COUNTRY NOTES

The Country Notes on Geothermal Energy have been compiled by the Editors. A wide range of sources have been consulted, including national, international and governmental publications/web sites, as well as the *Proceedings of the World Geothermal Congress*, Antalya, Turkey, 24-29 April, 2005 and the updated reviews of direct applications (Lund, et al.) and power generation (Bertani) as published subsequently in *Geothermics*. Use has also been made of direct personal communications.

Albania

Albania possesses a large low-enthalpy geothermal resource located in three zones. The largest, Kruja, extends from the Adriatic Sea in the north southwards into northwestern Greece. Of the other two zones, Peshkopia lies in the northeast of the country and Ardenica in the coastal area.

The direct use of the available resource has been recognised and utilised for many centuries. Hot springs, often for recreational purposes, have also been incorporated into spa clinics, many as balneological centres. However, possibilities exist for the resource to be used for space heating and heat pumps.

Algeria

With abundant fossil fuel resources, there has historically been little development of the geothermal resource in Algeria. However the New and Renewable Energy Policy of the Ministry of Mines and Energy will help to utilise the resource, which research has shown to exist in the zone to the north of the Tellian Atlas mountains and to the south in the Saharan platform.

Although the area around Biskra has been found to have high-temperature springs, the more than two hundred springs that have been recorded in the northern part of the country are low-temperature. They are used mainly for balneological purposes, although a small amount of greenhouse heating also exists.

Argentina

Argentina is in the forefront of South American utilisation of geothermal resources and in recent years there has been much progress in the knowledge of, and direct use of, the resource. This has undoubtedly been helped by the bill for the Renewable Energies Development Act being passed by the Senators Chamber which states that renewable technologies (including geothermal) will supply 8% of electricity consumption.

High-temperature geothermal heat exists in the western region, along the Andes range and moderate to low-temperature thermal fields have been identified in other parts of the country. In the period between 2000 and 2005 nineteen new areas were studied resulting in seven of them moving to the Development and Production stage, eleven to the Pre-Feasibility stage and one to the Reconnaissance stage.

The seven projects in the Development and Production stage are located in the provinces of Entre Rios, Córdoba and Rio Negro and will supply thermal spas and tourist centres, as part of the Government's drive towards a diversification of the economy.

With the plan of providing further thermal spas, the eleven Pre-Feasibility projects are located in the provinces of Córdoba, Entre Rios, Santa Fe, Misiones and Buenos Aires. In early 2007 the Argentine Ministerio de Economía y Producción reported that the projects were at varying stages of development. Those in Córdoba province (3) were the least well advanced, owing to technological difficulties; projects (2) located in Misiones province had shown considerable progress and drilling had taken place; the status of the projects (4) in Entre Rios province were well-advanced with drilling either under way or completed; thermal drilling of the Santa Fe province project was imminent and drilling of the Buenos Aires province project was due to begin in the near future.

The Reconnaissance stage projects (2) are located in Chubut province but only one, a trout-breeding scheme is progressing well.

Of the currently installed 150 MW_t capacity, 22 MW_t is used for individual space heating, 22 MW_t for greenhouse heating, 7 MW_t for fish farming, 14 MW_t for animal farming, 1 MW_t for snow melting and 84 MW_t for bathing and swimming.

The 670 kW binary-cycle pilot power plant at Copahue went off-line in 1996 but construction of a new station (Copahue II) is currently being considered for the generation of electricity again, either as a 100 MW_e plant or as 2 x 50 MW_e built progressively.

Australia

As a result of the Federal Government's ongoing promotion of renewable energy and the introduction in 2001 of the Mandatory Renewable Electricity Target (MRET), the development of the Australian geothermal resource continues. In mid-2004 the Government published a new policy, *Securing Australia's Energy Future* and reconfirmed its commitment to MRET. The Policy introduced a A$ 500 million Low Emissions Technology Fund which is intended to assist low-emission technologies, resulting in the abatement of greenhouse gases.

A 20 kW experimental electric power plant at Mulka (South Australia) which operated for three and a half years in the late 1980s was scaled up and commissioned in 1992 at Birdsville (Queensland). This 150 kW plant ran until end-1994. After environmental considerations dictated a change in the working fluid, and also after a change of ownership, the plant was put back on line for demonstration in mid-1999. Birdsville continues to produce a net output of 120 kW (after deducting own use of 30 kW) and supplies the town's night time electricity requirements and generally during the winter. Although the town also has access to fossil-fuel generated electricity, an automatic switching system shuts down this additional power system when the geothermal plant is able to satisfy demand.

Geothermal energy is largely used directly, particularly in southeastern Australia. Many public buildings in the city of Portland, Victoria have been heated with geothermal water since 1983 when a district heating system was installed. Additionally, there are a number of locations in Victoria and New South Wales where popular spas, visited by hundreds or thousands of people each year, have been established.

It is believed that the use of ground-source heat pumps (GSHP) continues to grow but the market (both residential and commercial) is largely unmonitored. Nevertheless, the building (40 000 m^2) that houses Geoscience Australia in Symonston, (a suburb of Canberra) has its temperature controlled by 350 bores, making it the largest single GSHP installation. It is also known that many systems have been installed in public and commercial buildings in Tasmania, Victoria and New South Wales.

It has been estimated that Australia's very significant hot dry rock (HDR) resource is sufficient to generate the country's electricity requirement for centuries to come. The current federal renewable energy legislation and also specific HDR laws in New South Wales, South Australia and latterly Queensland are particularly favourable for the development of this resource. Research has found HDR is particularly prevalent in the centre of the country, extending into the northeastern corner of South Australia and the southwestern corner of Queensland. The most advanced project is in the Cooper Basin, northeast South Australia, but other schemes in the state as well as in New South Wales are under way.

Austria

The balneological importance attached to the country's spas together with the restrictions imposed by the Austrian Water Law, have somewhat impeded the progress of development of the geothermal resource. Generally, there has been a lack of public interest and support; the management of spas have expressed concern for the quality of water supplied which could possibly be affected by further and diversified use of the resource and the difficulty of combining different uses at new sites have all contributed to this lack of progress. In the case of the Water Law, it is stated that the groundwater below the land belongs to the landowner and this can be highly problematical when deviated drilling is necessary.

The aggregate installed capacity of 62 MW_t is utilised for direct applications such as district heating (45 MW_t), bathing and swimming (3 MW_t), industrial process heat (2 MW_t), the heating of greenhouses (2 MW_t) and electricity (Organic Rankine Cycle) (11 MW_t).

Two small binary power plants, Altheim and Blumau, were brought into operation in 2000 and 2001 respectively.

In the late 1990s the European Union's THERMIE programme provided support for the Simbach-Braunau scheme, a cross-border joint venture between South Germany and Upper

Austria - one of the largest district heating schemes in Europe. An installed capacity of over 30 MW serves five hundred people with some 9.3 MW of power.

In addition, it has been estimated that there are in the order of 25 000 heat pump installations throughout the country.

Belarus

To a great extent Belarus, with its reliance on fossil fuels, has historically depended on neighbours for its supply of energy and although geothermal heat is available, development of this resource (together with the other renewable energies) is still at a very early stage.

The geothermal resource, underlying most of the country, is mainly located in the Pripyat Trough, in the southeast and the Brest Depression, in the southwest. Some initial exploration work was undertaken in the mid-1950s but it is only in recent years that any use of direct heat has been made. Several small installations (in the region of 500 kW) in the north east and central parts of the country have now been built for the purpose of space heating. During 2005 drilling began for an installation in the town of Brest. It is expected to be completed and tested during the first half of 2007, with a geothermal heat pump supplying a local greenhouse complex. A second installation in the town of Soligorsk is planned.

Since the late 1990s several municipal heat pump systems have been installed to serve Minsk.

Brazil

The utilisation of Brazil's huge low-temperature geothermal resource has until now been extremely small. Much research has been undertaken by the Geothermal Laboratory of the National Observatory since the 1970s and it is thought that high-temperature geothermal heat exists only in the offshore Atlantic islands.

At the present time, the installed capacity (some 360 MW_t) is used directly, largely for bathing and swimming, with just 4 MW_t used for agricultural drying/industrial process heat. The 12 or so systems in place (mostly located in the western-central area and the south) can be classified as BRT (bathing, recreation and tourism), PIS (potential for industrial use and space heating) and TDB (therapeutic, drinking and bathing). The BRT systems total 16 MW_t, the PIS, 343 MW_t and the TDB, 3 MW_t, although currently the PIS element is not being used industrially, but for recreational purposes.

Bulgaria

Different assessments put the number of hydrothermal sources in Bulgaria at between 136 and 154, with about 50 of them having a total of 469 MW_t of proven potential for extraction of geothermal energy. The majority of the waters have been found to be low-temperature at intervals of 20-90^{o}C. Only about 4% of the total capacity has been found to have water hotter than 90^{o}C. The theoretical potential of Bulgaria's geothermal energy amounts to 13 856 TJ/yr with the technical potential put at 10 964 TJ/yr.

There are in the region of 100 MW_t geothermal systems installed in the country, representing some 23% of the currently discovered thermal potential (440 MW_t). Together with the as-yet undeveloped resources, the total capacity of thermal waters could reach from 5 100 l/s to 6 400 l/s. The energy that could be obtained when the temperature is reduced to 15°C is estimated at about 751 MW_t.

Currently, geothermal heat is used entirely for direct purposes: a situation that has persisted since the Romans installed under-floor heating in their hypocausts. Today, individual space heating has the majority share at some 50 MW_t, with air conditioning (10 MW_t), greenhouse heating (17 MW_t), bathing and swimming (26 MW_t) and other uses – aquaculture, and the extraction of chemical derivatives (7 MW_t) - as the remaining shares. A small plant, located on the northern Black Sea coast, has been installed for the production of iodine paste and the extraction of methane.

Since 1999 there has been significant development of ground-source heat pumps (GSHP) utilising the low-grade geothermal heat.

As part of the Bulgarian effort to reduce greenhouse gas emissions, the Government has received a grant (under the Japan Climate Change Initiative Grants Program and administered by the International Bank for Reconstruction and Development), to support the development of geothermal energy projects. Phase I covered the collection of technical data, the detailed analyses of financial and economic aspects of implementation and site case studies. Phase II beginning at end-2005 is covering the detailed planning of eight identified projects and also the study of the further use of GSHP.

Canada

Canada has significant and widespread geothermal potential for heating and cooling purposes. As of 2005, 36 000 geoexchange units have been installed in Canada, with an estimated installed capacity of 396 MW_t, and an energy output of 2 161 TJ in 2005.

A significant example of geothermal technology is the first Deep Lake Water Cooling System installed by Enwave Energy Corporation in Toronto. It has been in operation since 2004, serving several buildings in the city's financial district.

The geography of Canada does not easily lend itself to electricity generated from geothermal resources. There is one small generation project under environmental review in southwest British Columbia.

Chile

There has been interest in geothermal exploration in Chile since the beginning of the 20th century and although in recent years the question of security of energy supply has given the development greater impetus, a higher emphasis on the use of renewable energy generally needs to be instituted prior to further progress.

It has been established that the Chilean Andes has more than 300 hot spring areas, giving the country an estimated high-temperature (over 150^{o}C) potential of some 16 000 MW_t.

In the opening years of the 21st century the Geology Department of the University of Chile together with the National Oil Company (ENAP) and various countries with geothermal expertise undertook a research project in the central-southern areas of the country. Additionally, ENAP has worked with CODELCO (the National Copper Corporation) in the northern and southern regions. The intention of the studies was to establish areas that would be suitable for the generation of electricity.

Statistical data regarding the utilisation of geothermal heat is sparse but at the present time all usage is for recreational purposes (spas and swimming pools). It was stated during 2005 that the National Commission of Energy (CNE) was considering the possibility of installing three 100 MW electricity generating plants within the next ten years.

China

With its move to a fast-growing market economy and increasing environmental concerns, the utilisation of geothermal energy in China continues to increase, albeit with private investment rather than with state funds.

Studies have identified more than 3 200 geothermal features, of which some 50 fields have been investigated and explored. High-temperature resources are mainly concentrated in southern Tibet and western parts of Yunnan and Sichuan Provinces, whereas low-medium temperature resources are widespread over the vast coastal area of the south-east, the North China Basin, Songliao Basin, Jianghan Basin, Weihe Basin, etc.

Historically, the primary development has been in geothermal energy used directly for installations as diverse as space heating, agricultural drying, fish farming, irrigation and earthquake monitoring. However, in recent times there has been much expansion of recreational installations. The term ‘Hot Spring Economy’ has been adopted as a result of the establishment in Beijing of the World Geothermal Natural Science Park and the Geothermal Popular Science Exhibition Centre where all aspects of geothermal energy are demonstrated.

Although recently the major developments have taken place in the localities of Beijing, Tianjin and coastal towns, a development has taken place in the area of the Daqing oil field. It was found that some of the oil and gas exploration wells could supply hot water sufficient for a 310 000 m^2 district heating scheme and furnish warm water for 3 000 dwellings. In total, the country utilises geothermal energy for about 13 million m^2 of space heating.

The development of geothermal power generation has been, by comparison, relatively slow, owing to the large hydro-electric resources in those provinces with high-temperature geothermal resources (Tibet and Yunnan). The largest power complex is located at Yangbajain (Tibet). China's aggregate capacity is approximately 28 MW_e, generating about 100 GWh annually.

The utilisation of ground-source heat pumps forms a very small part of the overall use of geothermal heat. At end-2004 it was reported that 15 units of about 2.5 MW_t were in operation.

Colombia

In the first years of the 21st century, the renewable energies have gained favour to the extent that legal dispositions have been passed in support of their promotion. Although knowledge and understanding of the Colombian geothermal resource is still at an early stage, the Colombian Institute of Geology and Mines (INGEOMINAS) is carrying out inventories of the hot springs in the areas of Cerro Bravo – Cerro Machín Volcanic Complex and Cundinamarca department and also the initial stage of exploration in the areas of the Azufral volcano and Paípa.

Currently, the small use of geothermal heat is confined to bathing and swimming (including balneology).

Costa Rica

The Central American volcanic belt passes through Costa Rica, evidenced by numerous volcanoes and geothermal areas. The fields of Miravalles, Tenorio and Rincón de la Vieja are located in the north-western part of the country and have been studied in detail.

To date, Costa Rica's geothermal resources have been utilised almost entirely for electric power generation. A 55 MW_e single flash condensing unit was commissioned in 1993 at Miravalles, followed soon afterwards by an additional 5 MW_e back-pressure unit. A second 55 MW_e condensing unit came on stream in 1998, and subsequently (in 2000) another 29.5 MW_e back-pressure unit. With the commissioning of a further 18 MW_e unit in December 2003, the total installed capacity now stands at 162.5 MW_e

The Instituto Costarricense de Electricidad (ICE) owns and operates Miravalles, with the exception of the 29.5 MW plant, which operates under a 15-year BOT contract.

Exploration work on the slopes of the Rincón de la Vieja volcano at the Las Pailas and Borinquen geothermal fields has resulted in the discovery of high-temperature fields.

Following the feasibility study for a 35 MW_e plant at Las Pailas, ICE will start construction of the first unit during the second half of 2007. Further drilling will take place prior to a feasibility report for the second unit. It is expected that studies will be completed by 2010; the first unit will be on line in January 2011 and the second by July 2014.

The feasibility study on the Borinquen field was 40% complete when it was halted and exploratory work moved to the Las Pailas field. The two are less than 9 km apart, but it is considered that they are fed by separate reservoirs. The feasibility study is now expected to be completed in 2013, with the first unit scheduled to be on line in November 2018.

In the last 20 years, with the help of the Italian Government and the United Nations Development Fund (UNDP), Costa Rica's low- and medium-temperature resource has been studied. However, at the present time direct use is confined to hotel swimming pools in areas of ecotourism.

Croatia

The considerable Croatian geothermal resource is located in the southeastern and northeastern areas of the country and although usage is increasing, it is still at a very low level.

There are 28 reservoirs in the country, with a total potential of about 1 000 MW_t. Of these, 18 (representing some 114 MW_t) have been exploited for direct-use purposes (balneology, recreation and space heating).

As the acceptance and adoption of renewable energies become a reality, it is foreseen that there will be an increased use of geothermal energy within Croatia. It is planned to install a 4.4 MW_e power plant in Velika Ciglena by 2010, with an expansion to 13.1 MW_e by 2015.

Czech Republic

Geothermal energy has been little used, and then only directly (in spas and swimming pools), for over a century. However, with a view to the resource being incorporated within the national energy policy (to 2020), it has now received detailed study.

The Czech Republic's considerable potential has been categorised into high-temperature, hot dry rock (HDR) and low-temperature resources. There is thought to be high-temperature potential for 10 MW_e of electrical generation and 25 MW_t of heat production; a total HDR potential of 3 388 MW_t, based on boreholes in 847 areas, each producing 4 MW_t; and a low-temperature potential that has been estimated at 8 750 MW_t (dry rock) and 2 390 MW_t (groundwater).

More than 10 000 small (20 kW) geothermal heat pumps are installed throughout the country, providing some 200 MW_t of heat energy in residential buildings, hotels, small commercial buildings and swimming pools. A larger (1 MW_t) heat pump is providing warm water for the Prokop ore mine. Research is being undertaken for the further installation of heat pumps for district heating, recreational and industrial uses, and of an electrical power plant.

Denmark

With the Government's positive attitude towards the utilisation of the country's low-enthalpy resource, there has been an increased usage during the first years of the 21st century, which is expected to continue. It is estimated that there is a sufficient resource to supply heat to several towns for hundreds of years.

There are presently two district heating plants in operation. The first, at Thisted (northern Jutland) began operating in 1984. In 1988 it was enlarged to 4 MW_t and again to 7 MW_t in 2000-2001. The second, a 14 MW_t plant at Margretheholm, Copenhagen, started operating in 2004.

Additionally, approximately 250 groundwater-based heat pumps and 43 000 other types of pump (about 10%-20% of which are vertical closed-loop), totalling 309 MW_t , are in operation.

DONG, the Danish energy company, working in conjunction with the Geological Survey of Denmark and Greenland (GEUS), has in recent years carried out a re-evaluation of the country's geothermal potential.

With a view to the installation of further district heating plants and geothermal water production, DONG is currently in discussions with potential clients on a co-ownership basis (there is no public funding available for geothermal projects).

Ecuador

Exploration of the Ecuadorean geothermal potential was begun during the 1970s in order to establish the extent of both high-temperature and low-temperature resources. Despite follow-up prefeasibility studies on the former and prefeasibility studies on the latter, plans for industrial and direct uses were found to be uneconomic.

At the present time geothermal power supplies only a small amount of energy for direct-use purposes. Some 5 MW_t of installed capacity is used for recreation and balneology. The country's energy supply is entirely satisfied by hydroelectricity and fossil fuels, but with Government plans to develop indigenous resources (both conventional and renewable), it has been stated that the role of geothermal is set to increase. Higher oil prices and increasing energy demand may well provide the impetus to completely survey, map and reassess the country's potential.

El Salvador

Like Costa Rica, El Salvador lies on the Central American volcanic belt and there is thus a plentiful geothermal resource. The main emphasis has been on using the resource for power generation and although a potential exists for the direct use of geothermal (drying grains and fruit), it has not yet been developed.

Geothermal energy accounts for over 20% of El Salvador's electricity output. In 2005, power generation from the Ahuachapán and Berlín geothermal facilities was 985 GWh.

Of the 151 MW_e of geothermal capacity currently installed in El Salvador (95 MW_e at Ahuachapán, and 56 MW_e at Berlín), only about 124 MW_e is reported to be actually available (72 MW_e at Ahuachapán and 52 MW_e at Berlín).

Both the Ahuachapán and Berlín plants are due for expansion. The optimisation of the Ahuachapán plant is under way with 17 MW_e successfully completed by end-January 2007. Work continues on the drilling of a new production well and the necessary analysis is being undertaken for a more efficient use of the additional steam. At the beginning of 2007 it was reported that a 40 MW_e third condensing unit at the Berlín plant was in a reliability testing phase and initiation of commercial operation was expected in February 2007. A 5.5 MW_e binary unit was expected to come on-line in March 2007.

Research is under way on the exploration of the San Vicente and Chinameca fields.

If all plans come to fruition, geothermal capacity could total in excess of 210 MW_e by 2010.

Ethiopia

Ethiopia is one of a minority of African countries possessing geothermal potential. Considerable resources of both high- and low-enthalpy geothermal have been located in the Ethiopian Rift Valley and in the Afar depression. Exploration that began in 1969 has, to date, revealed a potential that could possibly generate more than 1 000 MW_e of electricity.

In mid-1998 the 7.23 MW_e Aluto-Langano geothermal plant became operational. It became the first geothermal power plant in Africa to use integrated steam and binary power technology. The plant has experienced operational difficulties, owing to problems with field and plant management skills, but it is hoped that in time these can be overcome.

In addition to the Aluto-Langano geothermal field, the other areas that have been explored are Corbetti and Abaya in the Lakes District, Tulu-Moya, Gedemsa, Dofan, Fantale, Meteka, Teo, Danab in the Southern Afar region and Tendaho and Dallol in the Central Afar region. The exploratory investigations are at different stages of development, ranging from advanced exploration to reconnaissance. Three deep and three shallow exploratory wells have been drilled at Tendaho, four of which are productive.

The country is heavily dependent on petroleum fuels for transport and some electricity generation, biomass for household cooking and lighting and an erratic hydro supply for the remaining electricity generation. If the financial difficulties that research often experiences can be solved, Ethiopia's geothermal potential could certainly assist in providing base-load electricity generation.

France

There are only low-enthalpy geothermal resources in metropolitan France; high-enthalpy geothermal resources are found in France's overseas departments.

The resources are found in two major sedimentary basins: the Paris Basin and the Aquitaine Basin in the southwest. Other areas (Alsace and Limagne) have geothermal potential but it cannot be so readily utilised.

Although the first French geothermal district heating plant was constructed in 1969 in the

Paris region, the main development of geothermal energy began following the oil crises of the 1970s. Development continued throughout the 1980s, culminating in nearly 100 exploration wells being brought into operation. However, the 1990s saw a diminution of interest in geothermal energy and approximately one-third of the plants were closed. The installed capacity is mainly used for space heating (80%+) but also greenhouse heating, fish farming and bathing and swimming.

For a considerable number of years France's low-enthalpy resources have been utilised by heat pump installations but the 2004 Energy Law together with support from EDF (French Electricity Board) and ADEME (French Agency for Environment and Energy Management) has given greater impetus to the development, particularly in the Paris area. It has been estimated that by 2010 some 40 000 heat pumps per year will have been installed in single-family houses.

Since the 1980s the French authorities have supported research into the potential of HDR. Work began at Soultz-sous-Forêts (northeastern France) in 1987 and based on the success of tests and drilling to a depth of 3 900 m (1987-1997), the next phase (1998-2001) was planned. During this period the drilling was extended to 5 000 m and further tests were conducted. Long-term circulation testing continued during Phase I (2001-2004) and during Phase II (2005-2008) it is expected that a 1.5 MW_e power plant will be installed followed by the planning and installation of a 6 MW_e plant.

An Arrêté for the long-term investment in electricity generation was passed on 7 July 2006. As far as geothermal energy is concerned the law includes a target for an additional 90 MW_e capacity by 2010. By end-2015, the target is for a total of 200 MW_e to have been installed.

Georgia

Geothermal resources are prevalent throughout the area of the South Caucasus and are utilised intensively in Georgia. However, development has been slow in recent years despite the fact that foreign aid has been available to assist with the country's difficult energy supply situation.

In 2002 it was estimated that total availability of geothermal water exceeded 100 000 m^3/day. To date, the main use has been for district heating schemes, the most important of which is in the Tbilisi area (10.6 MW_t).

The first stage (3 MW_t) of a plan for the Zugdidi-Tsaishi field was due for completion in 2005. Ultimately it is hoped that a district heating scheme of 100 MW_t will be completed in 2008-2009.

A project in the resort of Tskhaltubo foresees using a heat capacity of 40 MW_t for balneological purposes (by means of heat pumps).

Germany

Germany does not possess high-enthalpy steam reservoirs. Its geothermal resources are located in the North German sedimentary basin, the

Molasse Basin in southern Germany and along the Rhine graben.

Nevertheless, the country's geothermal resource has played a role in Germany's energy supply in recent years. By end-2004 total installed capacity for direct thermal use was 505 $MW_{t,}$ of which 80% was derived from 30 000 decentralised heat pumps (estimated to represent in the region of 400 MW_t) and the remaining 20% from 30 centralised systems (of which, 3% was attributable to individual space heating; 86% to district heating and 11% to bathing and swimming).

Germany's 2000 Renewable Energy Act (EEG) was revised in August 2004 and it is expected that the increase in remuneration for the feed-in allowance from €0.089 to 0.15 per kWh for geothermal energy will lead to greater development than hitherto. The first German geothermal power plant (230 kW_e) was inaugurated at Neustadt-Glewe in November 2003 to provide electricity for 500 households.

The Geothermische Vereinigung (GtV) is promoting the installation of the 1 GW_e Programme from enhanced geothermal systems (for example, HDR) and deep hydrothermal resources.

Already there are two power plants using HDR in development: Groß Schönebeck and Bad Urach, and plans for converting the heat of deep hot aquifers to power at Offenbach, Speyer, Bruchsal and Unterhaching. These projects are being supported by the Federal Government's Zip-Programme (Zukunfts-Investitions-Programm).

In the period 2005-2010 it is expected that 15 projects will come to fruition, providing an additional 126 MW_t of thermal capacity and 18 MW_e of electric power.

Greece

Generally, geothermal energy has encountered opposition from the local population (chiefly the inhabitants of the islands involved) because of the lack of an appropriate introduction and public relations policy by DEI, the Greek public power corporation. A 1984 law brought the exploration and exploitation of geothermal energy under the regulation of the 'mining exploration decree'; a law passed in 2003 replaced it but kept the regulation; the Development Law of 1998 favoured investments for electricity production and generation from renewable energy, but the legislation has not led to a high level of development. However, the first years of the 21st century have seen progress made in the utilisation of the geothermal resource, especially with the rise in heat pump installations.

High-enthalpy geothermal fields occur in the islands of Milos and Nisiros, which are located in the South Aegean volcanic arc. DEI attempted to install a prototype electrical generating unit of about 2 MW_e in the mid-1980s, but the whole project was eventually stopped because of operational problems (mainly due to inadequacies in the system's desalination technique) and consequently opposition from the local population. There is currently no electricity generation from these two fields because of the opposition of the local people.

Low-temperature geothermal fields occurring in structurally active sedimentary basins have a considerable potential. A small proportion of this heat resource is currently utilised, with an installed capacity of about 75 MW_t for space heating, greenhouse and soil heating, bathing and spas, industrial uses, fish farming, cultivation of spiroulina and geothermal heat pumps.

Research conducted by the Institute of Geological and Mineral Exploration (IGME) has discovered many new areas of geothermal potential in the northern regions of Macedonia and Thrace, the Aegean Islands and the northwestern region of Epirus and despite the lack of fast growth, there are several projects under development. These include an 80 000 m^2 heating and cooling scheme for the Macedonian regional airport and various heating/cooling systems for further space heating, greenhouse heating and fish farming.

Guadeloupe

The double-flash plant at La Bouillante in the French Overseas Department of Guadeloupe is at present the only example of the island's geothermal energy being utilised for electricity production. The plant was commissioned in 1985 but was closed between 1992 and 1996.

The French Agency for Environment and Energy Management (ADEME) contributed to the development of the Bouillante high-enthalpy field by supporting 20% of the cost of drilling new wells.

Following the rehabilitation of Bouillante 1, a 5 MW_e double-flash unit, in 1996, the plant was able to supply 2% of the island's electricity supply in 1998. Extensive exploration of the Bouillante field ensued and led to the drilling of three new production wells and a plan to construct Bouillante 2, an 11 MW_e unit some 400 m from the original plant. Bouillante 2 was put into service in 2005 and currently some 10% of electricity generation is supplied by the geothermal resource. Pre-feasibility studies for Bouillante 3 began in 2004 with the aim of geothermal power supplying up to 20% of the island's electricity in the future.

Guatemala

Guatemala's Instituto Nacional de Electrificación (INDE) has five geothermal areas for development. All five (Zunil, Amatitlán, Tecuamburro, San Marcos and Moyuta) lie in the active volcanic chain in southern Guatemala. INDE has conducted both investigative work and development of geothermal power since 1972. It has been estimated that Guatemala's geothermal resource could supply 20% of the country's electricity supply. However, at the present time, only about 3% is derived from geothermal power. The 2004 law, Incentives for the Development of Renewable Energy Projects (which provides a favourable tax regime), together with help from the Global Environment Facility (GEF) and various other agencies, will provide the basis for growth in forthcoming years.

The first geothermal power plant in the country was constructed in the Amatitlán area; electricity was produced from a 5 MW_e back-pressure plant for a period of three years (from October 1998), during which time the field was evaluated. The Amatitlán field is again producing electricity from a 5 MW_e unit and also supports the direct use of geothermal energy, in the form of using steam for drying concrete blocks and a fruit dehydration plant. It is estimated that the area has a total potential of 200 MW_e.

A second geothermal plant (in the Zunil I field) with a running capacity of 24 MW_e has been operating since July 1999. Following INDE's exploratory drilling work, a contract was signed with Orzunil I for the private installation and operation of the plant. Until 2019 the company will buy steam from INDE and sell power to the national grid. Exploratory drilling in the Zunil II field has shown that it possesses 4 MW_e proved capacity and Zunil I has been found to have a potential capacity of 50 MW_e.

Hungary

Hungary possesses very considerable geothermal resources and it has been estimated that the country has the largest underground thermal water reserves and geothermal potential (low and medium enthalpy) in Europe.

To date, there has been no utilisation of geothermal energy for the production of electricity. The principal applications of geothermal power used directly are for balneological purposes, greenhouse heating, space heating, industrial process heat and other uses. It has been reported that geothermal heat pumps represent an additional 4 MW_t.

There are around 3 000 abandoned oil industry exploration wells that may potentially be transformed for geothermal use. In late-2006 it was announced that the Hungarian Oil and Gas Company (MOL) was working in conjunction with Enex of Iceland and Green Rock Energy of Australia, and with support from the World Bank's Geothermal Energy Development Fund (GeoFund) would be undertaking a pre-feasibility study on the possibility of building a 2-5 MW_e geothermal power plant at Iklódbördöce in western Hungary. Drilling is taking place in disused hydrocarbon exploration wells. The plant would supply its surplus heat for agricultural, industrial purposes and district heating.

Iceland

Geothermal energy resulting from Iceland's volcanic nature and its location on the Mid-Atlantic Ridge has been utilised on a commercial scale since 1930. The high-temperature resources are sited within the volcanic zone (southwest to northeast), whilst the low-temperature resources lie mostly in the peripheral area. A realistic assessment of Iceland's potential for electricity production has been put at 20 TWh annually, after taking into account economic factors, environmental considerations and technological elements.

Iceland's total annual primary energy consumption was 550 GJ per capita in 2006 - amongst the highest in the world. Geothermal energy provides about 55% of the total primary energy supply while the share of hydropower is 16%, oil 26% and coal 3%. The principal use of geothermal energy is for space heating, where about 89% of all energy used for house heating comes from geothermal resources. There is a total of 26 municipally-owned geothermal district heating systems located in the country, the largest of which is Energy Reykjavik, serving 190 000 people. In addition to the heating of houses, direct use of geothermal energy is made for swimming pools, snow melting, industrial use, greenhouse and fish farming. In 2005 total direct heat use was 23 600 TJ from an installed capacity of 1 800 MW_t.

In recent years there has been an expansion in Iceland's energy-intensive industrial sector and thus a considerable increase in electricity demand. This has been met partly by increasing geothermally-produced electricity. The total capacity of geothermal power plants has increased from 50 MW_e in 1998 to the 2006 level of 422 MW_e. Of 9 925 GWh total electricity generation in 2006, 2 631 GWh or 27% came from geothermal energy, 73% from hydro and a negligible amount from fossil fuels.

Two co-generation power plants are in operation. The Svartsengi energy plant, in operation since 1977 has a capacity of 200 MW_t for hot water production and 46 MW_e for electricity generation, of which 8.4 MW_e comes from binary units using low-pressure waste steam. The effluent brine is disposed of in The Blue Lagoon, a bathing and balneological facility which is becoming a major tourist attraction. A new 30 MW_e generator is being installed at Svartsengi, with completion scheduled for the end of 2007.

At the Nesjavellir energy plant there is an installed capacity of 250 MW_t for hot water production and 120 MW_e for electricity production. The primary purpose of the plant is to provide hot water for the Reykjavik area, 27 km away.

Two conventional geothermal power plants are in operation: Krafla, a 60 MW_e double-flash condensing plant and Namafjall a 3 MW_e back-pressure system. At Husavik generation of electricity began by installing a binary plant of the Kalina type. In generating 2 MW_e of electricity, the geothermal water is cooled from 120ºC to 80ºC. The water is then used for district heating of the town.

It is planned to add a further 40 MW_e to the plant at Krafla and a new plant in the same area is being considered.

Two new power plants began operating in 2006: the first, Reykjanes, 100 MW_e (2 x 50 MW_e) in May, and the second, Hellisheidi, 90 MW_e, in October.

Although the growth of space heating has been fairly slow in recent years, a distinct increase of geothermal's share (from 89% to 92%) is foreseen, owing partly to demographic movement and partly to further exploration for sources of geothermal heat.

India

It has been estimated by the Geological Survey of India that the geothermal potential is in the region of 10 000 MW_e, widely distributed between seven geothermal provinces. The provinces, although found along the west coast in Gujarat and Rajasthan and along a west-southwest – east-northeast line running from the west coast to the western border of Bangladesh (known as SONATA), are most prolific in a 1 500 km stretch of the Himalayas.

The resource is little used at the moment but the Government has an ambitious plan to more than double the current total installed generating capacity by 2012. This would be achieved by utilising both conventional fossil fuels and the range of renewable energies at India's disposal (bioenergy, hydro, geothermal, solar and wind).

The Tattapani field in the far northwest of the Himalayas is estimated to have a potential of 1 MW_e and if this could be developed it would substantially benefit the isolated villages in the mountainous areas.

Direct utilisation is almost entirely for bathing and balneological purposes but greenhouse cultivation of fruit could be developed extensively in the future.

Indonesia

The islands of Indonesia possess enormous geothermal resources: geological surveys conducted by the Government have identified as many as 255 prospects, of which 70 are specified as high-temperature reservoirs with an estimated total resource potential of nearly 20 000 MW_e. Of this potential about 48% is in Sumatra, 30% in Java-Bali, 7% in Sulawesi and 15% in other islands. Taken together, the low- and high-enthalpy potential totals some 27 000 MW.

A very small amount of geothermal energy is used directly for bathing, balneology and swimming. In recent years research has been undertaken into the possibility of using geothermal heat for the sterilisation of the growing medium for mushrooms.

The effects of Indonesia's financial crisis in 1997 are still being felt. Prior to this time the Government had planned to install some 3 000 MW by 2006 but by end-2004 the country had increased its installed geothermal electric power generation capacity to 797 MW_e (operationally capable of at least 807 MW_e). This latter figure includes currently operating facilities with a capacity of 330 MW_e at Gunung Salak, 140 MW_e at Kamojang, 145 MW_e at Darajat, 110 MW_e at Wayang Windu, 2 MW_e at Sibayak, 20 MW_e at Lahendang and an additional 60 MW_e at Dieng.

It remains the Government's policy to significantly alter the fuel mix of electricity generation by increasing the use of coal, geothermal energy and hydro power and thus reducing the use of oil and gas. To this end it plans to have 6 000 MW_e of geothermal generating plant installed by 2020.

Iran (Islamic Republic)

Iran's geothermal potential is embodied in low- to medium-enthalpy resources found in provinces fairly widely distributed across the country. However, two provinces, Damavand in the north-central area and Maku-Khoy in the far north west, are likely to be the most productive.

The Ministry of Energy instituted a study of the geothermal resources in 1975 and a proposal for power generation from the Meskinshahr field (in the Sabalan prospect - also in the northwest) followed. Drilling of three exploratory wells began during 2002 and work continues on research and development.

Traditionally, geothermal heat has been used directly for recreational and balneological purposes but currently study is being undertaken on the feasibility of using the heat for greenhouses, aquaculture and space heating.

The country is extremely well-endowed with low-cost fossil fuels and this has proved a disincentive to the development of the renewable energies. However, the Government is showing a growing interest in progressing renewable energy in order to meet fast-growing national energy demand.

Ireland

There are no high-temperature geothermal resources in Ireland and all instances of low-temperature potential are only suitable for direct utilisation. To date, only one of the 42 warm springs located in the east and south of the country has been exploited, for heating a swimming pool.

The country does however possess an adequate supply of groundwater sources suitable for heat pumps. Since the late 1990s, the market has grown significantly so that now more than 1 500 domestically installed systems (typically, 12-14 kW) exist. This trend is expected to continue. Additionally, more than 30 large-scale heat pumps have been installed in commercial buildings. In total, heat pumps represent some 20 MW_t of installed capacity.

Israel

In recent years progress on the development of Israel's low-enthalpy resources has been relatively slow. Geothermal heat has been utilised directly for fish farming, spas and greenhouses.

Italy

Italy is one of the world's leading countries in terms of geothermal resources. The high-temperature steam-dominated reservoirs lie in a belt running through the western part of the country from Tuscany to Campania (near Naples). Commercial power generation from geothermal resources began in Italy in 1913 with a 250 kW unit. Subsequently the main emphasis has been on the production of power rather than on direct use of the heat.

Following the limited development of resources during the first half of the 20th century, it was the second half of that century that saw rapid growth. By end-2004, total Italian installed geothermal capacity stood at 790.5 MW_e, comprising operational units in the areas of Larderello, Travale-Radicondoli and Mount Amiata. The Italian WEC Member Committee reports that capacity at end-2005 was 810 MW_e.

Geothermal plants are eligible for various kinds of government support, including national mandatory quotas and tradable green certificates, renewable energy certificates, guarantees of origin and dispatching priority.

Power generation potential is almost fully tapped, so major efforts are being made in deep drilling and in keeping output at 5 500-6 000 GWh/yr through re-injection and well stimulation.

In 2004 an exploration study began in the areas of Larderello-Radicondoli-Montieri. This includes the drilling of eleven wells to depths of 3 000–4 000 m. However, opposition from various local communities has hindered progress. Nevertheless it is foreseen that another 100 MW_e of capacity could be installed by 2010.

In addition to Italy's geothermally-powered electricity generation, the country also utilises its resources for direct purposes. Of the 600 MW_t of installed capacity at end-2004, 58 MW_t are used for industrial space heating, 74 MW_t for district heating, 94 MW_t for greenhouse heating, 92 MW_t for fish farms, 10 MW_t for industrial process heat, 159 MW_t for bathing and swimming and 120 MW_t for ground-source heat pumps.

It was estimated that in 2005 some 6 000 heat pumps were in operation, with an installation rate of some 500 per annum. In the north of the country the heat pump market is destined to grow. A plan was announced in 2005 for 5 x 50 MW_t district heating schemes to be installed in Milan, each serving 30 000 inhabitants.

Japan

Japan has a long history of geothermal utilisation, both direct and for power generation. It is one of the world leaders in terms of generation of electricity. The first experimental power generation took place in 1925, with the first full-scale commercial plant (23.5 MW_e) coming on-line at Matsukawa, in the north of the main island of Honshu, in 1966. Following each of the two oil crises, development of Japan's geothermal resources was accelerated and by end-1984, 314.6 MW_e capacity had been commissioned. Growth continued and unit size decreased as technological improvements occurred. By end-2003, installed capacity stood at 535.25 MW_e (consisting of 20 units at 18 locations). The existing plants are all located in the Tohoku region of northern Honshu and on the southern island of Kyushu.

The country's geothermal potential is estimated to be in the order of 24.6 GW_e. Only a small fraction of this potential has been used to date and until ways of tapping Japan's deep resources can be developed, this situation will prevail. In 2000 the planned government deregulation of the electricity sector took place. This was followed in 2003 by the Special Law

Concerning the Use of Renewable Energy by Electric Utilities – a method for the encouragement of generation from renewable energies by means of a renewable portfolio standard (RPS). In the case of geothermal, the RPS is confined to binary-cycle plants.

In recent years, development of electricity generating plant has been slow but at the beginning of 2004 a 2 MW_e power unit was installed at the Hatchobaru power station – the first binary-cycle plant in Japan.

Direct use of geothermal hot water has a long tradition in Japan, where enjoyment of natural baths (more than 25 000) is a national recreation. In 2005 it was estimated that total installed capacity for direct use totalled more than 400 MW_t (excluding recreational hot-spring bathing). Of the total, hot water supply and swimming pools account for 26%, space heating 25%, snow melting 23%, greenhouse heating 11%, air-conditioning/cooling 10% (70%-30% split), fish breeding 4%, ground heat uses (including heat pumps) 1% and industrial and other uses negligible.

Jordan

Jordan possesses considerable thermal water resources spread along the Rift Valley, in addition to thermal wells in the Central and the Eastern Plateau.

Several studies on the evaluation and assessment of these resources have been conducted by the Natural Resources Authority (NRA). The results have shown that the thermal resources are of the low-enthalpy type and range in temperature from 30^{o}C to 60^{o}C. Their optimum use is for space heating, greenhouses and fish farming.

At the present time the geothermal resource is used directly in spas and for bathing and balneological purposes – installed capacity stood at some 153 MW_t at end-2004. The NRA plans to further diversify direct uses into the winter heating of greenhouses, the provision of heated water in winter for fish farming and refrigeration by absorption. It has been reported that, in cooperation with Japan (and funded by a Japanese Policy and Human Resources Development [PHRD] Grant through the World Bank), Jordan is currently implementing a study on the technical and economic evaluation of geothermal drilling data for energy applications.

Kenya

The country has a high dependence on hydropower for electricity generation (approximately 60%), but the unreliability of the water resource poses a problem, particularly for the industrial sector's power supply and also more generally leads to the purchase of expensive and polluting fossil fuels. With its substantial geothermal resource, the Kenyan Government has expressed its commitment to support the further development of this potential.

It is often reported that Kenya possesses a geothermal potential in the region of 2 000 MW_e (Kenya Electricity Generating Company

[KenGen] states that research has shown a potential of more than 3 000 MW_e). The fourteen prospects that have been identified lie in the Rift Valley but to date wells have been drilled at only two sites. These are situated at Olkaria near Lake Naivasha (about 120 km north-west of Nairobi) and Eburru, but only the former has been exploited.

KenGen's Olkaria I was Africa's first geothermal power station when the first unit came into operation in mid-1981, with an initial installed net capacity of 15 MW_e. Two more 15 MW_e units were added in 1982 and 1985.

The 2 x 35 MW_e units of the Olkaria II plant (African's largest geothermal power plant and co-financed by the World Bank, the European Investment Bank, KfW of Germany and KenGen) were commissioned in late-2003. The World Bank has approved funding for a further 35 MW_e unit to be added to Olkaria II.

Kenyan geothermal power output was increased by 12 MW_e in 2000 when the first two stages of Kenya's first private geothermal plant were installed at Olkaria III. It was announced in January 2007 that the necessary regulatory approvals for an additional stage of Olkaria III (35 MW_e) had been made; construction was expected to begin during the first quarter of 2007 and completion was expected some 20 months later.

KenGen announced in December 2006 that the drilling of wells that would eventually lead to the construction of the 70 MW_e Olkaria IV plant would begin early in 2007.

The use of thermal waters for direct purposes is limited, although hot springs are being utilised by hotels to heat spas and there is some use of steam at Eburru for domestic purposes. The Government has proposed the creation of a company to specifically develop the country's geothermal resource, which in turn would encourage the development of direct uses.

To date there has been one successful instance of a commercial direct-use application. Oserian began as a 5 ha vegetable-growing farm in 1969. Today it has grown to be a 210 ha farm specialising in floriculture with an annual output of 380 million stems. The Geothermal Rose Project covers an area of 50 ha. The greenhouse heating system is powered by a 2 MW_e binary-cycle power plant commissioned in September 2004, making the company self-sufficient in electricity needs.

In forthcoming years it is expected that much exploration drilling will take place in the Suswa, Longonot and Menengai prospects, with the aim of helping Kenya to generate a greater proportion of its electricity from geothermal power.

Korea (Republic)

With its current heavy reliance on fossil fuels and nuclear power for electricity generation, Korea's energy supply structure may well develop into having a greater share of renewable energy in the coming years.

Historically, knowledge about and use of the country's geothermal potential has been relatively limited. As further research is undertaken it is not expected that a high-temperature resource suitable for power generation will be discovered. However, utilisation for direct purposes, mainly bathing, has existed for many hundreds of years.

The Korea Institute of Geoscience and Mineral Resources (KIGAM) is currently collecting data in respect of the low-temperature geothermal resource with a view to establishing a district heating scheme near the southeastern city of Pohang. The installation of geothermal heat pumps is at a very early stage of implementation but it is expected that this market will grow substantially.

Latvia

The utilisation of geothermal energy is getting under way in Latvia. The results of geological investigations have shown that there are geothermal anomalies in the central and southwestern parts of Latvia, where the temperature of rocks and underground water (at depths of 1 300-1 950 m) reaches 30-65^{o}C. Such low-temperature waters are suitable for the provision of heat and balneology. Furthermore, waters of 10-30^{o}C can be used for fish farming. It is also foreseen that heat pumps could be installed.

A geothermal database has been created with financial support from Denmark. Preliminary calculations have demonstrated that the use of thermal underground water resources (within the limits of geothermal anomalies - above 30^{o}C) could total 175 MW_t. However, the first experimental projects (to cover the base load of a centralised heat supply system) have shown that cost factors will prevent commercialisation of geothermal energy in the short term. There has also been some theoretical research on the use of geothermal energy in Latvian health resorts.

Lithuania

In the years following independence (1990), Lithuania has firstly been transforming its political system into a market economy and secondly moving away from its heavy reliance on fossil fuels and nuclear to a greater dependence on renewable energy. Membership of the European Union (2004) and national legislation passed in the first years of the 21st century are the main driving forces for this development.

Lithuania's geothermal resource, lying in the west of the country, has been found to be significant. In 2000 the 41 MW_t (18 MW geothermal heat and 23 MW heat from absorption heat pump driven boilers) Klaipeda Geothermal Demonstration Plant (KGDP) was commissioned and began producing 25% of the heat required by the city of Klaipeda.

Much work has been undertaken on the thermal waters in Vilkaviskis, a city in the southwestern part of the country, with a view to developing balneological uses and also a district heating scheme.

To date, Lithuania's extensive low-temperature resource has been harnessed for more than 200 ground-source heat pumps. A total of some 3 MW_t has been installed in the residential sector.

It is planned to increase the contribution of geothermal energy by developing new plants including possibly some for power generation.

Luxembourg

Luxembourg's low-temperature (<20^{o}C) geothermal resource is exploited for groundwater heat pumps in the residential sector. However, neither their production nor capacity is recorded.

FYR Macedonia

Research has shown that there are 18 geothermal fields in Macedonia, with more than 50 thermal springs, boreholes and wells with temperatures of 20-79^{o}C. The resource, utilised for spas, greenhouse heating and space heating before and during the 1980s, suffered a great setback during the collapse of the economy in the 1990s. Several projects failed completely and at the present time those that remain need financial support prior to the re-establishment of a viable geothermal industry. It is hoped that in the near term an atlas of Macedonia's geothermal potential can be compiled and a strategy for the country's geothermal usage be formulated.

Mexico

Reflecting the country's location in a tectonically active region, geothermal manifestations are particularly prevalent in the Mexican Volcanic Belt (MVB), as well as in the states of Baja California and Baja California Sur. Development has, in the main, been concentrated on electric power production, although there is a small amount of geothermal power used for direct purposes.

At the present time the country has four operational fields, with a total installed capacity of 953 MW_e: Cerro Prieto (northern Baja California), 720 MW_e (13 condensing units, ranging from 25 MW_e to 110 MW_e); Los Azufres (MVB, 250 km west of Mexico City), 188 MW_e (14 condensing, back-pressure and binary units, ranging from 1.5 MW_e to 50 MW_e); Los Humeros (MVB), 35 MW_e (7 x 5 MW_e back-pressure units) and Las Tres Virgenes (northern Baja California Sur), 10 MW_e (2 x 5 MW_e condensing units).

It has been estimated that there is a potential of 500 MW_e for additional power generation from extensions to the four existing fields and development of new zones. Planned projects include construction and installation of about 200 MW_e in the present fields of Cerro Prieto, Los Azufres and Los Humeros and the Cerritos Colorados project in a fifth field - La Primavera (MVB).

Geothermal heat used directly is predominantly utilised for bathing and swimming. The reported 156 MW_t installed capacity is widely distributed throughout the country. Minimal amounts of direct heat are utilised for space heating, greenhouse heating, agricultural drying and mushroom breeding. Geothermal heat pumps are virtually unknown.

Mongolia

To date, very little comprehensive research has been undertaken on Mongolia's geothermal potential. However, with a view to diversifying electricity generation (presently mostly fossil-fuel based), especially for isolated rural communities, the Government may develop a greater use of renewable energy.

Regional studies have identified five areas with resource potential, while the country's hot springs have been used directly for heating, bathing and balneology for many years. There is scope for the resource to be utilised further in district heating schemes, industrial processing and agricultural applications (greenhouse heating, cashmere and wool washing/drying).

A study of the Shargaljuut hot springs (west-central Mongolia) suggests that the area would be suitable for small-scale power generation.

Nepal

With the country's high availability of, and reliance on, hydropower for electricity generation, there has not historically been an incentive to develop any other forms of supply. However, for reasons of climatic change, political and financial problems, there needs to be a diversification of energy sources in the future. To this end, the Government has incorporated a review of Nepal's geothermal potential within the Alternative Energy Perspective Plan (2007-2017).

Most of the 30 geothermally active areas are located in the remote northern regions and the low-temperature resource is unlikely to be utilised for power generation in the near term. A more likely use is for development of direct use for bathing purposes (currently approximately 2 MW_t). This would have the effect of popularising the technology and thereby providing revenue for further research.

Netherlands

Whilst the Netherlands has a similar geological situation to neighbouring countries, its geothermal potential (estimated by the Netherlands Institute of Applied Science to be a theoretical 90 000 PJ) has not been utilised to anywhere near the same extent. The country has access to indigenous low-cost natural gas and other forms of renewable energy that have resulted in a general lack of long-term support and publicity for geothermal power, unlike for example, Germany.

The Dutch Agency for Energy and Environment (NOVEM) initiated the Platform for Geothermal Energy in 2002. It is expected that this will result in study of the country's deep-layer geothermal heat – a resource that to date has not been utilised for heating or electricity generation.

Heat pumps using vertical borehole heat exchangers have been and continue to be installed in private houses and small commercial buildings: some 1 100 were in place at end-2004. Groundwater heat pumps are also used on a small scale, again mainly in small commercial buildings. However there is a significant market for medium to large-scale heat pumps combined with groundwater wells. Most of the 300 systems in operation at end-2004 were installed in commercial buildings, industrial zones and housing developments to provide district heating and cooling schemes.

New Zealand

New Zealand is exceptionally rich in geothermal fields, as well as in a large number of other geothermal features. Temperatures range from 70°C to greater than 220°C in the 129 identified areas. Substantial capacity exists for both the generation of geothermally produced power and also for geothermal heat used directly. However, in common with many countries today, New Zealand is experiencing the effects of privatisation of its electricity industry, together with inter-fuel competition for generation, environmental concerns and the effects of climate change. These factors have all helped to slow the pace of geothermal development in recent years.

The first geothermal power plant came into operation at Wairakei, north of Lake Taupo (North Island) in November 1958. It has generated electricity for nearly 50 years and today its capacity stands at 162 MW_e. Wairakei was the second geothermal power station to be built in the world and the first to tap a hot pressurised water resource. An additional 14 MW_e binary capacity became operational in September 2005.

By end-2005 some 263 MW_e of additional geothermal capacity had come on line, in the central North Island's Taupo Volcanic Zone (TVZ). Included in this total is the 39 MW_e binary-cycle extension at the Mokai plant, which was the first geothermal development to be owned by a Maori Trust.

One further plant (10 MW_e) began operating in 1998 in the locality of Northland – in the far north of North Island.

At end-2005 installed capacity for direct heat uses stood at about 350 MW_t. The main user of direct heat is at Kawerau, where a 210 MW_t plant generates clean process steam for various procedures within a pulp and paper mill operation. Geothermal steam at other locations is also used for agricultural drying (10% of direct-heat capacity in 2004), bathing and swimming (9%), space heating (7%) and fish and animal farming (6%).

Geothermal heat pumps are virtually unknown in New Zealand, with only isolated installations in South Island.

Nicaragua

Nicaragua is the Central American country with the greatest geothermal potential, in the order of several thousand megawatts. Reserves that can be estimated with a higher degree of confidence total about 1 100 MW_e. Medium- and high-temperature resources are associated with volcanoes of the Nicaraguan Depression, which parallels the Pacific Coast.

Geothermal exploration began at the end of the 1960s, focussing on the Momotombo and San Jacinto-Tizate geothermal fields. Studies increased after 1973, at a time when the oil crisis had a large impact on Nicaragua's economy. Geothermal electricity production started at Momotombo in 1983.

Exploitation of geothermal power in the Momotombo area, located at the foot of the volcano of the same name, began when the first 35 MW_e single-flash unit was commissioned in 1983. A second 35 MW_e unit was added in 1989. Gross output of electricity reached a peak of 468 GWh in 1992 but subsequently fell away to a low of 102 GWh in 1999 owing to over-exploitation of the field and lack of re-injection.

In 1999, ORMAT secured a 15-year contract to improve electricity output at Momotombo. Since then, the company has drilled four deep wells (OM-51 to OM-54), and of these, only OM-53 was a good producer (9-11 MW). A number of wells have been cleaned of scale and chemical inhibition systems installed. About 80% of waste geothermal fluids are being injected back to the reservoir and a new reservoir management plan has been implemented. Since May 2002, these efforts have increased and stabilised the electrical output of the flash plant at about 29 MW_e. In November 2002, a 7.5 MW_e binary energy converter came online, raising total generation capacity at Momotombo to 77.5 MW_e. The field now has 12 production wells, and four injection wells.

The San Jacinto-Tizate field was granted an exploitation licence in 2003. The project proposed consists of a plant of 20 MW_e combined-cycle technology (Phase I) followed by a 46 MW_e expansion using condensing turbine generation (Phase II). At the start of 2007, 2 x 5 MW_e back-pressure units were operational (Stage 1 of Phase I). An additional 10 MW_e will represent Stage 2 of Phase I and subsequently Phase II will add 46 MW_e, bringing the total installed capacity to 66 MW_e.

Nicaragua's total geothermal electricity output has been on a rising trend since 1999 and in 2006 totalled 310.8 GWh.

Norway

Norway's total reliance on indigenous hydropower resources for its electricity supply has meant that historically, no other energy resource was utilised. In 1999 a 2 MW_e HDR pilot plant was planned for Oslo but the project was abandoned. Heat pump installations are extremely common in Norway, albeit the majority are air-source. However, it has been stated that the market will develop in favour of ground-source heat pumps.

Papua New Guinea

Positioned as it is in the same tectonic region as Indonesia and the Philippines, exploration has been undertaken to establish the geothermal potential of Papua New Guinea. To date, 27 wells have been drilled and since 2002 activity has focussed on the island of Lihir, off the northeast coast. In June 2002 a 6 MW_e back-pressure unit was approved by Lihir Gold Ltd, the owner of the island's gold mine, one of the largest in the world. Commissioning of the plant came just 10 months later and provided the mine with 10% of its power needs.

At end-July 2005 the plant was expanded with the addition of a 30 MW_e unit. A further 20 MW_e are due for installation before end-March 2007. At 56 MW_e the plant will satisfy current electricity demand. However, the company announced during fourth quarter 2006 that an expansion to the gold-processing facility had been approved. In order to meet the subsequent increased power demand in 2010, funding for further geothermal exploration drilling had also been approved.The power from the Lihir Gold plant not only provides electricity to the mine and associated buildings but also to housing and local villages.

Philippines

The Philippines archipelago is exceptionally well-endowed with geothermal resources. Today the country is the world's second largest user of geothermal energy for power generation. With only some 46% of the stated geothermal potential of 4 340 MW harnessed, there is much room for growth. The Government plans to double the current installed capacity from renewable energy in the next decade (the so-called '100 in 10' target) and the geothermal sector will undoubtedly benefit.

As recently as 2000, geothermal energy was contributing about 25% of national electricity generation. However, the supply of indigenous gas has become significant, so that by 2005 the share of geothermal stood at approximately 18%. At end-2005 eleven power plants in six fields were operating with a total installed capacity of 1 978 MW_e. The fields, spread throughout the islands, are at Mak-Ban (Luzon), Tiwi (Luzon), Tongonan (Leyte), Palinpinon (Negros), Bac-Man (Luzon) and Mindanao (Mindanao). Four of the steam-fields are operated by PNOC-Energy Development Corporation, whilst the remaining two are operated by Chevron Geothermal Philippines Holding Inc. (CGPHI). PNOC-EDC's first vertically-integrated operation (49 MW_e) was commissioned at the beginning of February 2007. For the period 2006-2014, the Department of Energy lists two 'committed' projects and 20 'indicative' projects, with a total capacity of 824 MW.

Direct use of geothermal heat is currently at the very low level of 3.3 MW_t of which 1.6 MW_t is used for agricultural drying and 1.7 MW_t for bathing and swimming. The Government plans to further develop direct utilisation.

Poland

Poland has substantial resources of geothermal energy, but not at high temperatures. The available resource ranges from reservoir temperatures of 30°C to 130°C at depths of 1 to 4 km.

Although thermal water has been used for balneological purposes for many centuries, development of geothermal power for heating has only taken place during the past 15 years or so. Both the Strategy of Renewable Energy Resources Development which came into effect in 2000 and Polish membership of the European Union in 2004 have helped to encourage the growth of renewable energy use in general, but greater promotion of geothermal energy is needed.

Three heating plants were installed in the period 1992-1999 in the Podhale region (near Zakopane), in Pyrzyce (near Szczecin) and in Mszczonów (near Skierniewice). Two further heating plants came into operation in 2001 (Uniejow) and 2002 (Slomniki). Some of the geothermal units work in conjunction with heat pumps and/or fossil-fuelled boilers.

Geothermal water is mainly used for heating purposes. The bulk of the capacity installed for direct heating is utilised for district heating, with much smaller amounts for bathing and swimming, greenhouse heating, fish farming and wood drying. The number of ground-source heat pumps has grown steadily and capacity now stands at about 53 MW_t.

At the present time it is not foreseen that geothermal heat will be utilised for traditional electricity generation. However, there is an interest in studying binary plants which would be based on 90+^{o}C water.

Portugal

The limited geothermal resources in mainland Portugal have been developed for direct use, whereas geothermal occurrences in the Azores are utilised for the production of electricity as well as being used directly.

Twelve areas with potential for developing geothermal electricity generation have been identified on the islands of Faial, Pico, Graciosa, Terceira and São Miguel in the Azores. Two plants are in operation on São Miguel: Pico Vermelho, a 3 MW_e back-pressure steam turbine integrated in a single-flash system and Ribeira Grande with 2 x 2.5 MW_e + 2 x 4 MW_e ORMAT dual turbo-generators. The 3 MW_e unit at Pico Vermelho is due to be replaced, with a new units with a capacity of up to 10 $MW_{e.}$

Research has shown that the island of Terceira has a high-temperature resource suitable for power generation. Construction of a 12 MW_e plant is planned for 2009. Output will then meet approximately 50% of local electricity demand.

Low-enthalpy occurrences are spread throughout the mainland and have been harnessed for small district heating schemes, greenhouse heating and bathing and swimming (including balneology). Direct use in the Azores excludes district heating. To date there has been little interest in geothermal heat pumps. At end-2004, total installed capacity stood at 30.35 MW_t of which 27.09 MW_t was for bathing and swimming, 1.79 MW_t for greenhouse heating and 1.47 MW_t for district heating.

Romania

Romania's low-enthalpy geothermal potential lies mainly along the western border with Hungary and in the south-central part of the country. Usage of the country's springs has been known since Roman times but it was only during the 1960s that energy-directed exploration began. To date some 230 exploration wells have been drilled, of which 76 have become production wells and six have become injection wells.

The transition to a market economy, together with the run-up to membership of the European Union, have certainly assisted with the development of geothermal energy in Romania but for the full potential of the resource to be realised, access to adequate funding and the latest technology is required.

Currently geothermal heat is used only for direct purposes - there is no use for electricity generation or heat pumps. District heating output represents about 43%; bathing and swimming (including balneology) 28%; greenhouse heating 17%; industrial process heat 9% and fish farming 2%.

Russian Federation

Russia has a significant geothermal resource. Thermal waters of 100–120°C have been identified in several areas of the Federation: Kaliningrad, the Northern Caucasus (Alpine and Platform provinces), Western Siberia, Lake Baikal, the Russian Far East, Sakhalin, Chutotka and, most significantly, in Kamchatka and the Kuril Islands where the thermal water reaches 300°C. It has been estimated that the high-temperature resources defined to date in the Kamchatka Peninsula could ultimately support generation of 2 000 MW_e.

The country's energy sector has long been based on fossil fuels and the exploitation of hydroelectric and nuclear power, and the contribution from geothermal energy represents less than 1%. Considering the Federation's vast area and also the logistics of fuel transportation, the use of geothermal heat for power generation could be particularly important in the northern and eastern regions. However, the main thrust of Russian geothermal utilisation has been, and continues to be, for direct purposes.

The first plant using geothermal energy for power generation in Kamchatka was commissioned at Pauzhetka in 1966. It was a 5 MW_e single-flash unit which was enlarged to 11 MW_e in 1980; in 1998 a 4 MW_e plant was commissioned at Mutnovsky, followed in 1999 by an additional 8 MW_e – all single-flash units. 2002 saw the commissioning of a 50 MW_e plant at Verkhne Mutnovsky. The islands of Kunashir and Iturup in the Kuril group have small units of 2.6 MW_e and 3.4 MW_e. In 2005, total installed capacity thus stood at 79 MW_e.

It has been reported that development is under way for a 6.5 MW_e binary unit at Verkhne

Mutnovsky, a 100 MW_e unit at Mutnovsky, a 50 MW_e unit in the Kaliningrad region and a 4 MW_e unit in the Stavropol region.

The end-2005 estimate for total installed capacity for direct use amounted to more than 307 MW_t (excluding heat pumps, known to exist in the Kamchatka region), of which 52% was used for greenhouse heating, 36% for heat supply, 8% for industrial processes and 1% each for cattle and fish farming, drying of agricultural products, and swimming pools and baths.

There is much scope for the installation of heat pumps in Russia, but their use is presently at an early stage of development.

Saudi Arabia

Exploration for geothermal resources in Saudi Arabia began in 1980. It was established that 10 hot springs with temperatures ranging from 50°C to 120°C exist in the southern part of the country and the volcanic areas of the west.

Saudi Arabia has access to energy not only in the form of indigenous oil and natural gas but also to a large solar and wind resource. Despite a burgeoning demand for electricity generation, to date no use has been made of the country's geothermal heat. It is believed that in future this available heat could be developed for power generation, but it is expected that solar and wind power will take precedence.

Serbia

Exploration for geothermal resources in Serbia began in 1974: four provinces were discovered and preliminary drilling and pilot studies ensued. At the present time the main utilisation is at the 59 established thermal spas for balneology and recreation. Of an installed capacity of 83 MW_t, 43% is used for bathing and swimming, 24% for space heating, 19% for greenhouses, 8% for fish and other animal farming, 5% for industrial process heat and 1% for agricultural drying. In addition, about 6 MW_t of thermal water heat pumps are in use.

It has been established that Serbia's geothermal resource is suitable both for power generation in the future and also for expansion of the heat pump market.

Slovakia

Slovakia's geothermal resources, first explored during the 1970s, have been located in 26 areas covering 27% of the territory. The country has thermal waters ranging from low temperature (20-100°C) to medium temperature (100-150°C) to high temperature (>150°C). At the present time, utilisation is only for direct purposes; out of an installed capacity of 186 MW_t in 2005, 64% was used for bathing and swimming, 17% for district heating, 17% for greenhouse heating and 2% for fish farming. Another 1.4 MW_t represented eight geothermal heat pumps.

Amongst other projects, it has been reported that a large district heating scheme is being considered for Slovakia's second city, Košice.

Slovenia

Slovenia has mostly low-enthalpy geothermal resources, with only one area in the northeast of the country possessing a high-enthalpy resource. To date, the latter has not been utilised and the former is used at 27 locations for direct purposes only. Bathing and swimming (including balneology) is the most significant use at 39% (out of an installed capacity of 44.7 MW_t), followed by individual space heating 36%, greenhouse heating 18%, air conditioning (cooling) 3%, district heating 2% and industrial process heat 2%. It has been estimated that there is 1.6 MW_t capacity of heat pumps used for raising the temperature of swimming pool water and also some 300 ground-source heat pumps totalling 3.3 MW_t.

Spain

Research has shown that a low-enthalpy geothermal resource is widely distributed across the Spanish mainland. The main areas are in the northeast (Barcelona, Gerona and Tarragona), southeast (Granada, Almeria and Murcia), northwest (Orense, Pontevadra and Lugo) and the centre (Madrid). Other minor areas also exist. In the Canary Islands, it has been found that a high-temperature resource exists on Tenerife (but is not commercially viable) and that Lanzarote and La Palma have an HDR resource.

In 2005 it was reported that the small amount of capacity installed for direct purposes (22.3 MW_t) was divided amongst individual space heating (4.8 MW_t), greenhouse heating (14.9 MW_t) and swimming and bathing (2.6 MW_t).

Sweden

Sweden's utilisation of geothermal heat is on a very limited scale. Lund, in the far south of Sweden, has had a 4 MW_t geothermal heat pump providing base-load heat to a district heating network for the past 20 years. A venture at the Lund scheme, the Deep Geothermal Project, plans to utilise deep water with a temperature greater than 100°C for direct heat application in the existing plant. Another project in Malmö, also in the far south, plans to extract geothermal heat by means of an absorption heat pump.

There are many small ground-source heat pumps installed in the country. It has been estimated that by 2005 some 275 000 (average size, 12 kW) had been installed in residential buildings. Some 600 larger pumps (average size, 900 kW) have been installed in district heating schemes.

Switzerland

Switzerland's installed capacity for utilising geothermal energy has grown rapidly in recent years and the country now ranks among the world leaders in direct-use applications (there is no geothermal-based electricity). There are two main components to Switzerland's geothermal energy: the utilisation of shallow resources by the use of horizontal coils, borehole heat exchangers (BHE), foundation piles and groundwater wells, and the utilisation of deep resources by the use of deep BHEs, aquifers by singlet or doublet systems, and tunnel waters. In virtually all instances heat pumps are the key components.

In 2005 there were over 35 000 ground-source heat pumps installed throughout the country, representing about 532.4 MW_t. The remaining 49.2 MW_t of capacity was utilised for bathing and swimming (40.8 MW_t), district heating (6.1 MW_t), air conditioning (2.2 MW_t) and snow melting (0.1 MW_t).

Research had shown that the area of Basle in northern Switzerland had the required criteria (a temperature of 200^{o}C at about 5 km depth and an existing large heat distribution system) for the development of Deep Heat Mining (DHM) to proceed. The project began in 1996 and progressed through the stages of site selection and preparation. During 2003-2006 drilling of the first well took place (reservoir definition) followed by the drilling of the 2nd and 3rd wells for production tests. Further testing will take place during 2007–2008, during which time the pilot plant will be designed. It is intended that the plant will be built and for operations to begin in the period 2009-2010. DHM research has also been conducted in the Geneva canton and a site selected for further studies.

There remains substantial room for growth in Switzerland's geothermal sector. The annual growth-rate for heat pumps is estimated at 15% and the Government is actively supporting research and development into geothermal energy.

Taiwan, China

Taiwan lies on major geological fault-lines along the Pacific Rim, and has abundant geothermal resources. A comprehensive exploration effort has indicated a total potential of up to 1 000 MW. However, most of the resources are located in remote areas or protected lands and that makes them difficult to develop. The Government has set a target of 50 MW for 2010. Currently, a BOT project at Chin-Suei, I-Lan County is under development and is aimed at the integration of geothermal energy usage with recreational facilities. It is planned to construct a 5 MW plant by 2008.

Tanzania

Preliminary studies conducted in different parts of Tanzania by surface geological exploration, magnetic and gravity data analyses and reconnaissance exploration have indicated that the country possesses high-temperature (exceeding 200^{o}C) fluids beneath the volcanoes.

The presence of hot springs has provided a positive indication of the country’s geothermal potential. Fifty hot springs have been sampled, with the majority having a surface temperature of 86^{o}C and a reservoir temperature of 220-276^{o}C.

Presently the country’s geothermal resource is not utilised. However, and especially in the light of an increasing energy requirement, the National Energy Policy 2003 highlights the need to assess the potential and establish its viability.

Thailand

Investigations of geothermal features in Thailand began in 1946 and subsequently more than 90 hot springs located throughout the country were mapped. However, it was not until 1979 that systematic studies of the resources began.

A small (0.3 MW_e) binary-cycle power plant was installed at Fang, in the far north near the border with Myanmar. Since commissioning in December 1989, this sole Thai geothermal plant has operated successfully, with an 85-90% availability factor. In addition, the Electricity Generating Authority of Thailand (EGAT) is using the 80^{o}C exhaust from the power plant to demonstrate direct heat uses to the local population. The exhaust can be used for crop drying and air conditioning (the latter not currently in use). A further example of utilising the heat directly is a public bathing pond and sauna that have been constructed by the Mae Fang National Park.

Geothermal systems at San Kampaeng, Pai and nine other locations are reported to be under further investigation, but to date Thailand's national programme on geothermal energy has still not been firmly established and no other developments have occurred.

Turkey

A significant factor in Turkey's high geothermal potential is the fact that the country lies in the Alpine-Himalayan orogenic belt. Geothermal exploration began during the 1960s, since when about 170 fields have been identified. Although some of these are high-enthalpy fields, 95% are low-medium enthalpy resources and thus more suited to direct-use applications.

At end-2005, installed direct-use capacity totalled 1 229 MW_t, of which 635 MW_t provided the space heating and thermal facilities of 103 000 residence-equivalents, 192 MW_t provided heating for 63.5 ha of greenhouses and 402 MW_t was utilised for bathing and swimming (215 spas).

Following research undertaken in 1968 into using geothermal resources for the production of electricity, a 0.5 MW_e pilot plant was installed in 1974 in the Kizildere field (near Denizli in south-western Turkey). In 1984 the 20 MW_e single-flash Kizildere geothermal power plant came into operation. In addition to electricity generation, the plant has an integrated liquid CO_2 and dry ice production factory that utilises the geothermal fluids.

Various geothermal fields with power generation potential have been discovered and are either undergoing study (Denisli-Sarayköy, 6 MW_e; Çanakkale-Tuzla, 7.5 MW_e and Kütahya-Simav, 10 MW_e) or are under construction (Aydin-Germencik, 25 MW_e and Aydin-Salavath, 8 MW_e).

Uganda

Uganda’s power sector relies heavily on indigenous hydroelectricity. The country is particularly well-endowed with a hydro resource but large losses due to long transmission lines, together with the possible effects of climate change on the supply of water, has ensured that the Government recognises the importance of diversification.

Research has established that three areas in particular, lying in the west of the country near the border with the Democratic Republic of Congo, have considerable geothermal potential. Assessments are being made of two prospects: Katwe and Kibiro. The former has been shown to have a temperature of 160-200^{o}C and the latter in excess of 200^{o}C. A pre-feasibility study is being conducted in the area of Buranga. It is hoped that in future these areas will enable electricity generation from small-scale geothermal plants in rural areas.

Ukraine

Research has shown that the country possesses four large artesian basins with significant resources of thermal and superheated waters. This geothermal resource allowed Ukraine to construct nine plants between 1978 and 2002, utilising the heat directly for individual space heating and district heating. Two of the plants are located in Yantarnoye (Krasnogvardeysky region) and Medvedevka (Dzhankoy region). The former with an installed capacity of 3 MW_t was operating until 2003 and is now undergoing modernisation; the latter is still in operation.

United Kingdom

There is no recorded high-temperature resource in the UK and although the country possesses a low- and medium-enthalpy resource it is, unlike some of its European neighbours, very under-utilised. Research into HDR technology has ceased.

There has been no direct Government support for geothermal energy despite the country being required to produce 10% of electricity generation from renewable energy by 2010. The only application of low-enthalpy geothermal energy has been a large-scale scheme to supply combined heat and power to 3 000 homes, 10 schools and numerous commercial buildings in the city of Southampton.

There are only isolated instances (estimated at 550 at end-2004) of ground-source heat pumps in existence, representing about 10 MW_t. The Low Carbon Buildings Programme (LCBP) was introduced in April 2006 (replacing The Clear Skies Project) to provide grants for a range of renewable technologies including ground-source heat pumps. It is hoped that this will stimulate the market.

The UK has many disused mines and at the present time there are two projects in Glasgow using water that has accumulated in the mines and then pumped via heat exchangers to heat apartment blocks. Several other schemes are under consideration.

An ambitious plan to regenerate the site of a cement works which closed in 2002 will hopefully lead to a renewable energy village in Upper Weardale, County Durham. The area, which was formerly mined for lead and fluorspar, is known to possess a source of geothermally-heated water (46°C at a depth of 1 000 m). The Weardale Task Force's Master Plan for the eco-friendly village envisages that the heat will be utilised for a public hot-springs spa and fish-breeding ponds. Additionally, the development will include environmentally-friendly commercial and residential property and a range of tourist and leisure activities based on the use of biomass (for a district heating scheme), wind, solar and hydro technologies.

Following the viability studies currently being conducted, it is expected that a planning application for the village will be submitted in early autumn 2007.

United States of America

The USA possesses a huge geothermal resource, estimated at some 50 000 MW_e, located largely in the western half of the country. Research has shown that geothermal energy has been used in North America for many thousands of years but the first documented commercial use was in 1830 in Arkansas. In 1922 an experimental plant began generating electricity in California but, proving to be uneconomic, it soon fell into disuse. Another 38 years were to pass before the first large-scale power plant began operations at The Geysers, north of San Francisco, California. The USA is the world's largest producer of electricity generated from geothermal energy.

Only California, Nevada, Hawaii and Utah utilise geothermal energy for power generation; investigative studies undertaken in Oregon during the early 1990s proved to be unsuccessful. However, the 1990s saw dramatic change in the geothermal power industry: plants came on line, plants were retired, there were changes of ownership (resulting, in some cases, in operational efficiencies), etc. By end-2005 total effective capacity stood at 2 564 MW_e. It is reported that 88 MW_e of capacity is under construction and planned projects would add 213 MW_e capacity.

Geothermal heat suitable for direct utilisation is far more widespread through the US, ranging from New York State in the east to Alaska in the west. At end-2004, a total of 617 MW_t installed capacity was used for fish and animal farming (138 MW_t), greenhouse heating (97 MW_t), bathing and swimming (112 MW_t), district heating (84 MW_t), space heating (146 MW_t), agricultural drying (36 MW_t), industrial process heat (2 MW_t), and snow melting (2 MW_t).

In addition, it is estimated that between 600 000 and 800 000 heat pumps are installed in the US (in all 50 states but more commonly in the mid-west, mid-Atlantic and southern states).

The US Department of Energy continues to support geothermal energy through sharing the cost of R&D with industry, funding state programmes and providing technical assistance to small developers (through GeoPowering the West Program).

Vietnam

The government-supported exploration and evaluation of the country's geothermal resource has shown that there is a total of 269 prospects and a potential of 649 MW_t. The south-central, north-western and north-central regions are the areas of Vietnam with the greatest potential.

At the present time there is no geothermal power generation: a pre-feasibility report for 6 plants (total capacity, 112.7 MW_e) in central Vietnam has been prepared but the project has been postponed.

Direct utilisation is limited to the provision of industrial process heat (iodide salt production, 1.4 MW_t) and bathing and swimming (29.7 MW_t).

Zambia

Zambia's wealth of available electricity generation from hydro power has resulted in a lack of progress in the development of other renewable energies. Although Government policy supports the use of renewables in general there is no specific policy for geothermal energy in particular. The country exports electricity surplus to its requirements and despite Government policy to raise the rate of access in both urban and rural areas, it is infeasible for rural areas to be supplied from the grid. To this end, a Rural Electrification Authority (REA) to administer Rural Electrification Projects (REPs) was established in 1994, with a view to the installation of mini-grids and/or stand-alone systems.

Exploration has shown that Zambia possesses in excess of 80 hot springs and that electricity generation could be possible by means of binary-cycle units. Two projects, at Kapisya and Chinyunyu, were formulated during the 1980s and although two Organic Rankine Cycle (ORC) turbogenerators (280 kW) were installed at the former (for rural electrification), it never became operational owing to insufficiently high resource temperatures. The plan for the Chinyunyu hot springs was to build a health resort and provide electricity for the local community. A lack of funding precluded this project from proceeding.