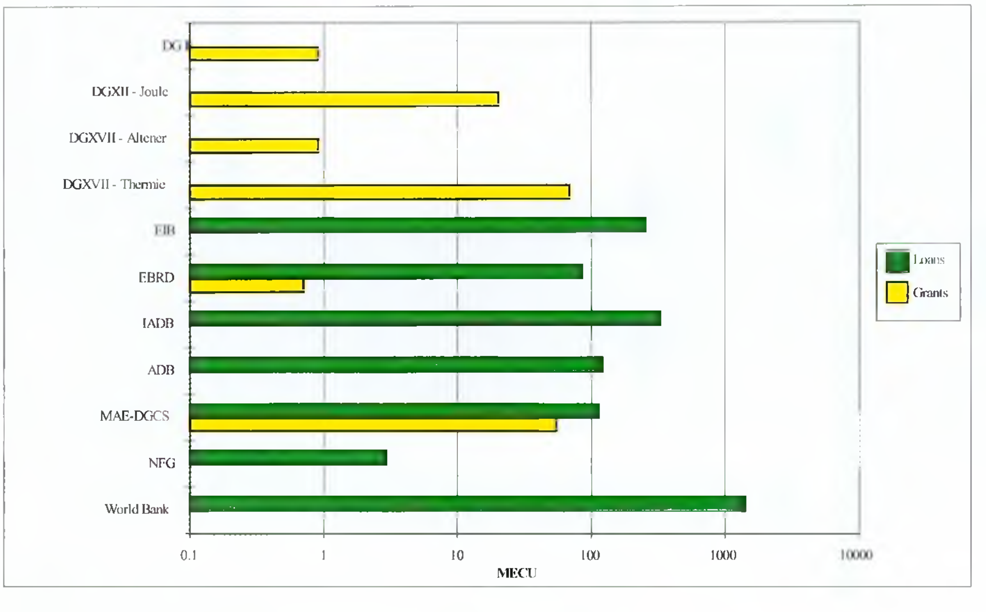


Fig. 5.3.3 Total funds (1978-2000) as loans and grants

	1978 – 1980					1981 – 1985					1986 – 1990					1991 - 1995					1996 – 1997 and 2000					TOTAL
	Elec.	Dir.	Com.	R&T	M ECU	Elec.	Dir.	Com.	R&T	MECU	Elec.	Dir.	Com.	R&T	M ECU	Elec.	Dir.	Com.	R&T	M ECU	Elec.	Dir.	Com.	R&T	MECU	MECU
EU-DG I																			0.6	0.6				0.3	0.3	**0.9**
EU-DG XII JOULE					1.0					1.0					2.0					13.6					2.5	**20**
EU-DG XVII																										
THERMIE	7.4	7.6	0	0	15.0	3.0	9.4	3.1	0.2	15.8	1	4.4	5.8	2.1	13.3	3.9	6.9	5.2	3.1	19.0	0	1.5	1.9	1.6	5.0	**68**
ALTENER																			0.4	0.4				0.5	0.5	**0.9**
E.I.B.		16.6			16.6		47.4			47.4		163.2			163.2		26.3			26.3						**254**
E.B.R.D																			0.2	0.2	85.0 Russia			0.5 Russia	85.5	**86**
I.A.D.B.				10.3	10.3	68.5			21.9	90.4	57.9			9.8	67.7	153.3			2.1	155.4				3.6	3.6	**327**
A.D.B											120 The Philippines				120											**120**
M.A.E. (1) DGCS						5.9			14.4	20.3	15.2			10.5	25.7	120.5			0.2	120.7						**167**
W.B. (2)						32.6				32.6	440.4				440.4	357.3		324.7		682.0	4.8		138.6	102	245.6	**1,400**
NFG																										
NIB																	0.86		0.09	0.95		0.45		0.04	0.49	**1.44**
NDF																	0.51		0.05	0.56		0.18		0.02	0.20	**0.76**
NEFCO																	0.23			0.23		0.21			0.21	**0.44**
NOPEF								0.01		0.01			0.2		0.2								0.05		0.05	**0.26**
TOTAL					**43**					**207**					**832**					**1,020**					**344**	**2,446**

Table 5.3.1 Organizations and funds committed to support geothermal activities from 1978 to 1997 and forecast to 2000

LEGEND

Type of use for the geothermal resources:
Elec.: Electric generation
Dir.: Direct use of heat
Com.: Combined use of heat
R&T: Research & Technology (including reconnaissance, pre- and feasibility studies, training courses

Geographical area of the funded geothermal

EUROPE
RUSSIA and GEORGIA
LATIN AMERICA
ASIA

(1) Projects funded by MAE were located in Latin America, Asia and Africa.
(2) Projects funded by WB were located in Latin America, Asia and Africa and Russia.

EU-DG I

European Commission - Directorate General I

Rue de la Loi 200 – B-1049 Brussels (Belgium)

The European Commission is organised in Directorates General (in charge of specific themes) and Directorates which are in charge of specific areas. DG I usually supports the technical assistance projects as grants and in case of co-financiation also loans.

DG I generally allocates an annual budget for countries distributed according to priority sectors established with local Authorities in those countries. Projects are planned on the basis of the established sectors and priorities by local Authorities with the participation of local E.U. representatives. The opportunities are diffused through the Official Gazette of European Community and the assignments are made through open tender subsequent to a pre-selection.

DG I has supported two geothermal projects, both of them in Guatemala. In particular it has granted 640,000ECU in 1993-96 for the pre-feasibility study of San Marco area and 300,000ECU for a study aimed at the optimisation of energy cost and price in that country.

[1] FUNDS COMMITTED TO SUPPORT GEOTHERMAL ACTIVITIES

EU-DG I

YEAR	PROJECTS SUPPORTED	TOTAL SUPPORT (ECU)	UTILIZATION	ITEMIZED SUPPORT (ECU)
1977-1992			Electricity generation	
			Direct uses	
			Combined uses	
			Research & Technology	
1993-1995	1	640,000	Electricity generation	
			Direct uses	
			Combined uses	
			Research & Technology	640,000
1996-1997	1	300,000	Electricity generation	
			Direct uses	
			Combined uses	
			Research & Technology	300,000
GRAND TOTAL	**2**	**940,000**		

[1] Item *Research & Technology* includes reconnaissance, pre- and feasibility studies, training courses and assistance. Items *Electricity generation*, *Direct uses* and *Combined uses* include maintenance & rehabilitation of the plants.

EU-DG XII

European Commission - Directorate General XII

Science, Research and Development

Rue de la Loi 200 - B 1049 Brussels - Belgium

DG XII has supported several projects related to Research and Development actions in the past 20 years.

With regards to the geothermal sector DG XII has supported and continues to support the research and development of technologies mainly through the JOULE Programme.

The JOULE Programme deals with and supports R&D projects generally related to the following topics, which can slightly vary during the time:

- Research and technology development strategy relevant to the energy framework as analysis, socio-economic research, environment, economical aspects;
- Rational use of energy aimed at the reduction of the energy demand and increasing the energy efficiency of the main sources of consumption;
- Stimulate the introduction of the renewable sources and increase their utilization;
- Introduction of innovations in the use of coal and hydrocarbons in the fossil fuels sector;
- Dissemination of technologies.

According to the recent policy of DG XII, conventional European geothermal development does not justify further R&D support from public funds as it is technically successful (even if problems, either of economic/financial or only of local significance, still remain).
For this reason, at present, support for *conventional* geothermal research (though this could change again in the future) it is not foreseen.

The support for *non-conventional* geothermal research still goes on; in particular DG XII still provides support for the research of Hot Dry Rocks. A single European HDR project brings together all the interested parties onto a single site (Soultz-sous-Forêts) which is progressing towards a pilot plant post-1998.

In the years 1977 to 1992 DGXII supported R&D into geothermal resources and technologies. During that period several projects where financed in conventional geothermal research and resource assessment sectors up to a total amount of about 4MECU.

In the period 1992-1996 a total contribution of 4.6MECU was devoted to 7 R&D projects in the geothermal conventional sector.

The support for non-conventional geothermal resources DGXII in the years 1993-1995 was 9MECU (out of 26MECU total cost) and the corresponding figures for 1996-1997 are 2.5MECU and 6.8MECU respectively.

Summing up, a total support of 20.1MECU has been allocated from DG XII for geothermics, conventional and non-conventional, from 1977 up to now.

FUNDS COMMITTED TO SUPPORT GEOTHERMAL ACTIVITIES

EU-DG XII - JOULE

YEAR	PROJECTS SUPPORTED	TOTAL SUPPORT (ECU)	UTILIZATION	ITEMIZED SUPPORT (ECU)
1977-1992	?	4,000,000	Electricity generation Direct uses Combined uses Research & Technology	
1993-1995	7	13,600,000	Electricity generation Direct uses Combined uses Research & Technology 7	
1996-1997	?	2,500,000	Electricity generation Direct uses Combined uses Research & Technology	
GRAND TOTAL		**20,100,000**		

EU-DGXVII

European Commission - Directorate General XVII

Energy

Rue de la Loi 200 - B 1049 Brussels - Belgium

The most important programmes funded by this Directorate are ALTENER and THERMIE:

ALTENER programme was established by a Council decision on 13rd September 1993 for the promotion of renewable energies in the Community.

ALTENER is the only programme which focuses exclusively into renewable energy sources close to commercial exploitation (wind power, solar energy, hydropower, geothermal energy) and is aimed at the renewable energy development across the Community providing support for pilot actions proposed by Member States.

The programme was established for five years (from 1993 to 1997) and appropriated a total budget of 40MECU.

The specific target by the year 2005 are the following:

- To increase the consumption of renewable energies with respect to the total energy consumption (from 4% in 1991 to 8% in 2005);
- To triple the production of electric energy obtained from renewable energies (except hydro power plants with more that 10MW of total installed power);
- To reduce the emission of carbon dioxide by 180 million tons;
- To attain of a market share of 5% for biofuels on respect to the total fuel consumption for motor vehicles.

The topics covered by the programme are:

- The integration of renewables and the removal of different kind of obstacles and creation of regional centers for RES;
- Financial and economic measures to improve the use of RES to elaborate development plans and prefeasibility evaluations;
- The training of potential developers and investors, exchange of experiences and dissemination of information;
- The cooperation of new Community Countries;
- Other projects useful to the general target of the programme.

The key players in the geothermal sectors as developers, investors, public authorities have to set a detailed proposal with sufficient technical economical explainatory elements according to the format established by the Commission.
Projects of national interest have a dead time while those of general interest can be presented in every moment.
The proposals are examined and judged. If passed, the financial support, that can vary from 50% to 100% of the total cost, is assigned.

From the beginning of the programme (1993) the support to projects exclusively related to geothermal resources had reached about 500,000ECU (not including projects relevant to the integration of different RES).

The projects financed were 3 in 1994, 1 in 1995 and 2 in 1996.

FUNDS COMMITTED TO SUPPORT GEOTHERMAL ACTIVITIES

EU-DG XVII - ALTENER

YEAR	PROJECTS SUPPORTED	TOTAL SUPPORT (ECU)	UTILIZATION	ITEMIZED SUPPORT (ECU)
1994	3	?	Electricity generation Direct uses Combined uses Research & Technology	
1995	1	360,000	Electricity generation Direct uses Combined uses Research & Technology	360,000
1996	2	488,000	Electricity generation Direct uses Combined uses Research & Technology	488,000
GRAND TOTAL	**6**	**848,000**		

THERMIE programme started in 1990 as a prosecution of the previous Community Demonstration Programme which covered the periods 1978-1982, 1983-1985, 1986-1989.

Although the detailed content of the programme has changed somewhat in the time, the general criteria remain to assure the energy supply, the energy saving, the reduction of the environmental impact and the strenghtening of technological skills within the industry.
The specific objectives are to improve the energy efficiency (demand and supply), to improve the use of renewable energies, to encourage an environment only friendly use for coal and solid fuels, the optimization of gas and oil exploitation in the EU, the dissemination of the new technologies and their the promotion.
The programme is updated yearly.

The proposals must be presented by at least two participants of different EU Member States and the Community financial participation is around 35% except for universities or similar institutions for which support may be total.

The projects must have innovative components or set improvement for the existing technologies. The products or processes must have passed the R&D phase in order to be demonstrative.

The key players interested in such demonstrative project have to set a detailed proposal, according to the format established by the Commission with detailed technical economical explanatory elements.

THERMIE programme has been and is still strongly active in the support to geothermal sector.
The specific sector which have been financed are electricity generation, direct uses (district heating, acquaculture, greenhouse heating), combined uses, industry &

technology.
Beneficiary countries are, in order: France (36 projects supported), Italy (30), Germany (20), Spain (12), Greece (7), Portugal (6), Denmark (5), UK (4), Belgium (3), Austria (2), The Nederlands (2), Iceland (1), Ireland (1).

From 1979 to 1996, 129 projects in geothermal sector have been supported corresponding to a total amount of around 68MECU.

FUNDS COMMITTED TO SUPPORT GEOTHERMAL ACTIVITIES

EU-DG XVII - THERMIE

YEAR	PROJECTS SUPPORTED	TOTAL SUPPORT (ECU)	UTILIZATION		ITEMIZED SUPPORT (ECU)
1978-1980	23	15,026,700	Electricity generation	5	7,443,400
			Direct uses	18	7,583,300
			Combined uses	-	-
			Research & Technology	-	-
1981-1985	34	15,775,000	Electricity generation	4	3,045,500
			Direct uses	24	9,444,700
			Combined uses	5	3,097,400
			Research & Technology	1	187,400
1986-1990	34	13,345,000	Electricity generation	1	1,000,100
			Direct uses	12	4,430,500
			Combined uses	11	5,813,000
			Research & Technology	10	2,101,400
1991-1995	32	18,853,400	Electricity generation	3	3,903,400
			Direct uses	12	6,698,500
			Combined uses	9	5,144,200
			Research & Technology	8	3,107,300
1996	6	4,941,900	Electricity generation	-	-
			Direct uses	2	1,488,900
			Combined uses	2	1,891,900
			Research & Technology	2	1,561,100
GRAND TOTAL	**129**	**67,942,000**			

E.I.B.

European Investment Bank

100 Boulevard Konrad Adenauer - Brussels - L-2950 Luxembourg

Ph. +352 4379 3149 - Fax +352 4379 3189 / 3188

EIB has funded 10 geothermal projects and only in Italy in the Mt Amiata area (near the big Larderello geothermal field). The beneficiary was ENEL and total funding from 1978 to 1993 was about 253.4MECU.

FUNDS COMMITTED TO SUPPORT GEOTHERMAL ACTIVITIES

EIB

YEAR	PROJECTS SUPPORTED	TOTAL SUPPORT (ECU)	UTILIZATION	ITEMIZED SUPPORT (ECU)
1976-1980	1	16,580,000	Electricity generation Direct uses Combined uses Research & Technology	
1981-1985	2	47,370,000	Electricity generation Direct uses Combined uses Research & Technology	
1986-1990	6	163,160,000	Electricity generation Direct uses Combined uses Research & Technology	
1991-1995	1	26,320,000	Electricity generation Direct uses Combined uses Research & Technology	
1996-2000			Electricity generation Direct uses Combined uses Research & Technology	
GRAND TOTAL	**10**	**253,430,000**		

E.B.R.D.

European Bank for the Reconstruction and Development

One Exchange Square - London EC2A2ETT - England

The European Bank for the Reconstruction and Development was founded by several leading countries with the purpose of providing Eastern European countries with a financial instrument to support their transition to market economies to achieve better efficiency for both public and private initiative and stimulating private enterprises growth.

EBRD gives financial opportunities through equity, quasi equity, depth instruments and grants for the realisation of projects and studies as well as engineering activities.

The Bank co-operates with other bilateral and multilateral institutions (WB, IFC, MIGA, EU, EIB, export credit agencies and commercial entities) co-financing projects.

The way to access funding generally occurs through a direct request from the investors either public or private. For the realisation of projects, supply of goods, technical assistance services, consultancy, studies and similar, the Bank acts through a specific call for tenders, open competition mostly on an international basis.

With reference to funding projects to private or public entities, the Bank performs a detailed evaluation and investigation on the technical/economical reliability of the project with special focus on the intrinsic profitability and cash flow generation of the project.

The applicant is subject to verification and has to offer adequate reliability and guarantees.
For operations in the public sector (governments, public agencies, public utilities owned or controlled by national or local governments, agencies and enterprises majorities owned by governments) the contracts follow open tendering if their value is esteemed equal or greater than 200,000ECU for goods and services and 5,000,000ECU for work execution. Notification is published in the Bank's bulletin “Procurement Opportunities” and in the United Nations “Development Business”.

For operations in the private sector the Bank acts mainly following the common banking procedures with lower constrains regarding the uses of international tenders to obtain goods or services.

For consultant services the Bank adopts flexible and transparent procedures. For contract values less than 50,000ECU the firm or the individual can be selected directly; for values of between 50,000 and 200,000ECU the selection is carried out on the basis of a short list of qualified candidates. For major contracts valued at over 200,000ECU, a more competitive procedure based on a short list of qualified firms is prepared on the basis of the response to the formal announcement, soliciting expression of interest, published in the Bank's “Procurement Opportunities”.

To date the Bank has granted consultancies and feasibility studies in Georgia and a feasibility study for the first geothermal power plant in Kamchatka (Russia). The total

amount funded is about 680,000ECU. Moreover, a loan for the construction of the first geothermal 40MWe plant in Mutnovsky field (Kamchatka) has been recently awarded, about 85 MECU.
The Bank, in the near future could finance the extension of the Kamchatka geothermal project for about the same amount as above.

FUNDS COMMITTED TO SUPPORT GEOTHERMAL ACTIVITIES

EBRD

YEAR	PROJECTS SUPPORTED	TOTAL SUPPORT (ECU)	UTILIZATION		ITEMIZED SUPPORT (ECU)
1976-1980			Electricity generation		
			Direct uses		
			Combined uses		
			Research & Technology		
1981-1985			Electricity generation		
			Direct uses		
			Combined uses		
			Research & Technology		
1986-1990			Electricity generation		
			Direct uses		
			Combined uses		
			Research & Technology		
1991-1995	1	219,000	Electricity generation		
			Direct uses		
			Combined uses		
			Research & Technology	1	219,000
1996-1997	2	85,460,000	Electricity generation	1	85,000,000
			Direct uses		
			Combined uses		
			Research & Technology	1	460,000
GRAND TOTAL	**3**	**85,679,000**			

I.A.D.B.

Inter-American Development Bank

1300 New York. Avenue, N.W. Washington, D.C. 20577

The Bank was founded in favour of the Bank's borrowing member Countries in the Americas and has about thirty-five years of operation.

The Bank actively promotes energy development by means of loans and technical cooperation for technically, socio-economically and financially feasible projects supporting electric energy generation, transmission and distribution projects and/or programs, as well as the development of hydrocarbon resources.

The Bank may participate in, promote or support the following activities toward these goals:

- exploration.
- evaluation and quantification of resources.
- development, production and processing.
- transportation, storage and distribution.
- institution strengthening.
- training and skills development.
- development and improvement of the technological infrastructure.
- energy utilization.
- applied research.
- energy planning and policy.
- cooperation among member countries.

The following aspects receive special consideration in projects to which the Bank extends support, either directly in the project itself or through its participation in other sectors:

- The reliability and conservation of the energy supply and its efficient use.
- Increase in the supply of energy through better utilization of installed capacity.
- The energy projects or programs should preferably be part of short, medium or long-term investment plans for financing the energy sector or its subsectors and should be integrated with the socio-economic planning at national level.
- The energy projects would serve as key elements to promote development in their areas of influence thorough the generation of subsidiary economic activities.
- There should be an assurance that the rural energy plans and projects include, within the national energy context, the economic and physical requirements of the rural areas and rural communities and that the energy projects would contribute to the creation of new jobs in the non-farming sector to strengthen rural social and economic development.
- The projects should increase the production of renewable energy.
- The projects should help the countries to continue their programs for institutional improvements in the energy sector and contribute to a transformation of the energy supply and consumption structure in Latin America.

- The activity must be such that in addition to meeting the requirement of overall financial feasibility, its benefits from the use of energy will reach the homes of the disadvantaged target sectors, consistent with the Bank's tariff policy.

- The energy projects should be conceived and designed in a manner compatible with environmental protection requirements.

In applying this policy, the Bank will maintain close coordination with all the international agencies operating in the energy field, especially those directing their efforts to Latin America.

The IADB support to the projects takes place through loans and grants. The Bank has been actively present in the small-medium scale RES projects, with almost 50 approved loan and grant funding for nearly 500MECU. This amount represents the 5% of the entire energy sector expense which since 1961 counted on some 250 loans (about 10 Billion ECU).

In this framework, the geothermal sector appears the most consistent with respect to other renewable energies, with 25 loans and grants (from 1975 to 1996) totalling about 330 MECU for geothermal feasibility studies, field development and plant construction. All beneficiaries are in South and Central America.

FUNDS COMMITTED TO SUPPORT GEOTHERMAL ACTIVITIES

IADB

YEAR	PROJECTS SUPPORTED	TOTAL SUPPORT (ECU)	UTILIZATION		ITEMIZED SUPPORT (ECU)
1976-1980	2	10,320,000	Electricity generation	-	-
			Direct uses	-	-
			Combined uses	-	-
			Research & Technology	2	10,320,000
1981-1985	8	90,370,000	Electricity generation	2	68,480,000
			Direct uses	-	-
			Combined uses	-	-
			Research & Technology	6	21,890,000
1986-1990	6	67,740,000	Electricity generation	1	57,920,000
			Direct uses	-	-
			Combined uses	-	-
			Research & Technology	5	9,820,000
1991-1995	7	155,380,000	Electricity generation	3	153,280,000
			Direct uses	-	-
			Combined uses	-	2,100,000
			Research & Technology	4	
1996	1	3,600,000	Electricity generation	-	-
			Direct uses	-	-
			Combined uses	-	-
			Research & Technology	1	3,600,000
GRAND TOTAL	**24**	**327,410,000**			

MAE - DGCS

Italian Ministry of Foreign Affairs

Directorate for Development Cooperation

Piazzale della Farnesina, 1 - 00194 Roma - Italy - Ph. +39 6 36912997 - Fax +39 6 3235911

The Directorate General for the Cooperation to Development is under the authority of the Italian Ministry for Foreign Affairs. It is active from long time in the support of worldwide projects mainly in developing countries.

The enterprieses which are supported cover several aspects (infrastructure, energy, services, transport, education, health, food & agriculture, industry, economy etc.) at different levels (education, training, planning, design, maintenance, technical assistance, supply of equipment and goods etc.).

The financial support is in the form of grants, loans, co-financing and participation in multilateral funds. The projects admitted to funds are then assigned through tenders.
The general approach (which can have exceptions) starts from the specific request of the Country which are transmitted to MAE-DGCS according to the formal channels. The requests are analysed, checked, discussed and support is usually assigned on the basis of the priority and the availability of funds according to the principles of the Project Cycle Management. Usually the different phases take place in joint partnership with bi-national commissions made up of political representatives and technical experts from both sides.

In the geothermal sector the DGCS has been particularly active in the 1980s in developing countries, mostly in South America, Asia and Africa for training, studies, surveys, drilling and some plants.

The total amount granted from 1976 to date is about 53.7MECU.In the years 1981, 1990 and 1992 three loans have been assigned totalling 112.900MECU for geothermoelectric power plants construction.

FUNDS COMMITTED TO SUPPORT GEOTHERMAL ACTIVITIES
MAE-DGCS

YEAR	PROJECTS SUPPORTED	TOTAL SUPPORT (ECU)	UTILIZATION		ITEMIZED SUPPORT (ECU)
1981-1985	17	20,354,000	Electricity generation	1	5,989,700
			Direct uses	-	-
			Combined uses	-	-
			Research & Technology	16	14,364,300
1986-1990	13	25,681,900	Electricity generation	1	15,156,200
			Direct uses	-	-
			Combined uses	-	-
			Research & Technology	12	10,525,700
1991-1995	4	120,626,500	Electricity generation	1	120,450,700
			Direct uses	-	-
			Combined uses	-	-
			Research & Technology	3	175,800
GRAND TOTAL	**34**	**166,662,400**			

WORLD BANK

The World Bank Group (WB) comprises five organizations:

- International Bank for Reconstruction and Development (IBRD),
- International Development Association (IDA),
- International Finance Corporation (IFC),
- Multilateral Investment Guarantee Agency (MIGA),
- International Centre for the Settlement of Investment Disputes (ICSID).

Since its inception, the World Bank has provided nearly 225,000 MECU in financing for some 5,000 projects.

Typically, the WB does not finance the total cost of a project, just the components that must be purchased with foreign exchange, which on average is about 40%. The rest of the funding is provided by the borrowing countries and by other agencies and commercial banks that cofinance with the WB.

Loans and credits are administered by the same WB staff and the project must meet the same criteria in order to qualify for a loan. They must be technically and financially sound, produce acceptable rates of return, and contribute to a country's economic growth and development. The project development follows the typical project cycle.
The loan amounts for the projects supported from 1983 is about 1,400MECU

IBRD

The IBRD, founded in 1944, is the World Bank Group's main lending organization. It lends to developing countries with relatively high per capita incomes. The money the IBRD lends is used to pay for development projects, such as building highways, schools, and hospitals, and for programs to help governments change the way they manage their economies.

The IBRD raises most of its money on the world's financial markets. It sells bonds and other debt securities to pension funds, insurance companies, corporations, other banks, and individuals around the world.

IBRD is owned by its 180 member countries with voting power in the institution based on a country's shareholding, which in turn is based on a country's economic strength.
During the past five years, the IBRD approved an annual average of 14,000 MECU in loans for development projects.

IDA

The IDA was established in 1960 to provide assistance on concessional terms to the poorest developing countries, those that cannot afford to borrow from the IBRD. IDA loans, known as "credits," are provided mainly to countries with annual per capita incomes of about 770 ECU or less; credits are interest free, but carry a small service charge. Terms on credits are 35 or 40 years, with a 10 year grace period.

IDA resources are derived from contributions from governments, IBRD profits, and repayments on earlier IDA credits. IDA has 159 member countries, each country must be a member of IBRD before it can join IDA.

During the past five years, IDA approved an annual average of 6,000 MECU in credits (lending) to help pay for development projects.

IFC

The IFC was established in 1956 to help strengthen the private sector in developing countries. IFC lends directly to the private sector, while the IBRD and IDA lend to governments. IFC aids the private sector by providing long-term loans, equity investments, guarantees and "standby financing," risk management and "quasi-equity instruments," such as subordinated loans, preferred stock, and income notes.

Interest rate on IFC loans and financing: Market rates, which vary between countries and projects. Maturity on loans: three to 13 years, with grace periods as long as eight years.
About 80 percent of funds are borrowed in the international financial markets through public bond issues or private placements and 20 percent are borrowed from the IBRD.

IFC is owned by 170 member countries.

Lending: IFC investments have risen from about 3,600MECU in fiscal 1993 to more than 6,250MECU in fiscal 1996, including syndications and underwriting for private-sector projects in developing countries.

IFC philosophy is to encourage the growth of productive private enterprises that would contribute many key components to development. The investments are placed according to business principles, taking on the full commercial risk and earning a profit from the operations.

Another principle is to complement the role of market operators attracting investments and projects in countries which private investors would otherwise consider excessively risky, provided there is co-participation of private, local and international, investors.

Funding is in form of loans, equity, quasi-equity.
The number of projects per year is 100-200 (in 1995, 213 projects funded with an investment of 35.5MECU.

The ways to access IFC funding are: direct contact with sponsors who have proven the economic and financial reliability, the existence of environmental standards; the proven technical, financial and economical viability (including profitability) of the project and for the private sector a condition is the ownership of the project.

The IFC has not funded yet projects related to the geothermal sector. A project for the installation of an ORMAT binary cycle 28MW power plant in Guatemala (Zunil project) with more than 20MECU support from IFC could be funded in future.

MIGA

MIGA was established in 1988 to help developing countries attract foreign investment. MIGA provides investors with investment guarantees against "non-commercial risk," such as expropriation and war. It also provides governments with advice on improving the climate for foreign investment.

MIGA may insure up to 90 percent of an investment, with a current limit of 45MECU per project. MIGA is owned by 134 countries.
In fiscal 1996, MIGA issued 68 guarantee contracts worth about 770MECU.

ICSID

ICSID was founded in 1966 to promote increased flows of international investment by providing facilities for the conciliation and arbitration of disputes between governments and foreign investors. ICSID also provides advice, carries out research, and produces publications in the area of foreign investment law.

ICSID is owned by 126 countries as of June 30, 1996.
Research and publications: ICSID's publications in the field of foreign investment law include multi-volume collections of investment laws and treaties and a semi-annual law journal.

FUNDS COMMITTED TO SUPPORT GEOTHERMAL ACTIVITIES

WORLD BANK

YEAR	PROJECTS SUPPORTED	TOTAL SUPPORT (ECU)	UTILIZATION		ITEMIZED SUPPORT (ECU)
1981-1985	1	32,631,600	Electricity generation	1	32,631,600
			Direct uses	-	-
			Combined uses	-	-
			Research & Technology	-	-
1986-1990	4	440,444,700	Electricity generation	1	440,444,700
			Direct uses	-	-
			Combined uses	-	-
			Research & Technology	-	-
1991-1995	3	682,000,000	Electricity generation	2	357,315,800
			Direct uses	-	-
			Combined uses	1	324,684,200
			Research & Technology	-	-
1996-2000	4	245,471,000	Electricity generation	1	4,813,100
			Direct uses	-	-
			Combined uses	2	138,684,200
			Research & Technology	1	101,973,700
GRAND TOTAL	**12**	**1,400,547,300**			

A.D.B.

Asian Development Bank

6 ADB Avenue 0401 Mandaluyon City, Manila (Philippines)

After the second oil crisis in 1979 together with the reassessment of the energy policies from international financing institutions and countries also the ADB readjusted its strategy for energy sector. The main criteria of the plan regarded:

- the strong increasing of investments in energy projects in the 1980s (almost three times that in the preceding decade,
- the substantial support to the indigenous sources of supply in Developing Member Countries.

The Bank has extensively financed the energy realizative projects (no. 82) for a total amount of 10,900MECU and has also provided 76MECU of Technical Assistance.

The general policy of ADB foresees also the joint financing operation with other international financing institutions (W.B., E.B.R.D., etc.). W.B. widely assisted the Developing Member Countries in the institutional and legal framework related to energy sector, especially restructuring and reforms resulting necessary for the open market economy.

The Bank is also interested in projects related to Renewable Energy System also if their share is generally low.
In the geothermal sector ADB financed only one project: the total amount of the loan is about 120MECU which financed a power geothermal plant in 1989 in Philippines.

FUNDS COMMITTED TO SUPPORT GEOTHERMAL ACTIVITIES

A.D.B.

YEAR	PROJECTS SUPPORTED	TOTAL SUPPORT (ECU)	UTILIZATION	ITEMIZED SUPPORT (ECU)
1981-1985			Electricity generation Direct uses Combined uses Research & Technology	
1986-1990	1	120,000,000	Electricity generation 1 Direct uses Combined uses Research & Technology	
1991-1995			Electricity generation Direct uses Combined uses Research & Technology	
GRAND TOTAL	**1**	**120,000,000**		

The main arguments and projects recommended for Board approval are the following:

- technical assistance and landing projects in Developing Member Countries for restructuring of power sector and incentive investments from the private sector,
- new capacity additions have to be adequately justified by the existing production framework (rehabilitation and efficiency increasing of existing plants as priority),
- environmental protection is carefully examined,
- BOO/BOT projects and joint venture ones.

The ADB is called for financing by Countries. The work opportunities are publicised in the monthly magazine "ADB Business Opportunities".

NORDIC FINANCE GROUP

Fabianinkatu 34, PO Box 249 - FIN-00171 Helsinki (Finland)

The Nordic Finance Group comprises four multilateral finances institutions:
- Nordic Investment Bank (NIB),
- Nordic Development Fund (NDF),
- Nordic Environment Finance Corporation (NEFCO),
- Nordic Project Fund (NOPEF),

The institutions within the Group are owned by the five Nordic countries (Denmark, Finland, Iceland, Norway and Sweden). We can participate in all project stages from financing the pilot studies to financing final implementation.

All projects financed have to be of mutual interest to the borrower and the Nordic countries.

In its activities both within and beyond the Nordic area, the Group co-operates with Nordic and multilateral finance institutions, banks and regional sources of finance (i.e. EBRD, EIB, IFC, ADB, etc.).

The Nordic Finance Group can offer solid financial competence in different parts of the world and with different associates. During the nineties the Group has taken part in projects in over 70 countries.

NIB

The Nordic Investment Bank (NIB) is a multilateral financial institution owned by the five Nordic countries founded in 1975. NIB finances private and public projects which have high priority with the Nordic countries and the borrowers.
NIB offers its customers long-term loans and guarantees on competitive market terms.

NIB finances projects of various kinds which bring the Nordic countries more closely together, such as cross-border investments and infrastructure improvements. NIB also finances investments securing energy supply and supporting research and development. High priority is given to projects improving the environment of the Nordic area and its neighbouring regions. NIB can also finance foreign direct investment in the Nordic area.
The Bank has financed more than one thousand projects which have helped to strengthen Nordic economic co-operation. Loans outstanding to Nordic borrowers in August 1997 totalled some ECU 5.5 billion.

NIB grants loans to companies, local authorities, public institutions and regional credit institutions. The Bank can finance up to half the total cost of a project. In this way its loans supplement loans from other banks and finance institutes and/or the customer's own funding.

The core of NIB's lending outside the Nordic Countries consists of Project investment loans (PIL) to the growth market of Asia, Latin America, Central and Eastern Europe, Africa and the Middle East. PIL loans are long-term loans with a repayment time of up to twenty years. The proceeds of the loans can be used to cover any part of project costs. So far, PIL loans have been granted for projects in more than thirty countries. Project investment loans are normally granted to governments or against government guarantees. The Bank is also open to participation in the financing of projects in the private sector, primarily in infrastructure investments and utility projects.

NIB also provides loans to investments, including joint ventures and corporate acquisitions, within the OECD area.

NIB is participating in the financing of projects of regional interest in the Baltic countries. As part of the Baltic investment programme of the Nordic countries, NIB offers investment loans to small and medium-sized companies in Estonia, Latvia and Lithuania.

Since 1997, NIB has been granting environmental investment loans to the neighbouring regions of the Nordic area. These loans are made towards public and private environmental projects in North-West Russia and the Baltic region. The projects must contribute to reducing environmental degradation and transboundary pollution.

NDF

The Nordic Development Fund (NDF) finances high priority projects of Nordic interest in developing countries with favourable and very long-term development credit.

NDF is a multilateral development financing institution which concentrates on the least developed, low and lower middle income countries. Projects in poor developing countries have priority. Credits are granted for projects promoting economic and social development in accordance with the development aid policies of the Nordic countries.

NDF grants credits with a repayment time of forty years, including a ten year grace period.

NDF credits are interest-free but carry a service charge of 0.75% p.a. and a committment charge of 0.5% p.a.. Credits are only granted on a basis of co-financing with other financiers, most of them other multilateral finance institutions such as the World Bank group, the big regional development banks and the Nordic bilateral development agencies.

The NDF specialises above all on fields in which Nordic enterprises are particularly competitive. Nordic competitive bidding is normally applied for procurement of both goods and services.
NDF supports private sector development. The fund offers direct co-financing of private sector projects in the developing countries, in collaboration with Nordic enterprises, local partners and other finance institutions.

NDF's fund capital amounts to 625MECU, financed through the development co-operation budgets of the Nordic countries. Annual lending is approximately 63MECU.

NEFCO

The Nordic Environment Finance Corporation (NEFCO) is a multilateral Nordic risk capital institution financing environmental projects in the Central and Eastern European Countries.
NEFCO's activities are intended to produce positive environmental effects in the project country and in the Nordic area. Priority is given to neighbouring regions of the Nordic area, i.e., the Baltic countries and the Barents region.

NEFCO can take part in projects by equity investments and by offering loans and guarantees. This usually takes place on market terms, but in certain cases also in the form of loans with equity features. NEFCO's share of total financing is usually between 25 and 30 per cent.

With priority being given to projects having a major Nordic environmental effect, the main emphasis is on water and air pollution. Financing may, for example, involve:

- companies manufacturing environmental equipment and equipment for improved energy efficiency,
- companies offering planning services in the environmental and energy sector;
- projects concerned with the modernisation of industrial and energy production plants, with environmental benefits;
- projects providing environmental services, such as water purification.

A Nordic partner should participate in the projects on a long-term basis. Generally, this implies participation in an enterprise, and the emphasis is on various kinds of direct investment. NEFCO co-operates i.e. with the national environmental assistance programmes of the Nordic coutries.

NEFCO also administers what is known as the Grant Financing Facility, under which funding is channelled into urgent environmental projects in neighbouring regions to the Nordic area, so as to facilitate or accelerate measures of environmental remediation.

NEFCO is an investment fund with a capital of ECU 80 million.

NOPEF

The Nordic Project Fund (NOPEF) promotes the internationalisation of Nordic companies. NOPEF grants favourable loans to feasibility studies for international projects and foreign investments with a Nordic interest.

NOPEF's ordinary loans are interest-free and can cover 50 per cent of the budgeted cost of a feasibility study. Loans should be repaid if the project is implemented.

The loans can be used for part-financing feasibility studies and preparatory business activities for project identification under the borrower's own suspices and for information activities among Nordic firms. Loans are granted for projects which can lead to project deliveries or investments with Nordic participation in countries outside the EU and Efra.

NEPEF's activities are partly funded by the Nordic Council of Ministers. NOPEF has taken part in 1,500 projects and has had widespread experience of project exports and internationalisation. During the 1990s, NOPEF has been involved in projects in over fifty countries.

NOPEF's loans within the framework of the Baltic Investment Programme (BIP) promote the establishment of small and medium-sized companies in the Baltic countries. The loans are interest-free and can cover 60 per cent of the budgeted cost of a feasibility study.

NOPEF represents JOP (Joint-Venture Programme, Phare-Tacis) within the EU, the purpose of which is to pave the way for new enterprises and business co-operation across national boundaries in Central and Eastern Europe. In addition, NOPEF administers a Danish Trust Fund for Danish firms and consultants taking part in projects of Nordic interest in neighbouring regions to the Nordic area.

NOPEF's annual lending amounts to 3.5MECU and loans outstanding in 1997 totalled some 9MECU.

FUNDS COMMITTED TO SUPPORT GEOTHERMAL ACTIVITIES

NIB

YEAR	PROJECTS SUPPORTED	TOTAL SUPPORT (ECU)	UTILIZATION	ITEMIZED SUPPORT (ECU)
1991-1995	1 1	945,900	Direct uses Research & Technology	854,600 91,300
1996-2000	1 1	486,600	Direct uses Research & Technology	451,100 35,500
GRAND TOTAL	**4**	**1,432,500**		

NDF

YEAR	PROJECTS SUPPORTED	TOTAL SUPPORT (ECU)	UTILIZATION	ITEMIZED SUPPORT (ECU)
1991-1995	1	558,800	Direct uses Research & Technology	511,900 46,900
1996-2000	1	194,400	Direct uses Research & Technology	178,000 16,400
GRAND TOTAL	**2**	**753,200**		

NEFCO

YEAR	PROJECTS SUPPORTED	TOTAL SUPPORT (ECU)	UTILIZATION	ITEMIZED SUPPORT (ECU)
1991-1995	2	227,500	Direct uses	227,500
1996-2000	1	210,500	Direct uses	210,500
GRAND TOTAL	**3**	**438,000**		

NOPEF

YEAR	PROJECTS SUPPORTED	TOTAL SUPPORT (ECU)	UTILIZATION	ITEMIZED SUPPORT (ECU)
1981-1985	1	10,900	Combined uses	10,900
1986-1990	4	172,900	Combined uses	172,900
1991-1995				
1996-2000	1	47,900	Combined uses	47,900
GRAND TOTAL	**6**	**231,700**		

Annex 5.4

MARKET SITUATION FOR GEOTHERMAL ELECTRICITY GENERATION AND DIRECT HEAT USES

INDEX

1. MARKET SITUATION IN CENTRAL AND SOUTHERN AMERICA FOR GEOTHERMAL ELECTRICITY GENERATION

The geothermal market in the last few years has shown that the present higher grow rate markets are located in South-eastern Asia. in these areas Japanese, American and new Zealand operators and developers have a dominating position.

As a consequence one of the main areas where the geothermal resources could offer in the future, high opportunities for the EUROPEAN operators is Central and Southern America.
The potential perspectives and the possible future opportunities were discussed in the seminar *"El papel de las fuentes de energia nuevas y renovables en el desarrollo sustentable de America Latina y el Caribe : el caso de la geotermia"* held in Santiago del Chile in late 1995.

It was organized by CEPAL(United Nations) and DG XVII (European Community) with the presence of institutional representatives from ten countries of the region, from European Community-D.G.XVII, Indonesia and The Philippines, various international public and private firms, research agencies, individual experts and national and international promotion and financing agencies.

Some considerations emerged by the Seminar as:

- a generalised interest toward the exploitation of the geothermal resources of the continent by different American and extra european firms.

- the request for regulatory and legislative national frameworks which guarantee the private investors' investments and profits

- the trend toward the complete privatisation of the sector from the early phases (assessment and exploration of the resources) to the subsequent ones (field development, plant installation, operation) with systems such as BOOT, BOO.

- the opinion that central and southern America could be a good chance for the European operators, who in the past have contributed considerably to the initiation of geothermal activities: however, in many cases (esp. South America) this involvement has not followed actual realisations. The necessity to favour the creation of strong consortia with joint complementary financial and technical capabilities is so evident.

Following the boost of the above initiative CEPAL and UE DG XVII promoted the implementation of a bridging project in order to prepare a successive wider project aimed at stimulating a Regional program of technical Assistance to identify and promote actions and pilot projects, and support the national management capabilities in geothermal operations.

This bridging project entitled "Desarrollo de los Recursos Geotermicos en America Latina y en el Caribe" has been recently finished. The main contents of the study are:

a) The elaboration of a questionnaire form to identify the different factors (Technical, legal, political, economical, etc.) which influence positively and negatively the development of local initiatives and the exploitation of the existing geothermal resources.

b) The identification (through reasonable hypothesis, and selection on the basis of feasibility considerations) of some general initiatives in the geothermal sector and of some projects which could be of mutual interest for local and European firms.

c) To elaborate the scheme of the above mentioned future Technical Assistance Regional Program (PRAT)

The indications contained in the above point b) identified some projects, not yet started and/or assigned, which have been planned and considered as a priority by local institutional Authorities.

The following projects and initiatives could offer actual short term future work opportunities, mentioned in brackets, for European operators ; also if the real implementation of many of them still requires the solution of some requirements and conditions (legal, financial etc.)

1.1 Central America

EL SALVADOR

- Berlin geothermal field (Plant installation, ..possible concession for further developments)

- In this field, whose potential has been estimated to be about 100 MWe, are presently installed 8 MWe.
  Feasibility studies for 1x50 MWe or 2x25 MWe condensation units have been finished already (BID and WB funds).
  The implementation of the plant 2x30 MW is ongoing and has been assigned to the Japanese firm Fuji. Studies for further expansion are expected.

- San Vicente geothermal field (Surface surveys, exploration drillings, feasibility studies,)

- The feasibility study has been suspended for contractual problems. Local Authority CEL is deciding the regulatory framework for the field implementation (direct charge or concession to private developers). Geophysical surveys, three exploration wells, tests (completion of feasibility studies) are specific work opportunities together with the possible field concession.

- Chinameca geothermal field (possible concession)

- Detailed surface surveys are presently underway for the assessment the field potential in order to assign the field concession.

For the above open initiatives preliminary intention of interest seems to have been expressed by local and North American private operators. The definition of regulatory schemes regarding the ownership of resource, and the generation/sell of energy are in progress.

NICARAGUA

- National geothermal master plan **(studies and surveys)**
  The plan has been already financed by BID and tenders for engineering companies/consultancy services have been issued, awarding is underway (february 1998).

- Granada-Masaya-Nandaime geothermal area **(studies/surveys, drilling services, equipment supply)**

  Preliminary prospections were performed around 1980, financed by Italian co-operation funds. Local government asked for funding from EU for a prefeasibility study in the area. Feasibility study (engineering services, studies and surveys, services and supply of equipment for exploratory wells) are foreseen as work opportunities.

El Hoyo-Monte Galan geothermal area. This area has been studied at a prefeasibility stage in the 1980's. It was recommended as a high priority. Since then no activity has been performed but the area remains a primary quality target.

Considering the high potential of the country mixed local/foreign consortia and Northern American investors have expressed interest to acquire concessions in some geothermal areas of the Country. This behaviour is also subsequent to some trends in the governmental energy policies, presently not officially established, which envisage the assignment of concessions for generation to private investors.

COSTA RICA

- Rincon de la Vieja geothermal field **(exploratory drillings, plant installation)**
After the conclusion of the prefeasibility study financed by BID, the exploitation should be implemented through exploratory wells and tests in the short term, while the following plant installation (in the medium term) will be achieved from the installation of a successive number of smaller nodular units as opposed to one single 55 MWe unit.

- Tenorio geothermal field **(surveys, exploratory drillings tests)**
The prefeasibility study has been completed by ICE (Instituto Constarricense de Electricidad) and Italian Cooperation funds. The next stage (feasibility study) including exploration drilling will be financed by ICE funds and consultancy services opportunities could occur for European operators.

- Miravalles geothermal field **(consultancy services, plant supply)**
The medium-long term binary cycle power plants could be implemented as a cascade system to complement the existing units. Further expansion will be financed under BOT contracts

Local recent legislation foresees that the early phases (exploration, evaluation of the field) are in charge of ICE while the generation of electricity and management of the plants can be assigned to private investors committed to sell energy to ICE

GUATEMALA

- Zunil II geothermal project **(engineering services, equipment supply)**
The feasibility study should be assigned.

  Amatitlan geothermal area (**engineering services , equipment supply**
Following the completion of the feasibility study the installation of a 25 MWe power plant should be assigned through an international tender. The implementation of a provisional back-pressure unit of 5 MW is underway on behalf of a Mexican Company. It is probable that the field will be assigned under a concession contract to possible private investors. The final possible potential of the field could be much higher than the currently proven potential.

  Tecuamburro geothermal project **(engineering services, equipment supply)**
Probable opportunities could follow after the conclusion of the feasibility phase (wells, tests) and in the long term for plant installation. After the drilling of a first exploration deep slim hole the area looks like the most promising in the country.

  San Marcos geothermal project (**engineering services)**
After the conclusion of the prefeasibility study the feasibility phase has been planned for which technical and financial assistance has been asked to EU.

The legal framework relevant to the exploitation of the geothermal resources has not been completely defined but private investments in the energy generation seem possible under BOO contracts.

HONDURAS

Projects for small scale generation such as Plantanares and El Tigre are possible future initiatives but are not yet well defined

SANTA LUCIA

La Soufriere-Qualibu **(engineering services, plant installation)**
The previous feasibility activities need to be integrated before the installation of a 10-20 MWe power plant. The main problem of the field is linked to the high acidity of the fluids found in the first well.

1.2 South America

The implementation of the geothermal exploitation in South America has been delayed in comparison with central America. Presently, in spite of many efforts and expenses in the early phases such as studies, surveys, drillings, only a very small (0.67 MWe) pilot binary cycle well head power plant has been installed in all the subcontinent (Copahue-Argentina).
No exist projects ready to start or are ready to be implemented in short term.
The few initiatives which have some probability of being implemented in the medium-long term are as follows:

COLOMBIA

Las Nereidas-Nevado del Ruiz project **(engineering services, exploratory drillings):**
The public-private company "Geoenergia Andina" has a programme to perform the feasibility of the field (drillings and tests) for the subsequent installation of a medium size power plant.

PERU

Tutupaca-Challapalca project **(surface studies and surveys, drillings)**
Only prefeasibility studies have been performed in this field . All the feasibility activities have yet to be conducted. The public agency CENERGIA is looking for private investors which are interested in charging (concession) for the whole project. International co-operation for funding the early phases of exploration is to be encouraged in order to stimulate private interest thus minimising the "mining risk".

BOLIVIA

Laguna Colorada project **(market study, plant installation?)**
A feasibility study was completed in 1990. Due to the long distance of the plant from the users and to the availability of a cheap energy supply alternative (natural gas), the installation of a generation plant may not be attractive investment. It is advisable therefore to carefully evaluate any investment through a devoted and focused market study. The project is presently managed by the "Secreteria de Energia del Ministerio de Desarrollo Economico".

CHILE

El Tatio project

This project has a long history and exploration wells already exist. A feasibility study was performed in 1975, and updated in 1982. Both studies recommended the implementation of a 15 MW power plant. The estimated total potential (30 MWe) has to be checked the context in of the present condition. Doubts on the economic convenience of a power plant installation still exist due to the lack of a nearby market. Nevertheless, the existence about 30 km away of a substation near the big copper mine of Chuquicamata (electrically self sufficient) could make the project attractive if a larger resource was discovered. Interest in the concession for the field has been expressed by private foreign investors provided that proper legislation is established by the local government.

1.3 Central and South American Market Considerations

The grow rate and local interest of geothermal resources and the consequent potential business opportunities for European operators are very different in Central and Southern America.

In Central America geothermal resources are extensively exploited and in some countries represent a noteworthy share of the electricity energy supply. Energy policies for the Government geothermal sector are almost exclusively devote to this kind of application, with very low interest in direct use applications.

High enthalpy geothermal potential, not yet exploited does exist and is broadly estimated to be 1,700 MWe as **"marketable resources"** (plants in construction, planned and proven resources).

Some non-technical problems in development (mainly delays and lack of funds) have been caused by the previous state management of the whole sector, but these difficulties should be progressively lessened by the privatisation processes already introduced or established.
The status of the electricity grid system is generally favourable and a certain amount of local experience and expertise .exist.

The region offers the competition from other renewable energy sources although traditional options can be limited. Geothermal energy is an indigenous precious resource which could supplement energy supply.

The international co-operation programme have in the past helped to sustain the birth and growth of the geothermal market especially in the early assessment and exploratory phases. In the future, and despite the privatisation processes, it is advisable that the support from international co-operation/financing Agencies or national support entities can be maintained especially for the early phases of the exploration where the "mining risk" represents the main disincentive for the private investor. In Costa Rica this criterion appears to be the policy which will be adopted.

From the above considerations <u>Central American countries</u> appear on the whole to be an area where the European geothermal operators could find real short and medium term work opportunities. The present and the incoming local energy policies will, however, considerably reduce the previous projects implemented from international financiation and tendering. Private investment as BOT, BOO, will be the key tools for the development of this market according to the results of models which range from fully comprehensive concession of the field and the production sale to intermediate schemes.

Private investors comprise of strong international technical-financial Consortia (mainly North American and Asian) are already present and commercially active in the countries where by contrary there is a still general reticence of most European operators to the adopt such schemes. This approach could strongly condition their future presence and business opportunities.

The **<u>Southern American countries</u>** offer slow progress in the exploitation of the high geothermal potential which has been estimated to be about 700-1000 MWe as **Marketable resources** (value rather indicative due to the fact that a feasibility stage is, in many areas, lacking or incomplete).

The recent deep changes in former energy institutions, with the generalised shift to privatisation and the concomitant reduction in governmental presence strongly affected these geothermal programs.
The main problem which will affect the progress of geothermal activity in South American countries is the lack of a genuine interest. The energy supply options are, in general, diverse both with fossil fuels and renewable resource alternatives so that geothermal energy is often in competition with cheap options such as hydroelectricity and natural gas.

The use of this latter resource is in strong development in the region with the construction of large scale gas pipe lines and distribution networks (Chile, Argentina) Moreover, many promising geothermal fields are located in high Andean areas which are relatively remote from the main centres of electricity consumption, which therefore require high costs for the relevant grid connections.

Given this situation economic and financial oriented market studies on the existing or evident geothermal fields would be a useful step in order to a reactivating interest. Also a strategic option of developing small-size plants in decentralised areas should be carefully analysed possibly lead to key pilot schemes, as a precursor to more widespread investment. These tasks probably require the support of international co-operation or at least national ones.

From the considerations above the Southern American Countries appear to be an uncertain market for geothermal European operators. Supplementary engineering services to complete the feasibility stages, studies of the market situation (competitiveness) and on pilot alternative options appear, at the moment, to be the most immediate and appropriate short term action.

Support from the European Union for the above activities could be a good opportunity to open possible future penetration by the European operators in this relatively under-developed area.

2. MARKET SITUATION FOR DIRECT HEAT USES IN OTHER EUROPEAN COUNTRIES

Market situation of other European countries, formerly as CEE's and CIS, is characterised by very high potential especially for the direct uses application both due to the presence of high amounts of geothermal resources and to the tradition of using in greenhouses and district heating applications. Some projects are outlined here both for those not yet started and/or assigned which have been planned and considered as a priority by local institutional Authorities, **(these could represent genuine short-term future market chances for European operators)**.

POLAND (Engineering services, equipment supply, concession)

Investigations and feasibility study for the plant have been recently completed (with WB funds) for the modernisation of the district heating system in the cities of Skierniewice and Zyrardow and for the substitution of coal-fired heat plants with geothermal ones. The engineering and the following implementation of all the geothermal plant components, up to the existing heat distribution network, together with the rehabilitation of this one, are planned in the near future. Private developers are looking for concessions.

RUSSIA (Engineering services, field development, plant implementation)

In the autonomous republic of Kamtchaka, project has recently started for the reconstruction of a 40 MWe geothermal power plant in Mutnovky geothermal field with EBRD loan.
A second 40 MWe plant has been planned for the year 2001.
Opportunities for engineering services, well drilling, plant manufacturing and installing are forecast.

GEORGIA (Equipment supply, well and pipeline rehabilitation, concession)

Rehabilitation works on four district heating station in Tbilisi are planned (replacing old equipment as well as reconstruction) together with the improvement of the Lisis geothermal field exploitation (well rehabilitation, pipeline construction/repearing, meter equipment etc). Moreover, the implementation of a geothermal heat supply system is planned in the Zugdidi-Tsaishi area from the exploitation of local geothermal resources. The project could be supported by EBRD adopting a concession scheme with the participation of a private developer.

MACEDONIA (Engineering services, component supply)

A national geothermal master plan is starting, with the support of the Italian cooperation, for the rehabilitation of the existing district heating and agroindustry plants.
In the medium term opportunities for engineering services and plant components supply are forecast.

UKRAINA (Engineering services)

In autonomous republic of Crimea are presently installed five geothermal heating plants for a total installed power of 12 MWt. A detailed master plan for renewable sources of energy (geothermal on included) has recently started (TACIS funds).
The implementation in other regions of Ukrtaina (western and central-eastern sides) of geothermal heat supply systems has been study at prefeasibility level. One the other hand the "National Energy programme of Ukraine up to year 2010" adopted by the Ukrainian Government stress the role and importance of heat and electricity production through geothermal resources. Funds are looked for by international agencies. In short term opportunities are forecast in engineering services and well rehabilitation.

Annex 6.1

COMPARISON WITH THE WHITE PAPER FOR A COMMUNITY STRATEGY AND ACTION PLAN. ENERGY FOR THE FUTURE: RENEWABLE SOURCES OF ENERGY

The sensibility of the world public opinion on the necessity to coniugate the economic development with the safeguard of the environment has grown considerably in the recent decades tens. The Rio Conference (1991), and the Kyoto Conference (December 1997) highlighted this as a prioritary issue.

The European Union is often in leading positions in the promotion and implementation of measures in this direction devoting specially programs, efforts and funds to the improvement of renewable energy sources.
The growth of their contribution is one of the most effective ways to reduce the environmental damage caused by the combustion of polluting fossil fuels.

From the European side this position was recently reaffermed at the Leeds Castle summit of the European Environment ministers (April 1998).
The "White Paper" of the EU Commission delineates a community strategy and an action plan in favour of renewable energy sources.

This document represents an important land mark for the future of energy policy in Europe. It establishes the overall target to double the present share of renewables in the EU's gross inland energy consumption to 12% by 2010.
This goal appears to be very ambitious but can be realistic if suitable and effective actions (underlined in the document) are put in place. It is based on specific studies, forecasts, debates between European institutional authorities, operators and experts in the field of energy. [1]

This above growth of use of RE will amount reduce CO_2 emissions about 400 Million tons per year which represents more than 8% of present total emissions.
The White Paper seems to assign a secondary role to the geothermal resources in the above strategic objective.
The growth by 2010 from the present geothermal contribution foresees additional 500 MWe in the production of electricity and 3700 MWt in heat production of which 1750 MWt by low enthalpy fields and 1950 MWt by heat pumps. The share by 2010 of geothermal resources in the total RE contribution indicated in the document is 1% for electricity and 1.2% for heat production.

To draft the Blue Book an inventory was conducted through direct and indirect contacts with national energy institutions responsible for energy policy and planning.
These forecast led to think that by 2010 the geothermal resources contribution could reach absolute and relative values in line but fairly higher than the White Paper ones.
According to the above forecasts, as reported in Chapter 5, by year 2010 the electricity production from geothermal energy in EU could increase of about 400 MW for a total

[1] Madrid Conference, 1994
European Energy to 2020. A scenario Approach, European Commission, 1996
Green paper: energy for the future: renewable sources of energy 1996
Sitges ALTENER Conference, 1996
TERES II, European Commission, 1997

installed capacity of about 1,2 GWe fairly in line with White Paper.
Regarding heat production, the foreseeable market scenario for EU countries (in the period 2000/2010), is lower, only about 1,1 GWt higher than present heat production, for a total thermal installed capacity share by 2010 in EU of about 2,1 GWt.

This heat production, as stated in the report (chapter 5.3) is expected to grow if energy policy decision focusing on reducing of energy demand and hence CO_2 emission will be built up and incentivated in a near future. Moreover this share is expected to grow considerably (even double it) if the development of geothermal heat pumps will be strengthened and expanded in all EU countries.

The White Book foresees long and medium term measures and campaigns together with short term measures, for take off renewables.
Some of the key actions underlined are political/legislative – fiscal/finance – targeted projects – consumer information . These actions are common to all the RE as well as geothermal energy.

Geothermal energy requires also specific measures as reported in the conclusions of the Blue Book (chapter 6). Due to the relative weakness of an industrial/economic "pushing" system, its "**visibility**", also in official occasions, appears lower than the other RE.

FOR FURTHER INFORMATION, PLEASE CONTACT:

DG XVII/C2 - Unit for "Rational Use of Energy (RUE) and Renewable Energy Sources (RES)
European Commission
Wetstraat 200, rue de la Loi
Bruxelles B-1049 Brussel
Belgium

Fax: +322-295.01.50
E-Mail: ***info@bxl.dg17.cec.be***
World Wide Web http://europa.eu.int/en/comm/dg17/dg17home.htm

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F./fax (358-9) 121 44 35
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URL: http://www.akateeminen.com

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Fax (354) 552 55 60
E-mail: bokabud@simnet.is

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Østenjoveien 18
Boks 6512 Etterstad
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Tel. (47-22) 97 45 00
Fax (47-22) 97 45 45
E-mail: info@no.swetsblackwell.com

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Fax (41-1) 365 54 11
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URL: http://www.osec.ch/eics

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Fax (359-2) 980 42 30
E-mail: Milena@mbox.cit.bg

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...nail: demetrap@ccci.org.cy

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URL: http://www.koda.ee

HRVATSKA

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Fax (40-1) 315 44 03
E-mail: euromedia@mailcity.com

ROSSIYA

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117312 Moscow
Tel. (7-095) 135 52 27
Fax (7-095) 135 52 27

SLOVAKIA

Centrum VTI SR
Nám. Slobody, 19
SK-81223 Bratislava
Tel. (421-7) 54 41 83 64
Fax (421-7) 54 41 83 64
E-mail: europ@tbb1.sltk.stuba.sk
URL: http://www.sltk.stuba.sk

SLOVENIJA

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Tokyo 102
Tel. (81-3) 32 34 69 21
Fax (81-3) 32 34 69 15
E-mail: books@psi-japan.co.jp
URL: http://www.psi-japan.co.jp

MALAYSIA

EBIC Malaysia
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Plaza MBf (Letter Box 45)
8 Jalan Yap Kwan Seng
50450 Kuala Lumpur
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Fax (60-3) 21 62 61 98
E-mail: ebic-kl@mol.net.my

MÉXICO

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PHILIPPINES

EBIC Philippines
19th Floor, PS Bank Tower
Sen. Gil J. Puyat Ave. cor. Tindalo St.
Makati City
Metro Manilla
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Fax (63-2) 759 66 90
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URL: http://www.eccp.com

SOUTH AFRICA

Eurochamber of Commerce in South Africa
PO Box 781738
2146 Sandton
Tel. (27-11) 884 39 52
Fax (27-11) 883 55 73
E-mail: info@eurochamber.co.za

SOUTH KOREA

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