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GEOTHERMAL DEVELOPMENT IN RUSSIA: COUNTRY UPDATE REPORT 1995-1999

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ABSTRACT

Since the last World Geothermal Congress (Florence, 1995), geothermal energy use in Russia has continued on a similar scale, dominated as before by direct use. Six towns and a number of settlements in the Northern Caucasus and Kamchatka with a total population of about 220 000 use geothermal energy for space and district heating. Geothermal energy is also utilized in several greenhouses with total area of 465 000 m^2 in the same regions. The installed thermal power of direct heat use is about 300 MW_t. Electric geothermal power is generated at Kamchatka where the Pauzhetka power plant (11 MW_e) has been joined by the new Verkhne-Mutnovka plant (12 MW_e) on the Severo-Mutnovka thermal field. Two other units of 50 MW_e in total are under construction on the Dacha sector of the same Severo-Mutnovka hydrothermal system. In the future, the total power of this plant is planned to be to 300 MW_e. In the project stage is a 30 MW_e Okeanskaya power station on Iturup Island in the Kuril Archipelago.

INTRODUCTION

In Russia, the energy industry is based on the use of fossil fuel (coal, oil, and gas) and the exploitation of nuclear and hydroelectric power stations. The contribution of geothermal energy is relatively small and, although significant resources are available, the present economic situation in Russia hampers development of the geothermal energy potential. Total electric power production decreased from 912 TW/yr at the end of 1994 to 822 TW/yr in January 2000. The availability of fuel and transportation difficulties aggravate the problems of energy supply, particularly in the northern and eastern regions of the country. Because of the economic shock in August 1998, the situation has been further impaired, especially in Kamchatka where, up till now, the rich geothermal resources have been used on a very limited scale compared with potential possibilities.

Besides the Kuril-Kamchatka region, which abounds with recent volcanic manifestations and the hottest hydrothermal systems, other hydrogeological provinces of Russia also contain significant geothermal resources. Among these are the following: 1) the Caucasus segment of the Alpine tectonic belt, 2) the recent Baikal rift zone, 3) the epi-Hercinian Scythian plate, and 4) the West-Siberian plate of the same age (Fig. 1). The latter two contain thermal waters (T=100-200°C) within the sedimentary cover, whereas in the two other regions hydrothermal resources are confined to reservoirs in fractured rocks. In addition, some geothermal resources are available in the pre-Riphean East-European and Siberian platforms, in the Paleozoic fold belts of Ural, Altai and Saiany, as well as in the Mesozoic Chukotka-Catasian volcanic belt. These regions are less promising in respect of geothermal resources; they contain inter-granularal and fissure hydrothermal systems with temperatures of 50-70 °C at a depth of about 3 km. The geological structure, hydrological conditions and geothermal features of these regions are described in more detail in (Kononov, 1992; Kononov et al., 1995).

ELECTRIC POWER GENERATION

Fossil fuel power stations currently produce 69 % of the total electric power generated in Russia. Hydroelectric and nuclear stations produce 20 % and 11 % respectively. Geothermal power stations contribute only 0.06 % despite some growth in the number of power plants and their capacity as compared with the previous period (Table 1).

Geothermal exploration for electric power use began in 1957 when the first bore holes were drilled on the Pauzhetka thermal field located in southern Kamchatka. In subsequent years, significant geothermal resources were discovered in the peninsula due to efforts of many researchers. However, the rate and scale of geothermal development were below either Kamchatka's potential or economic demand for electric and thermal energy.

The Pauzhetka power station came into use in 1967. At that time its installed capacity was 5 MW_e. For the following period, this capacity grew only to 11 MW_e. Three units are currently in operation: 2 × 2.5 MW_e and 1 × 6 MW_e (Table 2). Seven wells extract 240 kg/s of fluids with enthalpy 760-800 kJ/kg. In total, 79 productive wells were drilled on this field, so the capacity of the station can be increased up to 18 □W_e when 3 new 6 MW_e-units come into operation (old units will be retired).

The high-temperature Severo-Mutnovka thermal field has long been considered as the primary object for electric power production in Kamchatka. Its superficial manifestation, the so-called Dacha Springs, were found as early as in 1960, but the exploration drilling began as late as 1979. In total, 82 bore holes 255 to 2266 m in depth were drilled here. A vapor-dominated reservoir containing fluid (steam) with enthalpy 2100-2700 kJ/kg was found at depths of 700-900 m. It is underlain by a liquid-dominated reservoir holding fluids with enthalpy 1000-1500 kJ/kg (T=250-310 °C). Now, 17 wells producing 330 kg/s of fluids with average enthalpy of 1600 kJ/kg are ready for exploitation. Power plant construction was proposed here as early as the middle of the 1970s, but these plans began to be realized only in 1990s. Due to efforts of SC Geoterm founded by the regional administration, Kamchatenergo and RAO EES Rossii, the first set comprising three 4 MW_e-units Tuman 4K manufactured at "Kaluga Turbine Works" SC is now in operation on the upper sector of the field callled Verkhne-Mutnovka sector. Two other units, a single flash (3 MW_e) and a binary cycle (6 MW_e), are now under construction in this sector (Table 2). In 1999, the construction of a power line transmission from the field to consumers was completed. The next project in the Dacha sector of the same field (Mutnovka power plant) was developed by Geoterm SC. Nauka SC (Russia), WEST JEC SC (Japan) and GENZL SC (New Zealand). The capacity of this set for the first stage will be 50 MW_e; increasing up to 300 MW_e in the future (Table 2). The project is supported by a loan (99.9 million US$) from the European Bank of Re-construction and Development. Furthermore, this loan will provide for maintenance of bore holes and additional geophysical investigations to refine the geothermal resources of this sector.

The Severo-Mutnovka thermal field, however, is not the only site suitable for geothermal electric power generation in Kamchatka (Fig. 2). The partially explored Nizhne-Koshelev thermal field is a very promising site containing fluids with enthalpy up to 2800 kJ/kg. It is located near the Pauzhetka field, and the exploitation of both these fields could provide an important contribution to Kamchatka's economy. Another important site of the same kind is the Bolshe-Bannoe field, where the natural heat output by thermal water was estimated at 79 MW_t. This field is already explored, and the rate of boiling water discharge was evaluated at 285 l/s. The Kireuna field, in the Northern Kamchatka, also discharges boiling water estimated to provide 24 MW_t. Besides these, there is the Semyachik field adjacent to the Kronotskii Reservation, which includes the famous Geyser Valley. Limited use of the Semyachik field (for construction of a small power station of 5 MW_e capacity) could help development of tourist services in the reservation. Apart from the geothermal resources of the Kronotskii Reservation, the resources revealed in Kamchatka to date could provide the electric power generation of 1130 MW_e (Sugrobov, 1995).

Besides high-temperature fluids with enthalpy more than 700 kJ/kg, the lower temperature hot water with stratal temperatures up to 150°C can be used for power generation in binary-cycle installations with heat-exchangers utilizing low-boiling liquids (freon, isobutane, etc.). An experimental installation with capacity of 800 kW_e was designed by the specialists from the RAS Siberian Branch in the early 1960s and was successfully tested at Paratunka Springs of Kamchatka. Unfortunately, the installation was subsequently abandoned.

Beyond the Kamchatka region, the Kuril Islands show promising conditions for geothermal electric power generation. The Okeanskaya power plant on Iturup Island of the archipelago is projected to generate 30 MW_e (Fig. 1). Here, 9 wells are ready for exploitation. Two other power plants will be constructed on Kunashir and Paramushir islands, the most southern and northern islands of the archipelago, respectively (Table 2).

Another region where prospects for geothermal electric power generation exist is the Northern Caucasus. This region embraces two geothermal provinces. The first includes the Alpine tectonic units – the Greater Caucasus orogen together with Ciscaucasian foredeeps – whereas the second corresponds to the epi-Hercinian Scythian plate. Sedimentary cover of the plate and foredeeps hosts sufficiently hot waters. Because of the high content of dissolved solids in these waters, they can be used for geothermal development only in binary-cycle installations with re-injection of cooled water back into the reservoir. Such a project was proposed for the Kayasula field, where construction of a 3 MW_e pilot plant was planned. However high TDS (>100 g/kg), relatively low temperatures (150-170°C at 4000-4400 m depth) and injection pressures up to 7 MPa make this project problematical.

DIRECT USE OF GEOTHERMAL RESOURCES

Geothermal fluids are used in Russia mainly for space and district heating. In addition, they are used for a range of agriculture purposes (greenhouses, soil heating, fish and animal farming, cattle-breading), for various industrial processes (manufacturing, wool washing, paper production, wood drying, oil extracting), as well as for balneological and recreational applications (hydropathic establishments, swimming pools, etc.). Direct use of the earth heat is most widespread in the above-mentioned Kuril-Kamchatka and Northern Caucasus regions, as well as in the West Siberia and Baikal provinces (Table 3).

In Kamchatka there are about 150 thermal spring groups and 11 high-temperature hydrothermal systems (Fig. 2). They are confined to volcano-tectonic depressions, grabens and calderas serving as reservoirs for inter-granular and fissure-circulating thermal fluids. Excluding the geothermal resources of the Kronotskii Reservation, the resources revealed in Kamchatka to date could provide for the consumption of 1345 MW_t, for at least 100 years.

Based on the natural conditions, the following hydrothermal subprovinces can be distinguished in Kamchatka: the Northern, Median, Eastern, Southern provinces and the province of large structural depressions (the latter is less promising with respect to geothermal development).

The Northern subprovince includes 16 thermal spring groups. Among them, Tymlat, Palana and Rusakov springs are the most attractive for geothermal use. In the Median subprovince there are 24 hydrothermal manifestations. Among them, Esso and Anavgai springs are already used and two high-temperature systems (Kireuna and Apapel) seem to have great potential. About one third of all springs are located in the Eastern subprovince. The springs located in the Nalycheva River valley are most promising for agricultural and balneological applications. The Karym, Semyachik, Uzon and Geyser Valley high-temperature hydrothermal systems are situated in this subprovince. The latter three systems are sited within the boundaries of the Kronotskii Reservation where any industrial or agriculture activity is forbidden. Finally, 55 various hydrothermal manifestations connected partially with the Pauzhetka, Nizhne-Koshelev, Severo-Mutnovka, and Bolshe-Bannoe high-temperature systems, are found in the Southern subprovince. In spite of such an abundance of geothermal resources, the Kamchatka's economy experiences an acute shortage of electric and thermal energy.

At present, thermal Cl-Na waters with T=80-100°C and TDS=1-5 g/kg are utilized for space heating in Paratunka, Pauzhetka, Esso, and Anavgai settlements. The problem of heat supply for Petropavlovsk-Kamchatskii remains the focus of attention. One possible solution could be the construction of a transmission pipeline of ~80 km in length to transport waste geothermal fluids from the Severo-Mutnovka field. Agricultural application of geothermal resources is exemplified by 60,000 m^2 of greenhouses built 65 km away Petropavlovsk-Kamchatskii. Smaller enterprises of this kind are found in Esso, Anavgai and Pauzhetka settlements. The Nachiki and Nizhne-Paratunka hydropathic establishments (the latter supplemented with a swimming pool) complete the list of geothermal sites used at Kamchatka.

In the Kuril Arcipelago, the direct use of geothermal heat is developed on Kunashir and Paramushir islands for space heating (Yuzhno-Kyril'sk and Severo-Kuril'sk cities, respectively).

The platform geothermal province of the Northern Caucasus includes several artesian basins. The thermal waters are contained in multi-layered aquifer systems enclosed within Mesozoic-Cenozoic sedimentary cover. The waters contain mostly HCO_3-Na or Cl-Na dissolved solids; their salinity varies from 0,5 to 65 g/kg, the temperatures range up to 80 – 110°C at the depth of 1-2 km (Table 3). The waters are used mainly for agricultural and industrial purposes. In Mostovskoi settlement situated in Krasnodar territory, water at 75°C is used in a multi-purpose system involving; greenhouses (180 000 m^2), a space heating network (for 10 000 inhabitants), cow sheds, pig farms and poultry yards, as well as fabrication of concrete blocks and wood drying. Finally, the waste water at 20-30°C is used in a swimming pool and fish farm.

The Alpine foredeeps of the Northern Caucasus also contain multi-layered aquifer systems of the similar HCO_3-Na and Cl-Na thermal waters in Mesozoic-Cenozoic sediments. The salinity of the waters ranges from 0.9-2.1 g/kg (Khankala area) and 3-8 g/kg (Makhach-Kala area) up to 100-200 g/kg (Kayasula and Tarumovka fields). The water temperature ranges from 70-85°C (Makhach-Kala area) up to 150-170°C (Kayasula field). In Daghestan Republic, the thermal water is used mainly for space and district heating. Such systems completely satisfy the thermal needs of Izberbash, Terekly-Mekteb, Chervlenye Buruny and Tarumovka towns and partially satisfy Makhach-Kala, Kizlyar and Kayakent towns. Geothermal space and district heating in these towns is supplied to a total of 200000 inhabitants. In addition, sizeable geothermal greenhouse enterprises are located near Makhach-Kala (60 000 m^2) and Kizlyar (20 000 m^2). These greenhouses are used mostly for growing tomatoes, cucumbers and flowers. The thermal waters are also utilized for heating cow and pig farms and poultry yards as well as in a few resorts (hydropathic establishments).

By the end of 1999 the total number of direct-use geothermal wells reached 306 in Northern Caucasus and Kamchatka. Of these, 200 wells are used for production, 16 for re-injection, and 90 for monitoring (Table 4). Half of the extracted thermal water is used for space and district heating, 33% for greenhouse heating, 12.8% for various industrial processes (wool washing, paper production, wood and agricultural products drying), and 2.2% for animal and fish farming. (Table 5). Finally, 2.0% of these resources are used in about 150 hydropathics and 40 factories bottling thermal and mineral waters.

Besides Kamchatka and Northern Caucasus, the Western Siberian plate is a promising region for direct use of geothermal resources. Sedimentary cover of this epi-Hercinian plate of 3×10^6 km^2 in area encloses the artesian basin of thermal waters. In the marginal parts of the basin, the aquifers with a high hydrostatic pressure, temperatures of 35-75°C , and suitable TDS (1-25 g/kg) are located down to 3 km and capable of producing about 180 m^3/s (Mavritsky, 1971). Up to now, however, these geothermal resources are used on a very insignificant scale. Thermal waters provide the space heating of some small settlements and several buildings in the Tyumen and Omsk cities. These waters are also used to heat oil-bearing horizons to decrease oil viscosity thus enhancing recovery, for the extracting of iodine and bromine contained in thermal brines, for fish farming, etc. This region is very rich in natural gas and oil, which hampers geothermal development here at the present time.

There are many thermal springs and several geothermal wells near Lake Baikal and along the Baikal-Amur railway. These waters are locally used for space heating of separate buildings and small resorts as well as for bathing and swimming.

Geothermal space heating systems can also use heat pumps. A successful experiment of this kind was carried out early in 1999 in Philippovo settlment of Yaroslavl' district. The ground with a temperature of 5-6°C at 40 m depth served as low-potential thermal source. Eight heat pumps made at the Rybinsk instrument factory heat the water supplying the 160-pupil school building up to 60°C. In addition, an aquatic park that will use heat pumps for water heating is planned in Moscow.

CONCLUSION

As in previous years, the direct use of the earth heat dominated in Russia at the end of 1999. Geothermal energy utilization for electric power generation grew somewhat in comparison to the previous period. Now, two small geothermal plants (11 and 12 MW_e) are in operation and two power plants – Mutnovka (40 MW_e) and Okeanskaya (30 MW_e) – are under construction. All the plants are situated in the Kuril-Kamchatka region. The shortage of electric and thermal energy for industrial and civil activity is especially acute in this region despite an abundance of geothermal resources. In Russia as a whole, the possibilities of geothermal development are much higher than those realized at the present time.

Various geothermal problems are studied in 14 cities of Russia. These research centers unite the labs from 26 scientific institutes, 3 universities and 5 project bureaus. Their staffs comprise a large number of highly qualified engineers and 27 professionals holding Dr. Sci. in geology or technical disciplines (Table 6). These researches are coordinated by the Russian Academy of Sciences including the special Scientific Council on geothermal problems. Moreover, the following stock companies are involved in exploration and utilization of geothermal resources: Geotermneftegas, Neftegasgeoterm, Kamchatskenergo, Geoterm, KamES, Energiya-M. Also, the government enterprise Kamchatskburgeotermiya takes part in geothermal development in Kamchatka, and the Podzemgidromineral Institute constructs installations for extraction of chemical row from thermal brines in the Northern Caucasus.

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Figure 1.Some geothermal regions and localities in Russia

Table 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables		Total	
	Capacity MW_e	Gross Prod. GWh/yr	Capacity MW_e	Gross Prod. GWh/yr	Capacity MW_e	Gross Prod. GWh/yr	Capacity MW_e	Gross Prod. GWh/yr	Capacity MW_e	Gross Prod. GWh/yr	Capacity MW_e	Gross Prod. GWh/yr
In operation in January 2000	23	85	151 000	558 000	43 600	155 000	21 200	108 000			216 000	822 000
Under construction in January 2000	93	400	1 200	2 800	530	460					1 770	3 420
Funds committed, but not yet under construction in January 2000												
Total projected use by 2005	171	700	155 000	580 000	45 000	162 500	24 200	124 000			224 300	867 000

Table 2. UTILIZATION OF GEOTHERMAL ENERGY FORELECTRIC POWER GENERATION AS OF 31 DECEMBER 1999

Locality	Power Plant Name	Year Com-mision ed	No. of units	Status[1)]	Type of unit[2)]	Unit Rating MW_e	Total Installed Capacity MW_e	Annual Energy Produced 1999 GWh/yr	Total Under Constr. or Planned MW_e
Kamchatka									
Pauzhetka hydrothermal sistem	Pauzhetka	1966	2		1F	2.5	5		
		1980	1		1F	6	11	35	
		2000	3		1F	6			18
Severo-Mutnovka hydrothermal system	Verkhne-Mutnovka	1998	1		1F	4	4		
		1999	2		1F	4	12	50	
		2001	2		1F+B	3+6			21
	Mutnovka	2001	2		1F	25			50
		2005	2		1F	25			100
Kuril Islands									
Paramushir Isl.	Ebeko	1998	1	N	1F	2	2		
Iturup Isl.	Okeanskaya	1999	4	N	1F	2	8		
		2000	1		1F	4			4
		2001	2		1F	4			12
		2003	1		1F	20			32
Kunashir Isl.	Goryachii Plyazh	1992	1	N	1F	0.7	0.7		
TOTAL							34	85	171

1) N = Not operating (temporary), R = Retired.
2) 1F = Single Flash

Table 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 1999

Locality	Type[1)]	Maximum utilization: Flow rate (kg/s)	Temperature (°C) Inlet	Temperature (°C) Outlet	Enthalpy (kJ/kg) Inlet	Enthalpy (kJ/kg) Outlet	Capacity[2)] (MW_t)	Annual utilization: Ave.Flow (kg/s)	Energy[3)] (TJ/yr)	Capacity Factor[4)]
Kamchatka	HBG	532	85	30			122	372	2 701	0.7
Kuril Islands (Kunashir)	H						20			
Northern Caucasus region										
Platform Province										
Krasnodar territory	IAFHBG	370	80	30			77	222	1 465	0.6
Stavropol territory	AHG	60	100	30			18	36	335	0.6
Adygeya Republic	AH	49	80	30			10	25	162	0.5
Alpine Province										
Kabardino-Balkar Republic	G	70	70	30			2	6	33	0.5
Daghestan Republic	IHBG	339	80	30			71	203	1 340	0.5
Karachaevo-Cherkess Republic	O	25	65	30			4	13	58	0.5.
Northern Osetiya Republic	O	21	60	30			3	10	41	0.5
TOTAL		>1 466					327	>888	>6 135	

1) I = Industrial process heat, A = Agriculture drying (grain, fruit, vegetables), F = Fish and animal farming, H = Space heating and district heating (other than heat pumps), B = Bathing and swimming (including balneology), G = Greenhouse and soil heating, O = hot water supply
2) Capacity (MW_t) = Max. flow rate (kg/s)[inlet temp. (°C) - outlet temp. (°C)] $\times$ 0.004184
3) Energy use (TJ/yr) =Ave. flow rate (kg/s)[inlet temp. (°C) - outlet temp. (°C)] $\times$ 0.1319
4) Capacity factor = [Annual energy use (TJ/yr) $\times$ 0.03171] / Capacity (MW_t)

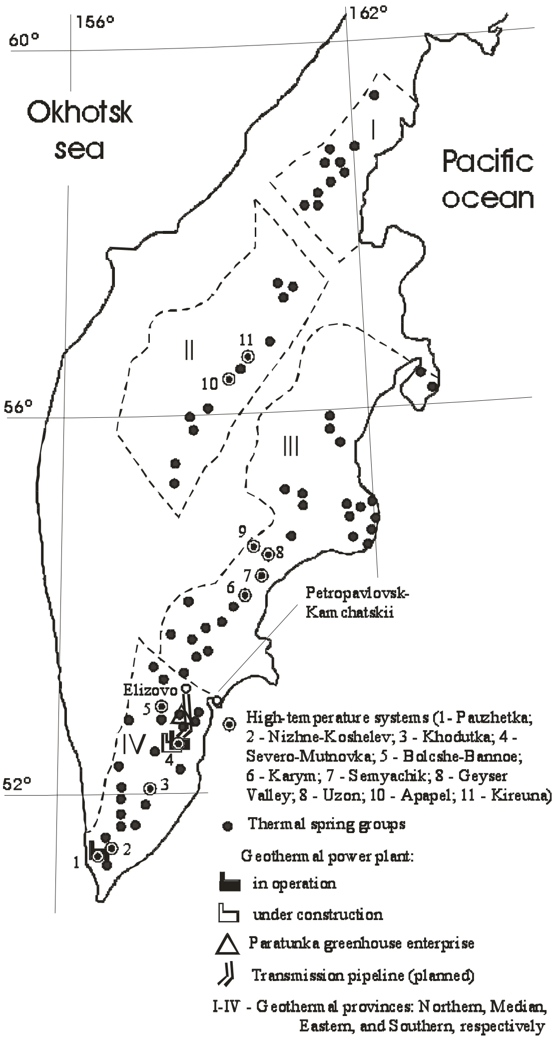

Figure 2. Geothermal resources of Kamchatka

Table 4. SUMMARY TABLE OF GEOTHERMAL DIRECT USES AS OF 31 DECEMDER 1999

Use	Installed capacity[1] (MW_t)	Annual energy use[2] ($TJ/yr=10^{12}$ J/yr)	Capacity factor[3]
Space heating[4]	110	2 185	0.63
Greenhouse heating	160	3 279	0.65
Fish and animal farming	4	63	0.5
Agricultural drying[5]	4	69	0.55
Industrial process heat[6]	25	473	0.6
Bathing and swimming[7]	4	63	0.5
TOTAL	307	6 132	

[1] Installed capacity (thermal power)(MW_t) = Max. flow rate (kg/s) × [inlet temp. (°C) - outlet temp. (°C)] × 0.004184
[2] Annual energy use (TJ/yr) = Ave. flow rate (kg/s)[inlet temp. (°C) - outlet temp. (°C)] × 0.1319
[3] Capacity factor = [Annual energy use (TJ/yr) × 0.03171] / Capacity (MW_t)
[4] Includes district heating
[5] Includes drying or dehydration of grains, fruits and vegetables
[6] Excludes drying and dehydration
[7] Includes balneology

Table 5. WELLS DRILLED FOR ELECTRICAL AND DIRECT USE OF GEOTHERMAL RESOURCES FROM JANUARY, 1, 1995 TO DECEMBER, 31, 1999

Purpose	Wellhead temperature	Number of wells drilled		Total depth (km)
		Electric power	Direct use	
Exploration[1]	all	40	90	195
Production	>150°C	20		30
	150-100°C	6	16	33
	<100°C		184	276
Injection	all	12	16	42
Total		78	306	576

TABLE 6. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES
(Restricted to personnel with a University degrees)

(1) Government (3) Universities and Acad. Sci. (5) Contributed Through Foreign Add Programs
(2) Public Utilities (4) Paid Foreign Consultants (6)Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1995	12	10	73	12	15	52
1996	10	10	70	12	17	52
1997	10	11	68	18	27	57
1998	10	12	68	27	10	62
1999	14	16	66	32	10	80
TOTAL	10-14	10-16	66-73	12-32	10-27	52-80