DIRECT USES OF GEOTHERMAL ENERGY 1995

(Preliminary Review)

D. H. Freeston

Geothermal Institute. University of Auckland, New Zealand

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ABSTRACT

The worldwide application of geothermal energy for non-electric use is reviewed This paper attempts to update the previous survey carried out in 1990 by the same author and presented at the International Symposium in Hawaii For each of these updates data has been requested from countries and analysed to give a world wide perspective and for this latest update an effort has been made to collate additional information on Heat pumps and investments This paper has been prepared on the basis of the draft manuscripts and information provided to the organising committee which are referenced at the end of this paper However some of these papers may not have been published in these proceedings, or the data or titles may have changed after the reviewing process. The numbers in this report should therefore be considered as preliminary, it is intended to publish the final analysis at a later date. However what is evident from the papers received, is that there is a large potential for the development of low to moderate enthalpy direct use across the world which is not currently being exploited due to financial constraints and the low prices of competing forms of energy. A preliminary estimate of the installed thermal power at the end of 1994 (1990 in brackets) from the current returns is 8207 MWt (8.064 MWt) utilising 35,998 kg/s (3 1,800 kg/s) of fluid and the thermal energy used is 105,475 TJ/y (61,747 TJ/y)

INTRODUCTION:

An update for both electric and non-electric use of geothermal energy worldwide was initiated by the World Congress 1995 Organising Committee as a follow on to the those carried out in 1985 and 1990. From experience of the last survey, the data forms sent to individual countries was slightly modified and additional material requested, namely geothermal investments for the past two decades, in an attempt to obtain a wider and more accurate perspective of the worldwide direct use scene The data in tabular form, requested for this direct use update included, information on projects on-line at December 1994. together with a summary of geothermal direct uses, geothermal heat pumps, wells drilled since 1990 as well as allocation of professional personnel to geothermal activities and investments in geothermal for the past two decades. These tables were to be attached to a country update paper describing direct use activity in the particular country. In all there were 57 responses, unfortunately not all countries responded in a similar manner for a variety of reasons, some countries had only exploration projects tu report, some had only a limited amount of data available, others had difficulty in putting together flows and temperatures for particular projects and some were only able to submit pan data in letterform Some countries however produced the information as requested in the wrrect format which made the transfer to the summary farm easy to compute As mentioned above this is a preliminary analysis based on the draft manuscripts and should be treated as such

The assumptions used in the analysis were similar to that used in the previous surveys with the methods of calculation listed at the top of the Tables issued, namely:.

Installed thermal power (MWt) = m (kg/s) x (ti - to) (°C) x 0 004184.
Energy Use (TJ/y) = Annual average flow rate (kg/s) x (ti.- to) (°C) x 0 1119
where m = max flow rate. ti = inlet temperature and to = outlet temperature

Bathing has been excluded from the total since it dominated, particularly the Japanese numbers, the 1990 survey, however it is acknowledged that this activity is an important use of thermal fluids Both swimming pools and other aspects of balneology however have been included where they were identified Heat pumps have been included as a separate item for the first time in the summary of uses. and they make a significant contribution to the totals

Table 1 shows from this preliminary analysis. that 36,000 kg/s of geothermal fluids are now used worldwide compared to 31,800 kg/s in 1990 Similarly the installed thermal power is estimated at 8,207 MWt, (8064 MWt) and the energy use is 105,475 TJ/y (61,747 TJ/y) with the average load factor based on these latter two numbers being 0 4 (0 39) The energy use figure could be inflated because there were a number of countries that did not distinguish hetween maximum (for power determination) and annual average (for energy flow utilisation) and others which had very high load factors for some uses which seem *unreasonable*. At this stage the figures used by the authors of the individual papers have been used In Freeston (1990) average growth figures were calculated for the five years 1985-1990 (12%), however this author does not believe that it is appropriate at this time to quote the equivalent number for 1995 until there is validated data to work with

Table 1 also shows the personnel and investment numbers collected Far both these columns it is difficult for some countries to separate those working on electrical applications and those involved with direct uses In the investment table the split between electrical and direct use utilisation was requested. where that has been presented the total allocation to R & D and field development etc has been divided on a basis of the percentage of direct use to total utilisation expenses to obtain the overall figure of US$1,325 million The personnel column numbers involve the total employed on geothermal both electrical and direct use, at this time this author, on the assumption that in many countries one work force caters far both disciplines. has used the total number quoted per country (690). It is of interest to use these numbers, for those countries that have submitted the appropriate data, and to obtain an average *cost /MWt* and *persons/MWt* These are $US2.9 *million/* 10 MWt and 1.4 persons/10 MWt respectively. However the variation around these averages is high For the cost/MWt they vary from 0 04 for the USA to 1 88 for Slovenia whilst far the personnel the variation is from 0.1 for the USA to 10.6 for Poland.

Figure 1 shows the distribution of the annual energy utilisation by use. Bathing here refers mainly to swimming in thermal mineral pools and pools heated by geothermal fluids. Snow melting and Air Conditioning (1%) have been put together. they each represent about 0 5% Space heating which includes both district heating and the supply of domestic hot water is the largest use of geothermal fluids with some big district heating systems in operation Heat pumps utilise 12% of the total, the major countries being Switzerland and USA.

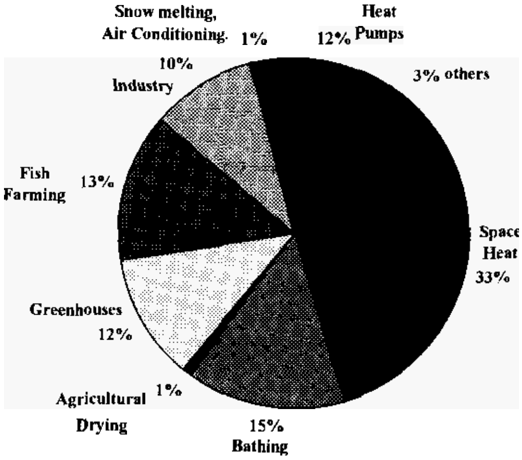

FIGURE 1: Summary of World Wide energy use of direct heat Data is based on returns from 23 countries. Total = 102,268TJ/y

Industrial uses represent 10% of the total. with New Zealand and Iceland being the major countries utilising geothermal fluids in this way with high load factors of 0 8 and 0 6 respectively Fish and other animal farming account for 13% with China and USA having the major energy utilisation, typical load factors for this use are in the range 0 3 to 0.7.

COUNTRY REVIEW:

The reports submitted for each country and published in the proceedings of the Congress are briefly summarised and any additional information from the recent literature added to give an overview of a countries programme and prospects.

AFRICA.

Algeria: **Fekraoui** and Abouriche (1995) repon that the inventory of thermal springs has been updated with more than 240 identified, the highest temperatures recorded **were.** 66°C **for** the western area. 80°C for the central and 96°C for the eastern areas. In the south the thermal springs have mean temperatures of 50°C The north east of the country, an area of 15,000 km^2, remains potentially the most interesting geothermally, with the Barda spring giving 100 l/s and another spring in the area, with the highest temperature in the country of 96°C. ***An*** estimate of the heat discharge from about 30% of the countries springs is **642** MWt based on a mean annual outdoor temperature of 18°C for the northern areas and 30°C for the central or Sahara area Some greenhouses at Ouargla and Touggourt **in** the central region are reported to be using 60°C albian geothermal water for heating. Bellache et al state (1995) that the geothermal potential in these regions is sufficient to heat 9.000 greenhouses, with a flow of 3,421 l/s. The same authors have also carried out a study recommending further use of the countries geothermal resources to improve food production, **using** greenhouses outside of the conventional periods when the climate requires heated greenhouses to enhance growth. that **is** during the severe climatic conditions from October to March No mention **is** made of the proposed residential heating projects mentioned in the 1990 update **as** to whether these have been commissioned The tables of data included with the repon are incomplete, however there is average flow rates and energy **use** for six of the localities amounting to 258kg/s and 793TJ/y respectively. Using these numbers **as** a basis it is estimated that for the total of eleven localities used **for** bathing the total flow would be about 516kg/s and an energy utilisation 1586TJ/y, which with a load factor for bathing of say 0 5 gives a thermal power of 100 MWt

TABLE 1. Summary of data collected from draft country update papers and tables

Country	Flow Rate kg/s	Power MWt	Energy TJ/y	Ave. Load Factor	Cost 85/94	Person man years
Algeria	550	100	1657	0.5	0.0	27
Argentina	0.0	0.0	0.0	0.0	4.4	56
Austria	173	19.5	184.0	0.3	0.0	0.0
Belgium	57.9	3.9	101.6	0.82	0.5	1
China	8628	1915	16,981	0.28	0.0	0.0
Denmark	44.3	3.5	45	0.4	5.5	7
France	2,971	337	3,190	0.3	580	24
Georgia	1,363	245	7,689	1.0	35	38
Greece	242	23.2	133	0.22	0.0	0.0
Guatamala	12	2.64	83	1.0	0.0	15
Hungary	1,714	340	5,861	0.54	0.0	0.0
Iceland	5,794	1443	21,158	0.57	240	100
Israel	1,217	44.2	1,196	0.84	0.0	0.0
Italy	1,612	307	3,629	0.37	54	250
Japan	1670	318	6978	0.69	0.0	0.0
Macedonia	761	69.5	509.6	0.23	26.7	9
New Zealand	353	264	6614	0.79	0.0	56
Poland	298	63	740	0.37	60	67
Romania	300	130	1230	0.30	0.0	0.0
Russia	1240	210	2,422	0.37	0.0	0.0
Serbia	892	80	2375	0.94	0.0	4.0
Slovakia	353	99.7	1808	0.57	0.0	0.0
Slovenia	573	39.1	780	0.63	73.5	13
Sweden	455	47	960	0.0	0.0	1
Swiss	120	110	3470	1.0	177	7
Turkey	700	140	1987	0.45	0.0	0.0
USA	3905	1874	13,890	0.23	68.4	15
TOTAL	35,998	8228	105,671	0.40*	1325	690

* Based on total power and energy.

Kenya: Freeston (1990) reported **on** warm and hot springs being used for livestock drinking water and other **uses,** however despite there being potential available little use has been made of the low enthalpy **resources** to date in Kenya One project on soil sterilisation for the Oserian flower farm located adjacent to the Olkaria geothermal field is reported by Melaku et al, (1995) A hot water spray system uses fluid from **an** existing well, which was not suitable for electric power production, to heat clean water **in a** plate heat exchanger, which is then sprayed onto the soil to sterilise it

Mozambique This country has a energy policy to encourage new and renewable **sources** of energy, including geothermal, Martinelli et al (1995) A map of the 38 known hot springs indicates temperatures ranging from about 20°C to **over** 90°C and bottom hole temperatures obtained during the logging of petroleum **wells** have been used to obtain preliminary data on heat flaw and geothermal gradient Heat flows are of the order of *50* mW/m^2 with thermal gradients approximately 15 to **39** mK/m, all data giving encouragement for the development of the most promising areas **in** the northern and central provinces of the country with small scale power plant being particularly suitable No mention **is** made of low enthalpy sources hut tabular data indicates that bathing and therapeutic **uses** of thermal water exist and with the range of temperatures obtained, direct uses will develop **as** and when finance is available for total development of the countries geothermal resources

Tunisia: In 1992 Tunisia's energy consumption **was** expected to exceed the petroleum production so that the country became an importer of energy. Since 1980 assessment and development of alternative domestic **resources** including geothermal has been undertaken There are 70 identified hot springs. 230 shallow wells and **350** deep petroleum wells that have been used to assess the potential for the utilisation of geothermal energy for agricultural and industrial uses. Ben Dhia and Bouri (1995) Ten areas have been identified where **low** to moderate temperature fluids, to about 150°C, are known to exist at shallow depths to make them useful **as** alternate Sources of energy. However not all pans of the country **are** assessed at the same level and far the last three years geothermal research has focussed on the northern pan, the object being to assess its geothermal potential However no new utilisation projects seem to have been started, the cooling tower and green house projects mentioned in the 1990 report appear in the latest update without any apparent expansion

Uganda: This country appears for the first time in these surveys A geothermal exploration project, funded by the government of Uganda, UNDP, OPEC and the government of Iceland ran between March 1993 to April 1994, Mboljana (1995) Its primary objective was to select from three prospects in western Uganda, which **are on** the western branch of the East African rift system, one for further geophysical exploration and exploratory drilling The three prospects for study had been identified by studies carried out earlier during some initial surveys in the 1950's to 1970's The recent study. phase I, which employed geologic and geochemical methods, gave reservoir temperatures in the range 120°C to 200°C The second phase is to **use** the data from phase I and create **a** geothermal model which will serve to identify suitable sites for detailed geophysics In 1981 Uganda was estimated to have a total geothermal power potential of 450 MWe

Zambia: There are two major geothermal energy developments in Zambia, Money (1994). The Kapisya project. on the shores of Lake Tanganyika, has 15 shallow exploratory and production wells used to supply two 100 kW ORC turbogenerators which have been installed but are currently unable to operate because the building of **a** transmission **line** has been delayed due to insufficient funds The second project **involves** the development of a health **resort** and **a** potential power plant at Chinyunyu hot springs 50 km east of Lusaka. This project, being undertaken by JICA and the Zambian Geological Survey has not progressed from the planning stage due to lack of funds

Other Countries: In **Eygpt** four thermal wells (50-75°C in the northwestern desert, drilled primarily for oil are considered to be a target for geothermal energy extraction The fresh water (TDS 464ppm) discharged from these wells is fed from the Nubian aquifer system which is located in the eastern Sahara desert, northeast Africa, Boulas (1989). The proposal is to use the waters not only for their present use, domestic and agricultural supply but also for irrigating large areas of land by pumping water using electricity generated from these fluids. These wells can also be used for suppling hot water to greenhouses for the production of vegatables and fruits There **is** no further information **on** progress on the developments mentioned in Freeston (1990) in **Djibouti** or **Madagascar** although Battistelli et al (1991) report on some reservoir engineering studies at the Asal field in Djibouti

ASIA.

China: Ren et al (1990) reported in Table 2B, utilisation of geothermal energy for direct heat 1989, a total average flowrate of 7,294 **kgis** which, with the temperatures provided, Freeston (1990) estimated a total energy utilisation of 5.527 GWh at an average load factor of 29% The latest survey, Ren et al (1995) shows a reduction in the average amount of fluid used to 5,996 kg/s, mainly **as** a result of a reduction in flow rates utilised in Tianjin, Shandong and Shanxi provinces and despite some small increases in flow rates recorded for the liangxi and Xinjiang provinces. Ren et al. also quotes an annual energy use of 16,981 TJ/y from an installed capacity of 1914 MWt, an overall average load factor of 0 28. The numbers are therefore essentially the same as 1990 indicating little or no change in the utilisation of geothermal energy for direct heat in the past five years For completeness in this report. the **uses** of geothermal fluid as outlined in Ren et al (1990), which are not detailed in this latest report, are used to recalculate the breakdown of the power and energy use for 1995 assuming there is no change in the percentage distribution **as** quoted by Ren et al. (1990), (it is noted that Wang et al. (1995) has utilised these 1990 figures in his 1995 paper) Ren et al (1990) states there are 49 projects using thermal water for industrial processing such as dyeing, drying fruit and vegetables, paper and hide processing. air conditioning and pre-heating boiler feed water etc with **a** net annual energy consumption estimated for 1995 of 1443 TJ/y. Space heating, mainly in North China, uses **a** 1995 estimate of 2836 TJIy, where 1,313,800 m^2 of heating area is supplied by geothermal fluids Geothermal fluids are used to heat 1,159,156 m^2 of greenhouses (1223 TJIy) and 1.6 million square meters of fish ponds (3617 TJ/y) **in** 17 provinces. swimming and bathing (7862 TJ/y) make up the balance to a total of 16, 981 TJ/y Huang and Zheng (1995) refer to some specific projects on space heating. industrial **uses** and medical treatment and tourism and Zheng and Cao (1995) discuss the growth of district heating in China This latter paper gives some costings and demonstrates that although the development of district heating systems in China has been slow there are good prospects for future geothermal systems **as** environmental and economic constraints are in favour of developing the geothermal **resources** for district heating particularly close to the load centres

India: This country did not appear in the 1990 survey however a detailed research and exploration programme to assess the geothermal potential started in 1973-74, Pandey and Negi (1995) This paper, Pandey and Negi (1995). is based mainly on the work carried out in the last **seven** or eight years More than 300 thermal springs with temperatures 30°C to 100°C and a number of high heat flow **areas** have been identified. *Some* thermal springs have deep reservoir temperatures beyond 200-250°C Some estimates of power potential from these thermal areas range from 2,000 MWe to 10,000 **MWe**. Exploitation of wells drilled for hydrocarbons in sedimentary basins are **also** considered to be suitable for development projects with temperatures measured of 100-150°C at I 5 to 3km deep in the Cambay graben but **use** of the countries resources for electric power production is at an early stage as ***no*** serious deep drilling to prove reservoirs has been undertaken. Direct utilisation is also in its infancy a number of projects have been started. The government of Himanchal Pradesh has finalised plans for direct utilisation of geothermal heat in selected areas for tourism and health **resorts** In general however the country lacks the infra structure to rapidly develop its large geothermal **resources.**

Japan Sekioka and Toya (1995) in their presentation of the geothermal direct use in Japan emphasise the small scale of most of the systems in Japan and the lack of detailed measurements to make a full analysis, however the data presented is of sufficient quality to enable an overview of the utilisation of geothermal fluids in the country The number of geothermal direct use facilities analysed is 208 with the majority of them in the Hokkaido and Tohoku districts which have a cold climate and Kyushu which has a large number of geothermal resources. Many of the load centres are close to the resources, **81%** of systems **are** within 1000 m of the **resource** Well depths range from about 100m to over 2000m with the majority of wells, 60%. drilled to less than 500m. The installed thermal power from all 208 facilities is about 319 MWt of which 182 MWt is for space heating and about *52* MWt for greenhouse heating. The average load factor for all systems is 69% with a high load factor of 81% for space heating and a low of 8% for air conditioning in an installation at Akita prefecture The data produced in this paper show substantial increases in the installed capacity and energy use **over** the past **5** years, however this is due *to* better reporting and not to evolution of direct **uses** in Japan Sekioka and Toya (1995) do not include the fluid and energy used **in** bathing which has been a dominant factor in previous surveys. In 1990 the mass flow, installed thermal power and annual energy **use** allocated to bathing was **31,213kg/s**, 3,321 MWt, and 31,428 Tlly (8730GWh) respectively Since there is no update on these figures, it is proposed, for the purposes of *analysing* the world direct use utilisation. to follow the lead of the authors and to ignore the numbers associated with bathing, For the future, combining binary plant with direct uses is planned The New Energy and Industrial Development Organisation (NEDO) is developing 100 kWe and 500 kWe binary cycle generators and has identified 63 existing geothermal and hot spring wells having potential outputs within this range to give a possible total of 15,527 kWe which together with a production of 11,251 kWe from 12 existing wells would give a total of 21.778 kWe available utilising these small scale binary plant. In addition the discharge temperature and flow rate From these plants, 76ºC and 125 ton/h is suitable for geothermal direct uses

Korea: A total of 276 sites have been identified for low temperature direct use in North and South Korea, Han (1995). Reservoir temperatures for 69 hot springs in South Korea, are in the range 25 to 78ºC. In North Korea 28 springs are tabled with reservoir temperatures 35 to 78ºC Most of these springs are utilised for public or private baths and hotels with many sanatoriums for medical treatment of illness. Swimming pools for athletic training have been developed in the Onyang hot spring area and greenhouses growing fresh vegetables and potted plants exist in the Kyungbook and Choongnam provinces. Fish farming in the Southern parts of Korea raise shrimps, turtles, eels, snails and snakes Space heating projects are under investigation in Masan and Chagweon areas and a feasibility study of the geothermal potential of Cheju Island is underway.

Philippines. The geothermal programme is centred around the development of electrical energy from its geothermal resources which for a while in the early part of the decade came to a stop, as there were no new developments, due in part to the structure of the industry, Gazo (1994). Javellana (1995) However a number of key events provided a stimulus for development and the 1990 objectives have been largely met A major direct heat project was undertaken with UNDP help, utilising waste brine from the Palinpinon I power development The demonstration crop drying facility was commissioned in 1994 to hot dry coconuts and a variety of fruits and fish The project has a high social content and it is anticipated that similar plant will be established at geothermal projects elsewhere in the Philippines. Plants producing ice are also planned for installation in Manito, Albay, using brine from several exploration wells not included in the Bac-Man I and II geothermal steam pipe network, Gazo (1994)

Thailand: Since 1990. Fang is the only geothermal field that has been fully developed for multipurpose utilisation, Ramingwong and Lertsrimongkol (1995). This includes generating electricity, drying and cooling processes and tourism. A deep drilling project was undenaken at Fang with the objective of defining the potential of a deep reservoir. The results indicated that the prospect of having a high enthalpy reservoir in the area was low. It was also concluded that it is necessary to develop deviated drilling techniques if the current reservoirs are to be fully utilised The San Kampaeng project has been postponed after two unsuccessful deep wells but a new prospect in the Pai district , Mac Hone Son province is undergoing the pre-feasibility stage No data is given to allow estimates of installed capacity etc.

Others: In Iran a geothermal exploration project was commenced in 1975 and Fotouhi (1995) repons that the nonhern region of Sabalan has potential with estimated temperatures of 140-251°C. It is recommended that an exploration well be drilled in the Meshkin-Shar zone Malaysia has done very limited work an its geothermal resources however since 1987 some detailed investigations which include water chemistry and resistivity traversing have been carried out in the Andrassy area, Lim (1994) Nepal has identified 23 geothermal springs with surface temperatures in the range 21 to 71ºC. At present the spring water is largely confined to bathing and washing activities. Ranjit (1995). The people of Juma use the water for medical purposes and tourists are attracted to the area, similarly the local people of Bajhang observe a festival at their geothermal site once a year and a guest house and temple have been built in the thermal spring area at Darchula to attract visitors undertaking mountaineering activities A complete inventory of all the geothermal resources is underway but a definite programme on their utilisation has yet to emerge. From 1992 to 1994 the Geological Survey of Vietnam has undertaken a preliminary assessment of the geothermal potential of some hot water resources in the south of the country. Thach Tru in the Modoc district of Quang Ngai province has been selected for detail study. Le Vinh Hong (1995). A reservoir temperature of 160 to 180ºC is indicated but for electricity generation to be economic it would be necessary to produce fluid from 500m, however an exploration well is considered justified

THE AMERICAS

CENTRAL AMERICA.

The majority of the countries in Central America have developed or are developing their geothermal resources for electrical power generation Costa Rica. El Salvador, Guatemala and Mexico have all submitted update reports which detail their electrical capacity and potential but only Guatemala give information an Direct heat projects Palma and Garcia (1995) tabulate four small projects in Zunil and Amatitlan. 2 for bathing, 1 for industrial process heat and I agricultural drying project at Zunil using production from a slim hole to dry fruits and vegetables Total installed thermal power is 2.64 MWt and energy use of 83.11 TJ/yr. The Platanares geothermal field in Honduras has been studied since 1987 A recent publication, Di Pippo and Goff (1994), has assessed the field so far explored as being capable of supporting 7 MWe with a load centre adjacent to the field of a mining company, which is able to absorb the energy *An* industrial park using Cerro Prieta. Mexico. residual heat and solid by-products was proposed in 1989, legal and economic implications of this 580 hectare industrial park were being reviewed, Lund (1991). Attempts to use the silica for bricks and soil stabilisation were being researched. An industrial laundry was under construction using waste brine from two wells at 180ºC to heat clean water for washing laundry from US hotels. hospitals, employing 200 people Projects using geothermal fluids for greenhouses and refrigeration plant at Cerro Prieto and Los Azufres were under consideration but no further details are available

NORTH AMERICA:

Canada: Geothermal research and development during the years 1990-1994 has been at a very low level, government have withdrawn funding and private industry has not been willing to take over, Jessop (1995a). With the exceptions of direct use development at Springhill Nova Scotia, where water is pumped out of a flooded coal mine and heated to supply heat with a heat pump, to four industries, lessop (1995b) and at Carleton University. Ottawa, which has a space heating project using six heat pumps with a total nominal output of 800 kWt utilising water at 9.5°C as a heat source, no geothermal project was within reach of profitable development. Jessop (1995a) also describes two other projects where wells have been drilled and feasibility studies completed without progress to utilisation From their world wide review of the literature, Fridleifsson and Freeston (1994) reported that seven geothermal projects were ongoing when the federal government ceased funding geothermal energy research in 1986 Of these six were utilising warm waters for heating agricultural buildings, swimming pools and deicing projects. Heat pumps are in use on two projects, one for heating and cooling a 14,000m^2 factory and the other as mentioned above. At Pebble Creek on the north slope of Mount Meager (British Columbia) a project to install 10 MWe condensing turbines is underway followed by a working plant of 100 MWe, progress will depend on funds becoming available, Jessop (1995a).

At the South Meager geothermal reservoir preparations are in hand to drill a large diameter deep well following extensive resource evaluation, GRC (1994).

United States: Since 1990 there were 18 new or expanded projects representing an increase in thermal capacity of 51 MWt and annual energy utilisation of 524 TJly, Lineau et al. (1995). Geothermal heat pumps represent the largest growth sector during the period adding an estimated 627 MWt and 2223 TJ/y to these **figures** Sixty two wells were drilled for direct utilisation to an average depth of 250m and the numbers of professional staff employed in the industry fell by 70%, mainly due to reductions in funding from both state and federal sources. There has also been **a** shift from public to private funding of direct heat projects. In Lund et al. (1990) two district heating schemes were reponed **as** under construction, Mammoth Lakes and Bridgeport, These systems have not been built but exploratory wells have been drilled There are no new geothermal district heating systems started but both Klamath Falls and San Bernardino have expanded their systems All categories of **use** have seen steady growth with the largest occurring in space heating, greenhouses and industrial plants A significant development **in** the industrial sector was the establishment of an onion and garlic dehydration plant in Nevada To expand utilisation of low temperature resources, ten state **resource** teams reviewed and updated their **resource** inventories within the temperature range **20** to 150°C many of which have potential to supply a load within 8km of the resource in addition *to* greenhouse, aquaculture etc locally. This assessment project has resulted in **a** catalogue of 8,710 thermal wells and springs for these 10 western states, an increase of 43% compared to the assessment **in 1983,** and priority sites have been identified. Lineau et al (1995) give details of new plant developments with forecasts of particular growth in the geothermal heat pump industry. They conclude that the potential for geothermal direct use in the US is very large however the large resource base **is** under utilised and there **are** impediments to development These include lack of information about the resources, the infra structure for development, high risk and low cost of gas coupled with consumer **lack** of knowledge

SOUTH AMERICA:

Only two reports were received of direct heat developments in South America

Argentine: Geothermal resource surveys have been carried out in eleven **areas** throughout the country, Pesce (1995) **Sin** of these were studied further to the feasibility stage of which two, Bahi Blanca (Buenos Aires) and Rio Valdez (Tierra del Fuego} were low enthalpy resources At Rio Valdez 13 springs have been located with an average temperature of **38.5°C,** the reservoir fluids are at temperatures between **88** and 98°C. It is anticipated that the fluids could be used for space heating. **as** the area has long cold winters, wood drying, processing wool. food refrigeration etc. The Biahia Blanca area has reservoir temperatures in the range 55 to 85°C at depths of *530* to 1000m. The raising of shrimps using this resource is under study Pesce (1995) shows 34 sites using thermal fluids, mainly for bathing with temperatures between 26 and 65°C Twenty wells have been drilled mostly **for** direct utilisation between 1949 and 1991 although **3** of these wells are for the 670 kWe binary plant at Copahue Fifty six professionals **are** employed in the industry which has spent US$9 17 million of public money **in** the past 10 years of which US$1.1 million has gone into direct heat utilisation. No details are given which would enable the utilisation of geothermal fluids to be evaluated

Chile: Investigation of the countries geothermal resources began **in** 1967 concentrated on two areas, El Tatio and Puchuldiza, Gonzalez (1995) and **in** 1977 **a** country wide, but divided into regions, geothermal inventory was staned which continued into the 80's. Later in 1993 a detailed reconnaissance of resources in central Chile **was** made This confirmed the possibilities for geothermal development

Low enthalpy **resources are** abundant along the eastern boundary of the central valley, which **are** areas of high population. Medium and high enthalpy resources are located along the mountain chain of Los Andes Cordillera, where mining centres are sited Permissibility studies **were** done **on** three hot spring areas with the economics favouring a cascade type of exploitation. El Tatio has been the primary area of investigation with 13 wells drilled between 1969-1974 which despite the exploration work the total energy potential of the field is unknown New governmental legislation is being written which it is hoped will stimulate geothermal development.

Others: High temperature resources have been identified by drilling in Bolivia, Columbia. Ecuador. Peru and Venezuela but there is little new information on their current **use** and plans and the status of any **low** temperature fields since that published in Freestan (1990). With reference to the **Bolivian** project Delgadillo ,1994) reported that six wells were drilled with UNDP and Italian government help, of which five are producers in the Sol de Manana field which together with an additional well are sufficient to install up to *25* MWe Currently funding is being sort to install two 4 MW units. In **Peru** the government is considering legislation to allow private investment in the governments electric power industry Koenig (1994) Since the early 80's exploration at a regional **level** has led to a detailed geochemical study of the El Pilar-Casanay, **Venezuela** prospect where a water steam shallow reservoir has been located with temperatures of 200 - 220°C, and a deep liquid dominated **reservoir** with temperatures **of** the order *250* - 300°C

EUROPE

Albania: 'There was no repon from Albania at the 1990 meeting so the data presented, which has been collected in the last three years. represents a new geothermal country. The country has both hydro energy, with 1427 MWe installed **in** seven plants and **20** oil and gas reservoirs producing about 649.8 kt of oil in 1993. down from **an** average 1.2 Mt in previous years The oil is used in domestic and industrial plant. and **a** thermal plant of 160 MWe **Coal** is also available in significant quantities Alternative sources of energy are being studied in view of the decline of both oil, gas and coal resources in the country in recent years The recent geothermal study has collected data which has included heat flow studies. natural thcrmal water springs. and water basins that have anomalous temperatures, Frasheri and Bakalli (1995). The investigation of the fields is based **an** temperature measurements carried out in 120 deep oil and gas wells located in the ***lonian*** and Kruja zones and the Preadriatic depression and in 15 bores in the ophiolitic belt in the Mirdita **zone.** Temperatures vary from a minimum at 100m of 12°C to 105 8°C at 6,000m. **In** the central part of the Preadriatic depression where there are many boreholes the temperature reaches 68°C at 3,000m The thermal springs which are situated mainly in the regional tectonic fractures. have temperatures ranging from **21** to 58°C. Maps of temperature at 2,000m and the thermal gradients and spring locations are included in the paper The authors conclude that there are eeothermal resources that can be used and a detailed evaluation of the energy available ***needs to*** be done as ***soon*** as possible

Belgium: Due to the low energy prices no major developments of Belgium's geothermal energy have taken place in the last five years. Berckmans and Vandenberghe *(1995)* The main development in geothermal research was initiated by the **European** Community in 1993 under the **JOULE** II program. This led to a review in 1994 of the geothermal resources of Belgium. The results **are** to be published in the 1996 of the Atlas of Geothermal Resources of **Europe** These results have indicated that the Dinantian in the Hainaut basin, the Buntsandstein and deeper lying areas of the Dinantian in the Campine basin have the best potential for future development

Technological and regional economic parameters. together with the nature of the aquifer warrant further evaluation In the North the chalk reservoir is used to heat a swimming pool in the summer at the town of Herentals whilst another pool at Turnhout is heated through the year. At Dessel close to Turnhout, fish are produced. In the South the local regional development company runs a geothermal installation which includes heating to a school. a swimming pool, a sport facility and residential buildings, from a well having a temperature of 70°C. In the second stage the water is cooled from 50 to 40°C to heat a 4,000m^2 greenhouse which after further cooling to 30°C, is used to heat waste muds at Wasmuel The total installed thermal power is 3.89 MW with an energy use of 107.3 TJ/y It is estimated that since 1975 US$10 7million have been spent on geothermal projects however only US$0.5million since 1985, mainly on research.

Bulgaria: The heat potential estimated for the thermal waters discovered in Bulgaria amounts to 488 MWt, one third of which can be obtained with the use of heat exchangers and two thirds using heat pumps. Temperatures in the range 32 to 42°C are not included as according to law these waters are reserved for balneological use, Bajadgieva et al. (1995) The thermal water utilisation in Bulgaria is related mainly to balneological needs (15% of the total), space heating (9.4%) and greenhouses (4.9%), bottling of potable water and soft drinks (1.4%). swimming pools (4.5%). and some industrial uses (7.6%). the rest (49.5%) is labelled as free capacity indicating that the estimated full potential of 488 MWt has not been utilised. The average duration of the heating season in Bulgaria is 180 days so load factors are moderate, many systems have heating and ventilating capability. However estimations based on all projects indicate that the price of one GJ of produced energy from geothermal resources is 2 to 4 times lower than for fossil fuels and the pay back period is 2.5 to 8 years, drilling costs are not included as all sites use existing wells Unfortunately the data presented is not in a format which allows inclusion in the summary table as there is some confusion as to the installed power capacity and total mass flow rate In 1990 the numbers were 2647 kg/s, 293 MWt and 2772 TJ/y (770 GWh). The figures that appear in Bojadgieva et al. (1995) are not consistent with these numbers

Croatia: There are two regions in the Republic of Croatia that have geothermal potential although only in the north, which belongs to the Pannonian sedimentary basin where the average geothermal gradient of 0 049°C/m is of significance, Cubric and Jelic (1995) Several geothermal reservoirs, discovered during hydrocarbon exploration have been extensively tested. however only three areas (Bizovac, Ivanic, and Zagreb) have been exploited with a total installed thermal power of 15 MWt At Biwvac the thermal water is used for balneology and some space heating with fluid extracted from two reservoirs at 1800m and 1600m Well head temperatures are 96 and 85°C with flows of 5 and 3 kg/s respectively. At Ivanic the water (2 kg/s) is at a WHT of 62°C, is used for balneology and at Zagreb two areas of the reservoir, the very permeable area of which is estimated to be about 10km^2, have been exploited. Reservoir temperature is 55 - 82°C between 500 - 1000m deep At Blato site the planned thermal power is 7 MWt whilst at Mladost 6 3 MWt with an additional 0 86 MWt of heat pump The energy is used for space heating and swimming pools. Data is also given in the paper of potential sites, particularly in the northern part of the country and it is estimated that 815 MWt is available for development from known resources, but like many countries financial and other constraints, the northern cities are close to a natural gas pipe line, are limiting the interest and development of these fields.

France: Over the past thirty years, the French have specialised in the development of geothermal energy using low enthalpy resources for urban heating, Demange et al (1995). Today geathermal energy is used for heating and hot water production of around 200,000 heating units Forty projects are located in the Paris basin with another 14 operations in the Aquitaine region, some of which are used for agriculture In addition there is a 4.5 MWe electric power station operating in Martinique and around a thousand operations exploit shallow aquifers with heat pumps for heating and air conditioning. Most of these installations were built between 1981 and 1986 Demange et al (1995) discuss in their paper the French experience in maintenance. remote monitoring and optimising and developing of geothermal heat networks and their work on reservoir behaviaur. Since 1986. when mast of the 55 geothermal doublet wells in the Paris region had been completed, three successive 3-year R&D programmes have been implemented. focussing on reservoir behaviour with the objectives of understanding the resource and managing its exploitation The last two programme to be completed in 1995 have been centred on the Dogger reservoir where at the scale of the Paris basin an understanding of the phenomena that defines the reservoir condition has been attempted and the last three years the geothermal doublet has been researched to explore the concept of life time and its characteristics. Since 1975 US$1320 million has been spent on research. development and utilisation of the geothermal resources of which US$640 million has been spent between 1985 and 1994, this includes HDR research and US$30 million on electrical utilisation There is no data in Demange et al (1995) that allows a calulation of power and energy use so that in the 1990 report is quoted here Mass flow of 2.97 kgis, thermal power 337 MWt and thermal energy 3,190 TJ/y

Georgia: The geothermal fields in Georgia are in the carbonate **rocks** of the intermontane trough to the west and fissured volcanics and sandstones **of** the Adjara-Trialety folded system in the east of the country. Buachidze (1995). In the far west the Gagra balneological resort uses 30 kg/s of 47°C thermal water, and at the Sukhumi - Dranda field balneology facilities, a flower greenhouse and the airport use the fluid To the south east the Kindghi - Okhurei fields supply hot water to hot beds and greenhouses over an area of IS hectares. Further eastwards there is another major field at Zugdidi - Tsaishi, here the hot water is used for a paper mill as well as heating the town of Zugdidi Again in the south east four further fields are used for balneological purposes and protection of citrus crop in inclement weather. In west Georgia. another papular resort at Tskaltubo uses thermal water whilst at Tbilisi field on the eastern edge of the Adjara - Trialety folded system the thermal water is tapped at I 5 to 4.0km giving temperatures about 65°C The total installed thermal power is 245 MWt with a total energy use of 7.685 TJ/y Process heat has 30 MWt installed with greenhouses 70 MWt and space heating and fish farming 66 and 64 MWt respectively. Since 1991 no development has taken place but it is estimated that since 1975 US$152 million has been spent on research, development and utilisation of geothermal fluids, all public money, of which US$35 million was spent from 1985 to 1990.

Greece: Geothermal research that started in 1970 has revealed geothermal potential, bath high and low enthalpy. in numerous fields around the country During the last five years related exploration activities were focussed mainly on the low enthalpy fields of Thrace and Macedonia and in the field of Soussaki in central Greece, Fytikas et al. (1995) At Magma (Thrace) a new, very promising geothermal field has been identified by 21 exploration and 3 production wells. Country wide geothermal development has resulted in approximately 160 acres of geothermally heated greenhouses in operation, approximately 80 acres of which were commissioned in the past 5 years From the data presented 242 kg/s of fluid are used solely in heating greenhouses giving a total estimated installed capacity of 23 2 MWt with total energy utilisation of 133 TJIy and an average load factor of 0 18. This represents a small increase from that reported in 1990

Hungary: The numbers of active thermal wells reported in Arpasi (1995) is 810, with 342 closed wells as at 31 December 1993 i e. a total of 1152, compared with a total of 1,045 reported in Ottlik (1990) of which Árpási (1995) quotes 138 wells were closed The current extraction rate is 6,032 kg/s (1990 - 9,533 kg/s) nearly half of which has a temperature in the range 30-40°C. Drinking water supply utilises 29 9% of the total. balneology 27 3%. agriculture 26% and space heating 1 3%, with typical load factors of 0 5 for space heating of buildings. 0.4 for greenhouses and hot water supply at 0 4 Thermal water production in recent years has declined from 403 Mm^3/y in 1989 to 190 Mm'ly in 1993 and there is no reinjection as all the water is discharged to surface water reservoirs Geothermal energy accounts for 0 25% of the total energy consumption of Hungary but only one system was commissioned in the period 1990-1994 Since 1990 there have been no funds injected into geothermal developments The geothermal energy utilised for agriculture and space heating is given as 1600 TJly which repesents 27 3% of the total The other 72 7% is used for balneology (1600 TJ/y) drinking water supply (3,352 TJ/y) and others (908 TJ/y) Using the load factors in the text an estimate of the installed power is obtained, 340 MWt, which is considerably less than the 1276 MWt estimated from the data supplied in 1990 It is thought that these 1995 figures are more reliable since a number of assumptions were made, which may not have been valid, to generate the 1990 numbers

Iceland: The principal use of geothermal energy in Iceland is for space heating with **85%** of all houses heated with geothermal water, Ragnarsson (1995) 20% of the total geothermal energy production is utilised for the generation of electricity which represents 5% of the electricity consumption of the country The total flow ofgeothermal fluid used is now 5,794 kgls (4.595 kgls in 1990) in over 30 projects with an annual energy use of **21,158** TJ/y. This represents a total installed power in 1995 of 1443 MWt from 774 MWt in 1990 The increases appear to have come, in general, from increased flows in mainly existing systems. For example Reykjavik is now drawing 1000 kg/s more than in 1990. in addition three new industrial projects are also reported By far the biggest use of geothermal fluid is for district heating which accounts for 59% of the geothermal primary energy supply, with electrical energy using 20%. The biggest district heating scheme is Reykjavik which serves about 145,000 people within a volume of $806,000m^3$, using 52 wells with a delivery temperature of 80°C and an installed thermal capacity of 640 MWt 110 public swimming pools of surface area of $28,000m^2$, $250,000m^2$ of snow melting systems. a total area of $170,000m^2$ of greenhouses together with $105,000m^2$of soil heating. 75 fish farms as well as the diatomite, seaweed processing and salt plant (recently closed down) and industrial plant represent the wide use of geothermal heat in Iceland In 1994, 100 professional man years of effort were utilised in the industry, about the same as for 1990. with US$249 million spent in the last 10 years.

Israel: This is the first time there has been a report from Israel, where investigations using logs from 340 deep drillholes. which cover most of the country. have enabled isotherms and qeothermal gradients to be established. Greitzer and Levitte (1995). A number of springs located in the Rift valley with temperatures in the range 26 to 60°C are presently used for spa and recreation and a few geothermal wells with temperatures of 26 to 60°C are used for agriculture, greenhouses and fish farming. In total 1217 kg/s of geothermal fluid are currently utilised giving about 42 MWt of installed thermal power and a total annual energy use of 1196 TJ, which gives a very high load factor of 84% The major use is for bathing (44%) and fish farming (43%) with the remainder (13%) used in greenhouses where the load factor is about 50%

Italy: The present use of geothermal energy for direct use is reponed in Allegrini et al (1995). The total energy use amounts to about 2700 TJIy with a peak thermal power of about 240 MWt These numbers are significantly different from those quoted at the 1990 conference where the figures used by Freeston (1990) were for an installed capacity estimated at 330 MWt It is not known where the discrepancy occurs but at that time 64% of the installed capacity *was* for balneology *use* Swimming and bathing utilises the most energy, 74% of this 1995 total, whilst two new district heating projects, at Ferrara and Vicenza, have come on line since the last report, the Vicenza plant is discussed by Leoni (1995) Fish farming accounts for only 1 2%. the aquaculture project is discussed in Berdondini et al (1995) The promotion activities carried out by the ENEL demonstration centre is discussed by Burgassi et al (1995) and this includes initiatives ranging from mineral and chemical recover). to the use of geo heat for agro-industrial applications Allegrini et al (1995) show that 250 professional man years of effort were utilised in 1994 compared to 220 in 1990, the numbers relate to the total employed in bath the electrical and non-electrical spheres of geothermal activity The total investment for the past 10 years is given as US$1,655 million with about 0 1% on direct utilisation and 27% on electrical utilisation. the rest is the cost of R&D and field development, including drilling

Republic of Macedonia: This is a developing country of $25,713km^2$ and 2 1 million people with an energy budget which is based on 50% imparted liquid fuel, coal for industry and electricity, and *50%* on hydro power and domestic fossil fuel. Dimitrov and Gorgieva (1995) Currently geothermal is supplying 508 TJ/y (141 GWh) of energy with electrical energy from hydro and thermopower supplying 24.408 TJly (6780 GWh) So far no high enthalpy fields have been discovered but mare than 50 shallow and deep exploratory and production wells drilled to depths between 40 and 2,100m have outlined 4 to 6 major geothermal areas including several minor fields The total flow is 1,000 l/s, total installed thermal capacity is estimated in excess of 70 MWt with an energy use of 510 TJ/y, of which 80% is exploited in greenhouse heating at load factors of about 0 33 Maximum temperatures measured were over 80°C with estimated deep fluid temperatures in some fields of 100 to 120°C Fifteen geothermal projects are in operation or under development in five main areas In 1994, nine professional man years of effort were utilised of which government and public utilities supplied two thirds. In 1990 the same professional effort was used but the most of it was from the government sector In the last ten years US$26 7million from mainly public funds has been spent on geothermal R&D, field and direct utilisation developments.

Poland: Geothermal waters for balneology purposes have been known and utilised since historical times but in 1985 data analysis of several hundred oil wells in the geothermal basins allowed estimates to be made of the geothermal potential in an area of $250,000km^2$ and occupied by over 30million people A program of research and construction of plant was initiated in 1985 During the period 1987 to 1994 a number of exploration wells were drilled and an experimental plant at Podhale was constructed and the construction of a heat generating plant at Pyrryce started. Sokolowski (1995). The tables show a total of thermal installed power of 63 MWt (9 MWt in 1990) and an energy use of 700 to 775 TJ/y, at load factors greater than 0 8 An 18 MWt heat pump is also shown to be operating at Pyrzyce utilising 25°C water The largest user of geothermal energy is the 40 MWt air conditioning plant at Pyrzyce using 70°C water Currently 63 professional man years of effort with 19 provided by foreign consultants and aid programmes are shown Over the 1985-1994 period it has been estimated that US$60million has been spent on the programme.

Romania: For the 1990 survey Freeston (1990) used data generated in the 1985 survey of Gudmunsson (1985) since none other was available at that time i.e thermal power 251 MWt, flow rate 1380kg/s

The latest information we have is from Panu (1995) where it is stated that a total of 195 wells have been drilled since 1964, four of which were drilled in 1994. A total of 54 geothermal wells are producing about 300 kg/s at temperatures ranging from 40 to 105°C, with a total installed capacity of about 130 MWt, from the text, although the table in the paper shows less than 30 MWt installed, numbers which are quite different from thosc used earlier. The paper by Sarbulescu et al. (1995) quotes 130 MWt as the installed power *so* this number is used in the summary table The use is for district heating for about 3,000 dwellings. 47ha of greenhouses. sanitary hot water for 16,000 dwellings, preparation of industrial hot water for about 10 factories and balneology uses. Some of the geothermal waters have high proportion of methane gas (80-90%) which has a heating capacity of 8,500 kcal/m^3, which some consumers are now using A number of new projects are underway, new wclls are being drilled in the Santandrei area where it is hoped that the temperatures will he sufficiently high to supply fluid to OKC generators far electricity. at Olanesti it is expected that an artesian flow rate of 200 m^3/h at a temperature about 90-92°C will provide heating for a hotel complex and in the north of Bucharest a doublet giving 80-85°C will provide heat to tourist dwellings

Russia Kononov et al (1995) presents the Current state of geothermal utilisation where apart from the small plant at Kamchatka (11 MWe) geothermal fluids are used mainly for space and district heating Six towns and eight big settlements with a total population of about 220,000 use geothermal district heating and a total area of geothermally heated greenhouses is about 340,000m^2 Direct use is most widespread in the following regions of the Russian federation, Northern Caucasus, pre-Caucasus, West Siberia, Baikal and Kuril-Kamchatka regions. By the end of 1994, 367 geothermal wells had been drilled, 185 for production, 10 for reinjection and 86 for observation Total flow is 1240 kgis producing 8180 TJly from an installed capacity of210 MWt. In Kamchatka temperatures of 80-100°C are utilised for space heating in a number of settlements and the construction of an 80 km pipeline for the transmission of thermal water is underway to connect the power plant at Mutnovsky to the town of Elizovo. Of the energy use, 45% is used in district heating with 48% in greenhouse heating with just over 15% for industrial processes which includes wool washing, paper production wood drying etc. About 150 bath resorts and 40 bottling factories using thermal and mineral waters operate in the regions. At Mostovskoy 75°C water is used in a complex system, involving greenhouses. space heating, cow sheds. pig farms. and poultry yards as well as fabrication of concrete blocks and wood drying Finally the resulting 20-30°C water is used in a swimming pool and fish farm. There are at present 14 geothermal centres involved in geothermal projects including 26 scientific institutes. 2 universities, 5 project bureaus with planned projects casting over US$600 million.

Serbia: Geothermal investigations began in 1974 and an assessment of the resources has identified four geothermal provinces of which the most promising are the Pannonian and Neogen magmatic activation provinces. More than 80 low enthalpy systems have been identified, the most important are located at the southern edge of the Pannonian Basin. Milivojevic and Martinovic (1995). Values of the heat flow density are higher than the average for continental Europe with the highest value in the Pannonian Basin (>100 mW/m^2). I59 natural thermal springs have been identified with temperatures in excess of 15°C with a total flow of about 4000 kgis. Between 1977-1988, *58* wells were drilled in the Pannonian Basin, with an overall yield of 550 kgis and a heat capacity above 25°C, of 48 MWt, but since 1988 only 4 exploration wells have been drilled In the other provinces 45 holes were drilled up to 1992 with a yield of 500 kgis and a total capacity of 108 MWt. The commonest use of the geothermal fluid is the traditional one of balneology, there are today 59 thermal spas and thermal waters are also bottled in nine mineral water bottling companies The direct use for space heating is in its initial stage and very modest in relation to the potential. The total installed thermal capacity is 80 MWt with 6 MWt of hsat pumps and a total energy use of 2375 TJ/y. 1150 TJly or 48% ofthe total are used for bathing and swimming, 24% for space heating and nearly 11% for greenhouse heating. The geothermal activity is currently manned by a total of 4 professional man years of effort , *3* from Universities. For the future the resource base data suggests that geothermal energy in Serbia could make a significant component to the national energy mix, in addition the intensive use of thermal water in agro and aqua-cultures and in district heating systems, particularly west of Belgrade could be of value to the Serbian energy situation.

Slovakia: Twenty six geothermal fields have been identified (27% of Slovakia) as prospective areas for potential exploitable geothermal resources in Slovakia. Since 1971, 61 wells have been drilled yielding 500 kgis of water in the temperature range 20-92°C, Remsik and Fendek(1995) The total estimate of geothermal energy in all the prospects is 6,608 MWt with the Eastern Slovakian basin having the highest heat flaw of 120mW/m^2 Low temperature waters < 100°C exist in 26 areas with 16 areas having temperatures inIthe range 100-150°C and only 5 areas with temperatures greater than 150°C. In the Kosice basin in east Slovakia, medium and high temperature sources of geothermal energy suitable for electricity generation(25-30 MWe) looks to he possible. The total average annual flow rate from the current exploitation is 353 kgis producing an annual energy use of 1808 TJ/y Of this 49% is utilised in greenhouses with a further 36% used in bathing and swimming. Space heating and fish farming are the other applications of the energy The total installed thermal power for the country is 100 MWt Franko(1995) describes the utilisation of geothermal present and future in the Vysoké Tatry Mountains and with temperatures of 50°C concludes that the potential thermal power available in this region is 94 MWt Tourist and sporting facilities space heating, domestic and industrial are seen as future projects for the region.

Slovenia: Slovenia is placed between the colliding margins of the Eurasian and African plates on the western border of the Pannonian basin Investigations started in 1982 and heat flow density temperature maps were published in 1991, whilst geothermal energy resources were investigated in 1992/93, Rajver et al. (1995) The main geothermal parameters were established from 130 boreholes in a depth range 100-4000m Temperatures at 4,000m do not exceed 200°C while temperature gradients vary from 10°C/km to about 70°C/km The geothermal energy potential is concentrated in the eastern part of the country. From the tables, geothermal energy utilises 753 TJ/y (the text show 1110 TJly) from a flow from 21 geothermal localities, thermal spas and recreation centres (56%) are the main consumers with some output to space heating (29%) greenhouses (10%) and industrial purposes (2%) More than 500 heat pumps extracting an additional 64 TJly from the shallow groundwater are also operating The installed thermal power is 36 5 MWt, heat pumps provide an additional 5 5 MWt 32 wells have been drilled since 1990 and in the past ten years it is estimated that US$73 5 million has been spent of public funds on geothermal development In 1994, 13 professional man years of effort were used in developing the geothermal programme

Switzerland: The early nineties marked a turning point in Swiss geothermal development. Deep drilling projects gave momentum to a country wide borehole heat exchanger (BHE) installations, Rybach and Gorhan (1995) Since 1990 significant steps in energy policy development towards the utilisation of indigenous and environmentally forms of energy have been undertaken A governmental risk coverage system for deep drilling(>400m) introduced in 1987 is still effective, 15million Swiss francs was awarded by federal government to cover activities 1987-1997, *6* wells have been drilled to depths between 650 and 2550m since 1991 with, in general too low flow rates for sensible utilisation. However wells drilled in the late 80's were more successful. resulting in a geothermal doublet system of 4.7 MWt starting up in 1993 at Riehen Shallow geothermics, 15-400m deep bores, has resulted in BHEs and their derivations,(energy piles, multiple BHE, combined heat extraction/storage etc) providing a new impetus to geothermal developments in the country. More than 6.000 such systems are installed representing heating amounting to 3.2PJ/y (Switzerland used 346PJ far space heating in 1993). In addition to the extensive use of BHEs Rybach and Gorhan (1995) describe other initiatives such as the use of Alpine Tunnel waters in heat pump installations, see also Rybach and Wilhelm (1995), and a contribution to the European HDR programme. The tables indicate that 218TJ/y are utilised mainly in conventional space heating with a total installed rated capacity of 104MWt and an annual energy use of 3252TJ/y. The professional man years of effort in 1994 was 7 and the total investment in the past ten years was US$177 million ofwhich 85% was private funds.

Turkey: The main geothermal provinces are classified by taking into account the tectonic and volcanic features, so a) high and moderate enthalpy fields are situated on the graben structure of western Anatolia, b) the low enthalpy fields are on the north Anatolian fault zone related to strike-slip fault and volcanic activity, c) geothermal systems on the sedimentary basin mainly related to volcanic activity and d) systems in mountainous terrain related to volcanism and compression tectonics, Koçak(1995) The exploration studies started in 1962 has identified more than 600 hot springs with the highest temperature of 102°C. The potential of the low temperature resources is estimated at nearly 1500 MWt although currently exploration drilling has only taken place at about 140 hot spring sites Almost all the direct use of the low enthalpy fluids is for space heating *(95%)* although extraction of CO, at Kizildare and some leather processing takes place in some fields. Currently geothermally heated installations total 140 MWt, 20,000 dwellings, with 90 MWt under construction and a future growth with completed feasibility studies of 635MWt This last figure is far 91,000 dwellings and about 80,000m^2 of greenhouses These numbers are different from those quoted by Mertoglu et al (1995), however these authors quote costs of heating in US Cents which again are different from Koçak(1995). Based on electricity, 6 c/kWh, fuel-oil, 5.6 c/kWh, natural gas, 4 8 c/kWh, coal 3.9 c/kWh, and geothermal at 0 1-0 56 c/kWh Also 1994 costs for heating a dwelling during the winter and domestic hot water throughout the year are 15US$/month with installation cost per dwelling of about 750US$ Unfortunately there is no table presented in either paper that allows a good comparison of the figures presented in 1990 neither is there a breakdown of uses In Freeston(1990) the total installed thermal power was 246 MWt, compared to the present 140 MWt.

Others: Wells for the exploitation of geothermal energy in Austria have been drilled in the Upper Austrian Molaase basin and the Styrian basin, both of which are bordering the Alps, since 1985, Goldbrunner(1995) At the end of 1993, the installed geothermal thermal power was 19.3MWt. The largest project is at Altheim in Upper Austria where 750 dwellings are heated. Wells drilled in the Styrian since 1985 are all used for bathing Spas are of growing economic importance in Southern Austria The only field quoted for Denmark is at Thisted which is a sandstone reservoir with a high dissolved solids wntent (150,000mg/kg) and a reservoir temperature of 46°C. Mahler (1995) An absorption heat pump extracts 3.5 MWt from the geothermal water when it cools 143m^3/h of thermal water from 44 to 22°C. The use is for space heating and utilises 45 TJ/yr. There is no country update paper for Germany but three papers in the conference give details of some direct heat activities and Freeston (1990) recorded that low enthalpy geothermal energy is utilised in 15 localities with a total installed capacity of about 8 MWt. The paper by Kabus and Jäntsch(1995) reports on a district heating system at Waren - Papenberg providing heat for 1,000 flats and Sanner(1995) reviews ground source heat pumps in Germany whilst Jähn(1995) details the utilisation of 8 MWt of geothermal heat from thermal water in Straubing by cascading through multi uses with heat pumps, swimming pools and space heating from a production temperature of 36°C down to a reinjection temperature of 13°C. In addition Bram (1993) reports on the German continental drilling program and Poppei et al (1993) reports on studies to utilise existing abandon oil and gas wells with closed loop water systems for extracting energy in heat pump,and district heating systems. In Iran a geothermal exploration project was commenced in 1975 and Fotouhi (1995) reports that the northern region of Sabalan has potential with estimated temperatures of 140-251°C It is recommended that an exploration well be drilled in the Meshkin-Shar zone. Latvia has recently established a geothermal data base and based on these data. existing district heating networks have been evaluated for partial conversion in a pilot demonstration plant at Liepaja utilising 420 TJly of geothermal energy, Eihmanis (1995) Lithuania is another country in the very early stage of geothermal exploration and utilisation Favourable conditions have been found, particularly in West Lithuania in an area of 42,444m^2, where a geothenal gradient of 4°C/100m has been measured The most promising technology is based on an absorption heat pump with a number of feasibility studies indicating that both technically and economically a project would be viable. Construction of a pilot plant at Klaipeda is under consideration, Suveizdis (1995) The geological prospects for deep geothermal energy for direct use are favourable in the Netherlands, which was established by making an inventory of resources during the period 1979-1984, but because of large reserves of natural gas etc no major geothermal developments have taken place, Walter(1995) However one trial well was drilled at Asten but was unsuccessful due to a lack of permeability Government policy has set targets for using sustainable resources. including geothermal and in 1993 the De Lier demonstration project, which is to be used for heating about 15ha of greenhouses and pre - heating natural gas in a decompression station, was studied. It is anticipated that a well doublet will be drilled in 1995 and the plant will became operational in 1996-1997. The exploitation of geothermal resources on the Portuguese mainland and Madeira islands is of little significance, but in the Azores Islands a programme on S Miguel island has resulted in a pilot geothermal generator plant of 4 9MWe producing 20-25% of the islands requirement, Rodrigues (1995) On the mainland there are some low enthalpy resources but limited at this stage to the heating of a hospital in the Lisbon region, no details are given Sweden has had a heat pump operating at Lund since 1986 currently using four production and six reinjection wells located at depths between 600-800m, Alm and Bjelm (1995). The heat pump is rated at 41 MWt and produces 960 TJ/y of energy, see Bjelm and Lindeberg (1995) for further details In the United Kingdom Batchelor (1995) states that there has been no new geothermal developments since 1990 although the Southampton direct use project is still operated by a private company and there is interest in ground loop heat pump systems.

OCEANIA

Australia: The Australian continent comprises sedimentary basins over a basement of Precambrian and palaeozoic metamorphics. without significant fold mountains or active fault zones. Volcanic heat sources are largely confined to the newer basalts of western Victoria Current geothermal production in Australia is in small projects dispersed across the eastern half of the continent, Burns,et al (1995). Natural hot springs and hot artesian bores have been developed for recreational and therapeutic purposes. A district heating system at Portland, in the Otway basin of western Victoria, which is servicing a building area of 18,990m^2 and has done so for the past 12 years without any significant problems, also has prospects for further expansion to use the hot water directly for the development of a wool scouring plant A geothermal well is providing hot water for paper manufacture at Traalgon, in the Goppsland basin of eastern Victoria. Power production from hot water aquifers was tested at Mulka in South Australia with a

20kWe binary cycle A plant at Birdsville in Queensland was commissioned in 1992, is now undergoing a four year production trial where a Rankine cycle engine using Freon, produces 150 kWe from water flowing at about 30 l/s and 99°C from a 150cm(6in) nominal bore drilled to 1221m An important Hot Dry Rock resource has been confirmed in the Cooper basin. It has been proposed to build an HDR experimental facility to test power production from deep conductive resources in the Sydney basin near Musselbrook The proposal is to develop a A$60 4 million experimental 20 MWe power plant designed around a resource volume one cubic kilometre of hot rock at a temperature of 250°C

Fiji: The Fiji department of energy has been carrying out a comprehensive resource assessment programme to identify and promote the local use of renewable energy resources where they are economically viable, Autar (1995) DOE is currently involved in investigating the extent of geothermal resources and in particular whether geothermal fields in the Savusavu and Labasa areas. the two fields with the greatest potential, are capable of exploitation for electricity generation/process heat It is also of interest to make a comparison of generation cost from geothermal with those from the other options on Vanua Levu. Results to date have indicated that the Savusavu resource is suitable for generation of electricity whilst the Labasa resource can only provide process heat. The initial geoscience studies have been completed and deep drilling to prove the resources is at the planning stage The tabular information supplied indicated a total investment since 1975 of US$ 0 7million and in 1994, 0.3 professional man years of effort

New Zealand: Thain and Freeston (1995) summarise geothermal developments in the country for the last 5 years Restructuring of the electricity industry in 1993 and creation of the Resource Management Act (RMA) in 1991 has impacted on both the geothermal electrical and direct heat developments The former enabled any power company to sell power to any customer anywhere in New Zealand. Promotion of private generation has generated the planning of a number of small scale geothermal projects. however none of them have started, although it is possible one or two will start in the next year or so The regional councils have been given the responsibility for administrating the RMA with respect to about 80% of the countries high temperature resources They have proposed that these be sustainably managed from a Macro perspective rather than anempt to manage individual systems This has given rise to the concept of a steam field management organisation which would be responsible for ensuring the resource is utilised efficiently and equitably Since the report of Lumb and Clelland (1995), the major direct heat developments have taken place on the Kawerau and Ohaaki fields At Kawerau two Ormat power plants with a total capacity of 5 9 MWe have been installed using 170°C separated water and a timber drying facility has been installed with a thermal power of about 3 2 MWt drying 100,000m^3/y and operating 340days/y, 24hrs/day, a load factor of over 0 9 At Ohaaki, the Lucerne plant and timber drying facility have been further developed to improve their efficiency, Pirrit and Dunstall (1995), they now use a total of under 10 MWt at peak times instead of the 45 MWt quoted by Lumb and Clelland (1990). The professional personnel allocated to geothermal activities is shown as 85 man years, an increase of 16 over the 1990 figure, this probably reflects the interest shown by non-governmental groups that have come about since the restructuring of the industry.

CONCLUDING REMARKS:

As in previous surveys Some countries stand out as major users of geothermal fluids for direct uses, and in these countries developments have in general proceeded at a slow pace This is not surprising since the price of oil and natural gas during the past five years has given developers cheaper options and financing of projects bath in developed and developing countries has been difficult to obtain However the prospects are there when the need arises and many new geothermal countries have been doing the basic ground work to establish data bases for future exploration and exploitation This particular survey has been limited. as explained in the text, however it is hoped that corrections and additions can be made in the near future which will allow a more authentic and accurate assessment of the worlds geothermal direct uses.

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