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Geothermal Resources of Russia and Environmental Problems

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ABSTRACT

Geothermal energy use is the perspective way to clean sustainable development of the world. Russia has rich high and low temperature geothermal resources and makes good steps in their use.

In Russia the geothermal resources are used predominantly for heat supply both heating of several cities and settlements on Northern Caucasus and Kamchatka. Besides in some regions of country the deep heat is used for greenhouses. Most active the hydrothermal resources are used in Krasnodar territory, Dagestan and on Kamchatka.

The most perspective direction of usage of low temperature geothermal resources is the use of heat pumps. This way is optimal for many regions of Russia - in its European part, on Ural and others.

The electricity is generated by some geothermal power plants only in the Kamchatka Peninsula and Kuril Islands.

At present, urbanization has become a truly global process. The gigantic concentration of people results in a multiple increase in the supplies of water, energy, and food to cities, which is responsible for the accumulation of a huge amount of polluted water and industrial and domestic waste in the city areas. Under these conditions the problems of urbanization and municipal engineering become part of the global problem of sustainable development of the modern society.

In this connection two important aspects are considered: clean alternative renewable energy use and organization of environmental parks as demonstration of preferences and advantages of such energetic supply. The concept of environmental parks on the territories of big towns and reserved territories is elaborated.

Choice of the optimal system of nature-friendly energy support is based on use of the deep-thermal energy and other ecologically pure sources, depending on concrete conditions of the environmental park, and takes into account all the environmental, economical and social factors. As a result the environmental passport of territories can be created.

The concept of environmental parks could help to demonstrate the advantages of renewable alternative energy utilization.

1. INTRODUCTION

In Russia the geothermal researches are carried out by 53 scientific centers and higher educational institutions located in different cities and inhering to different offices: Academy of sciences, Ministries of education, natural resources, fuel and energy. They can be conditionally joint in some regional centres of science, such as Moscow, St.-Petersburg, Northern (Archangelsk and Apatites), North-Caucasian (Makhachkala, Gelendgik, Groznij (before 1993)), Volga region (Yaroslavl, Kazan, Samara), Ural (Ufa, Ekaterinburg, Perm, Orenburg), Siberian (Novosibirsk, Tyumen, Tomsk, Irkutsk, Yakutsk), Far East (Khabarovsk, Vladivostok, South-Sakhalinsk, Petropavlovsk-on-Kamchatka). In such centers consisting usually of several institutes, the next directions of geothermal researches are conducted: theoretical, applied, regional, creation of special instrumentation.

2. GEOTHERMAL ENERGY USE

In Russia the geothermal resources are used predominantly for heat supply both heating of several cities and settlements on Northern Caucasus and Kamchatka with a total number of the population 500000. Besides in some regions of country the deep heat is used for greenhouses of common area 465000 м^2. Most active the hydrothermal resources are used in Krasnodar territory, Dagestan and on Kamchatka. (Fig. 1, Fig.2). Gadzhiev *et al*. (1980), Kononov *et al.* (2000). The approximately half of extracted resources is applied for heat supply of habitation and industrial puttings, third - to a heating of greenhouses, and about 13 % - for industrial processes. Besides the thermal waters are used approximately on 150 health resorts and 40 factories on bottling mineral water. Quantity of electrical energy developed by geothermal stations of Russia, per 1999 almost twice has increased as contrasted to by former level. Nevertheless, it remains extremely minor, making some 0,01 of percent from common development of the electric power in the country.

The Western Siberian plate is another promising region for direct use applications. The aquifers located down to 3 km in this region have a high hydrostatic pressure, temperatures of up to 75°C, and are capable of producing about 180 m^3 /s. These waters are used to heat dwellings in some small settlements and, on a small scale, assist in the recovery of oil, the extraction of iodine and bromide, and for fish farming. The region is rich in natural gas, which has limited geothermal development.

The most perspective direction of usage of low temperature geothermal resources is the use of heat pumps. This way is optimal for many regions of Russia - in its European part, on Ural and others.

Heat pumps are at an early stage of development in Russia. An experimental facility was set up in early 1999 in the Philippovo settlement of Yaroslavl district. The source supplies 5-6°C to eight heat pumps that heat the water to 60°C for a 160-pupil school building. There are some buildings with supply of heated water, using heat pumps, in Moscow

The electricity is generated by some geothermal power plants (GeoPP) only in the Kamchatka Peninsula and Kuril Islands. At present three stations work in Kamchatka: Pauzhetka GeoPP (11MW $_e$ installed capacity) and two Severo-Mutnovka GeoPP (12 and 50 MW_e). Moreover, another GeoPP of 100 MV_e is now under preparation in the same place. Two small GeoPP are in operation in Kuril's Kunashir Isl, and Iturup Isl, with installed capacity of 2,б MW_e and 6 MW_e respectively.

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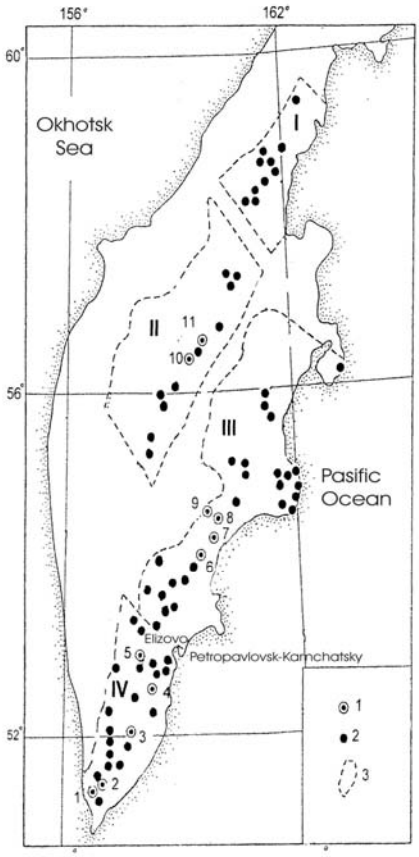

Figure 1: . Geothermal resources of Kamchatka

1 – geothermal deposits (1 – Pauzhetskoje, 2 – Nizhne-Koshelevskoje, 3 – Khodutkinskoje, 4 – North-Mutnovskoje, 5 – Big-Bannoje, 6 – Karimskoje, 7 – Semjachinskoje, 8 – Geysers Valley, 9 – Uzonskoje, 10 – Apapelskoje, 11 – Kireunskoje);

2 – groups of thermal springs;

3 – hydrogeothermal provinces (I – North, II – Middle, III – Easten, IV – South).

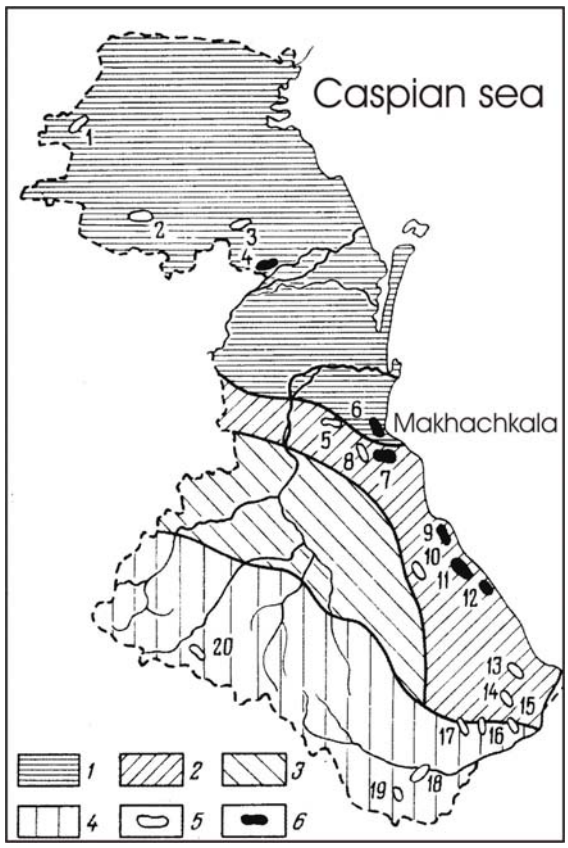

Figure 2: Map of hydrogeothermal deposits and perspective areas of Dagestan

1-4 – measure (1 – Quaternary, 2 – Neogene, 3 – Cretaceous, 4 – Jurassic); 5 – perspective areas; 6 - hydrogeothermal deposits; fingers on the map – thermal anomalies (1 – Bazhigan, 2 – Terekly-Mekteb, 3 – Tarumovka, 4 – Kizljar, 5 – Istisu, 6 – Makhachkala, 7 – Talgi, 8 – Zauzanbash, 9 – Izberbash, 10 – Salgabak, 11 – Kajakent, 12 – Berikej, 13 – Belidzhy, 14 – Choshmenzin, 15 – Giljar, 16 - Adzhinaur, 17 – Richalsu, 18 – Akhty, 19 – Khnov, 20 – Khzanor

3. PLACE OF RUSSIA AMONG OTHER COUNTRIES

Russia has considerable geothermal resources and the available capacity is far larger than the current application. This resource is far from adequately developed in the country. In the former Soviet Union, geological exploration was well supported for minerals and oil and gas. Such expansive activities did not aim to discover geothermal reservoirs even in a corollary manner; geothermal waters were not considered among energy resources. Still, the results of drilling thousands of "dry wells" (in oil industry parlance), bring a secondary benefit to geothermal research. These are the abandoned wells themselves, and the data on the subsurface geology, water-bearing horizons, temperature profiles, etc., that were collected during exploration. Not all currently operating companies are willing to disclose their well data, still, in face of the cost of maintaining shut-in wells, it is cheaper to turn them over to others for new purposes.

The Figures 3,4 (Lund .and Freeston ,. (2000)) show the geothermal resources use in some countries and in Russia in dynamics. They illustrate particularly fast advances taken place in Russia.

4. ADVANTAGES AND PROBLEMS OF GEOTHERMAL ENERGY USE

The environmental benefits of the use of renewable energy resources such as geothermal is recognized by few decision makers. Moreover, there are major barriers to the development of renewable resources which tend to discourage those few. Detailed geological investigations and expensive drilling of geothermal wells represent a major financial commitment with considerable geological and technical risks.

The use of renewable energy, including geothermal resources, denote benefits. First, use of indigenous energy resources can reduce some of the import dependence or part of the need to build new generating capacity for either supply of heat and industrial or residential hot water supply. Secondly, replacement of conventional fuels with clean energy induces major improvements in environmental conditions and public health and associated savings. Thirdly, a measure of energy savings an efficiency is involved. As district heating systems are common in urban centers of Russia and are in need of modernization, switching to renewable energy resources could take advantage of these benefits. This is particularly important from the economic perspective also; the antiquated district heating systems are not fuel efficient and the engineering life time of most have already expired.

Geothermal energy, much as hydropower, is "clean" compared to any fossil-fuel generated energy. Because of international conventions on climate change and European Community programs to promote renewable energy sources, interest in Russia in identifying these indigenous resources has enjoyed much attention. Policy support has also been generated, although overall, specific legislation for exploring for and producing geothermal waters is absent in all countries. This is partly due to the fact that waters are regulated under water resources laws, minerals under mining laws, energy under energy laws. Geothermal energy transcends all such legislation and makes it difficult to address the varying exploitation methods and uses of geothermal energy under one heading.

5. GEOTHERMAL ENERGY AND SUSTAINABLE DEVELOPMENT

The industrial evolution over the last two centuries brought plenty of innovations for the human civilisation, but enabled certain nations also to conduct the most disastrous wars in history and to exploit the natural resources at a frightening pace. Since the Seventies of the 20th Century serious warnings about the “limits to growth” went around the world with little effect: the resource exploitation, arms races and wasteful consumption habits squandered these resources at an accelerated pace, along with the exponential growth of world population. All this frenzy needed increasing amounts of energy.

The most wasteful and - in retrospect - irresponsible human habit was the combustion of the finite and rapidly dwindling energy resources coal, petroleum and “natural” i.e. mineral gas. This irresponsible activity is burning the feed-stocks of the chemical industry for the production of plastics, synthetic fibres, building materials, paints, varnishes, pharmaceutical and cosmetic products, pesticides and many other products of the organic chemistry for our descendants, who need these resources for Centuries to come.

But the most catastrophic effect of the fossil fuel age is the unbalancing of the biosphere and climate to a degree that is irreversibly affecting our life base: growing deserts and acid rains spoiling fertile lands, the poisoning of rivers, lakes and ground waters, spoiling the so badly needed drinkable water for the growing world population - and the worst of all - more frequent weather disasters, retracting glaciers, ruined ski resorts, melting ice caps, land slides, more violent storms, flooding of highly populated coastal areas and islands, thus endangering people and rare species, causing migrations, loss of fertile land and cultural heritages – all due to the incessantly growing fossil fuel emissions, causing global warming.

The way to the Clean, Sustainable Energy Age by conserving resources and bringing the biosphere and climate back into a natural balance is connected with renewable energy use.

This way is well illustrated in the Figure 5, where the top line represents estimate of the future world-wide energy demand over the next 50 years. Fossil fuel producers are fully aware of the bottom curve showing the expected mineral energy resources depletion over the next 50 years and the need to reduce fossil fuel combustion beyond the Kyoto Protocol targets in order to slow down global warming of the Earth atmosphere. The middle curve reflects the geothermal energy use future.

6. SUSTAINABLE DEVELOPMENT AND MEGAPOLICES

The development of the present-day world is impossible without large cities. Cities appeared on the Earth almost five millennia ago and gradually became centers of development of the Earth civilization. At present, urbanization has become a truly global process whose rates and scales increase catastrophically. Hardly more than 3% of the Earth's population lived in cities in 1830, 34% of the population lived in cities in 1966, and it is expected that the urban population will account for more than 57% in 2020. Cities-megapolices grow rapidly against a general background of urbanization. Recent megapolices have no historical precedent with respect to the number of population and the density of the infrastructure. It is expected that the total area of cities in the world will increase by 2.6 million km^2 and will be about 4% of the land area in 2020.

The gigantic concentration of people results in a multiple increase in the supplies of water, energy, and food to cities, which, along with an increased production and service, is responsible for the accumulation of a huge amount of polluted water and industrial and domestic waste in the city areas. This causes an aggravation of social, environmental, and economic problems in large cities. Under these conditions the problems of urbanization and municipal engineering take on an absolutely different social significance – they become part and parcel of the global problem of sustained development of the modern society.

Numerous forms of megapolice vital activity strongly affect the natural environment. This effect is variegated– gases are released into the atmosphere, cavities are formed in the underground space, pavements result in the reconstruction of the surface runoff, natural reservoirs are filled up and new artificial basins are created, the orientation of groundwater flows is changed and water from municipal service lines comes into these flows, new chemical compounds are carried into topsoil and subsoil, the latter is often replaced by an artificial substrate, and the natural

vegetation is survived in isolated areas and is replaced by artificial plantations in other regions. Thus, such a huge organism as a megapolice reconstructs the natural environment, replacing its previous stable state and existing relations between subsoil, water, topsoil, and vegetation by new relations.

A new state of the natural environment is not always stable, and we face actively developing processes such as subsidence and collapse of the ground surface, underflooding of structures, and contamination of the atmosphere and surface and ground water, which can be hazardous for the megapolice organism.

Such a situation makes it undoubtedly necessary to control environmental parameters and such parameters as urban air pollution, groundwater level, development of artificial plantations, and manifestation of hazardous processes in city This problem is typical of all large cities in different states. Only specific processes that develop in the natural environment differ depending on a city location.

In this connection some important aspects could be considered: complex environmental monitoring, clean alternative renewable energy use and organization of environmental parks as demonstration of preferences and advantages of such energetic supply, which are very close. The linking of these ideas on the base of scientific demonstration environmental center could be especially productive. The concepts of environmental parks, complex environmental monitoring and demonstration centers on the territories of big towns are presented below.

7. THE CONCEPT OF NATURE-FRIENDLY ENERGY SUPPORT SYSTEM FOR ENVIRONMENTAL PARK

Choice of the optimal system of nature-friendly energy support is based on use of the deep-thermal energy and other ecologically pure sources, depending on concrete conditions of the environmental park/aquapark, and takes into account all the environmental, economical and social factors. As a result the environmental passport of territories can be created.

The main directions of investigation are:

Geological and geothermal assessment of the Park's territory, taking into account the possibility to use the deep thermal sources for energy supply.

Hydrogeothermal and hydrogeochemical assessment of the territory (hot springs, thermal and mineral waters).

Geographical assessment of the territory from the point of possibility to use the non-traditional renewable energy sources (solar, wind, tidal energy and energy of small rivers).

Assessment of the possibility to use other specific energy sources of concrete area (waste utilization, biomasses, etc.).

Creation of criteria for choice of system of energy supply (depending on conditions of area).

Planning of energy supply for concrete area using both thermal sources (heat pumps) and other nature-friendly energy sources.

Optimisation on the system of energy supply on the base of environmental, social and economical factors.

Choice of concrete type of heat pump (types of design and thermal energy extraction) depending on concrete geological,environmental, economical, historical and social conditions of the Park's area.

8. COMPLEX ENVIRONMENTAL MONITORING FOR MEGACITIES.

The concept of system of complex monitoring for the natural environment of a megapolice is created in the Institute of Environmental Geoscience, Russian Academy of Sciences.. As a result of the operation of such a system, a city administration will obtain (at any necessary instant) complete information about a state of the natural environment of a megapolice, including the underground space, surface topography, surface and ground water, soil, flora, and fauna, and about computed changes in this environment under any possible impact.

Such a system should be based on the following principles :

synchronized and interrelated control of all components of the natural urban environment (geological environment, underground and surface hydrosphere, subsoil, atmosphere, and fauna);

consideration and use of the data on the interaction between different components (e.g., ground water and soil subsidence, vegetation and air quality) in the measurement and data processing;

joint use of the data of remote sensing and contact (ground-based) stationary and mobile control points;

automation of obtaining initial data of measurement and their transmission through radiotelephone communication channels;

complex automated processing the data on the natural environment of a megapolis in the united center for environmental monitoring based on the advanced geoinformation technologies;

data exchange between the center for megapolis environmental monitoring and other specialized control centers – emergency control, sanitary-epidemiological control, etc.

A similar system for complex monitoring will allow a municipal administration to have (in a real time) a knowledge of «an environmental face of a city» and to make timely administrative resolutions on prevention from environmental risks and assurance of safety of the population and city infrastructure.

9. SCIENTIFIC CONSULTATION AND DEMONSTRATION CENTRE ON ECOLOGY AND RENEWABLE ENERGY.

Creation of a scientific consultation centre on ecology and renewable energy aims the propagation of use of nature-friendly non-polluting effective energy sources, more detailed acquaintance of the public and the state decision making structures with opportunities and advantages of such use, and also the development of some the accompanying questions connected to use of alternative kinds of energy. One of basic such question is development, approbation and wide introduction of the concept of Ecological parks of Moscow and other regions. Also a very important aspect of the Centre activity is the development and promotion of the concept of Green Certificate.

The centre is created on the basis of Institute of Environmental Geoscience of the Russian Academy of Sciences in territory of a geophysical observatory of the Institute in area Kosino (Moscow).

Three-tier building of engineering case IEG RAS of area of 800 sq.m is located on the site of area 1 hectare.

There are three beautiful lakes in Kosino near geophysical observatory of IEG RAS –White, Black and Sacred lakes.

Activity of the Center will include the main directions:

1. Creation of environmental park Kosino - Black, White and Sacred lakes.

Construction of demonstration objects for different types of renewable alternative energy – solar, wind, biomass, geothermal.

2. Creation of model of geoecological system "Water object – city".

3. Organization of hydrogeothermal monitoring of underground waters. Ecological examination of mastered territories.

4. Creation of the ecological passport of territory of development and adjacent territories.

5. Estimation of influence on environment of objects of geothermal and other renewable energy.

6. Creation of atlas of geothermal resources of Moscow and the Moscow region, including additional temperature measurements. Hydro-geological and geophysical research and creation of bank of geological-geophysical data.

7. Installation of the heat pumps for heating of buildings on the site of IEG RAS.

8. Development of the concept of ecological house, including independent non-polluting heat supply and closed use of household waste products on the basis of bio-energy.

9. Creation of digital and cartographic models. Computer visualization.

10. Creation and support of Internet - site.

11. Advertising – publishing activity. Release of brochures, booklets, maps, advertising calendars, videofilms. Information on radio, TV, in press (mass media).

ENVIRONMENTAL ASPECTS

Development and implementation of geothermal power technology is facilitated by social, scientific, economical and environmental aspects.

Social aspects reflect public opinion and willingness to reject old, traditional power generating methods and implement new, non-traditional, environmentally friendly geothermal power technology.

Nowadays the scientific and technical level of geothermal technology is very high in Russia. Unique geothermal power equipment has been developed domestically and for the first time in the world two environmentally friendly power plants were constructed in Kamchatka, In 1999 the unique pilot Verkhne-Mutnovsky GeoPP (V-MGeoPP) of 12 (3x4) MW was constructed (Fig. 6, a, b). It has been operating in extremely severe climatic conditions on the site located near 1000 m above sea level. High level of environmental protection is provided due to isolating the geothermal fluid from the environment by using both air condensers and a system of full re-injection of the waste geothermal fluid back into reservoir. The major problem of protecting the GeoPP equipment from corrosion and salt depositions was solved by using a special technology of film-forming amine additives. Over the last years the V-MGeoPP has proved sustained reliability in generating reasonably priced electricity of about 1.5 cents/kWh (Nikolski, Parshin, and Bezotechestvo (2003)). The experience gained while constructing and operating the V-MGeoPP was used for construction of the 50 MW Mutnovsky GeoPP – a completely automated power plant with a satellite-based communication and control system (Fig. 7, a, b, c). The economic impact from geothermal power plants is especially high in remote locations. As there is practically no detrimental gases emission, modern GeoPPs can be considered as practically absolutely environmentally friendly (Tomarov, Bubon, and Martynova (2003)).

Environmental aspects of geothermal energy use are especially important in connection with global climate changes problem and Kyoto Protocol ratification in Russia. On June 27, 2002, the Russian Government approved the Action Plan on preparation for making decision on ratification of Kyoto Protocol to the UN Framework Convention on Climate Change. The Plan envisages preparation by Russian ministries and agencies of the National Climate Change Report, the Concept of legal acts necessary for compliance with Kyoto Protocol commitments by Russia, and the Draft Governmental Decree on greenhouse gas (GHG) emissions accounting system. The National Report includes sections on: (i) global climate change and changes in climatic conditions on the territory of Russian Federation, (ii) evaluation of GHG (CO_2, CH_4, N_2O, PFC_S, HFC_S, SF_6) role in the process of climate change, (iii) strategy and scenarios of economic development, (iv) relevant GHG emissions predictions, (v) potential benefits and costs of Kyoto Protocol mechanisms application, and (vi) forecast of compliance with potential commitments under Kyoto Protocol.

Kyoto Protocol envisages three variants of cooperation between countries, the so-called "flexible mechanisms". The first mechanism - Joint Implementation - means the projects of CO_2 emissions reduction. The second is Clean Development Mechanism, which implies the projects to reduce emissions in developing countries. And finally, the International GHG Emissions Trading. If a country exceeds the established emissions level, it can acquire a definite portion of emission reductions from other country. And vice versa, a country with surplus emission reductions can transfer them to another country. The transfer can be made through: (i) emission trading, (ii) investment projects in host country with subsequent transfer of emission reductions to investing country (Joint Implementation projects), and (iii) investment projects in developing countries (Business (2003)).

Modern geothermal power technology is environmentally friendly and able to reduce carbon emission by millions of tons. Reduction of CO_2 emission is available for sale on the international market as part of Russia's quota. The Carbon Fund's investment portion considerably increases the efficiency of geothermal power projects in Kamchatka.

CONCLUSIONS.

Geothermal energy use in Russia develops well and has good perspectives. Especial success is reached in Kamchatka area.

The problems of renewable energy use are connected very close with problems of sustainable development and environment. For research of these problems the concept of ecological parks and demonstration centers is developed.

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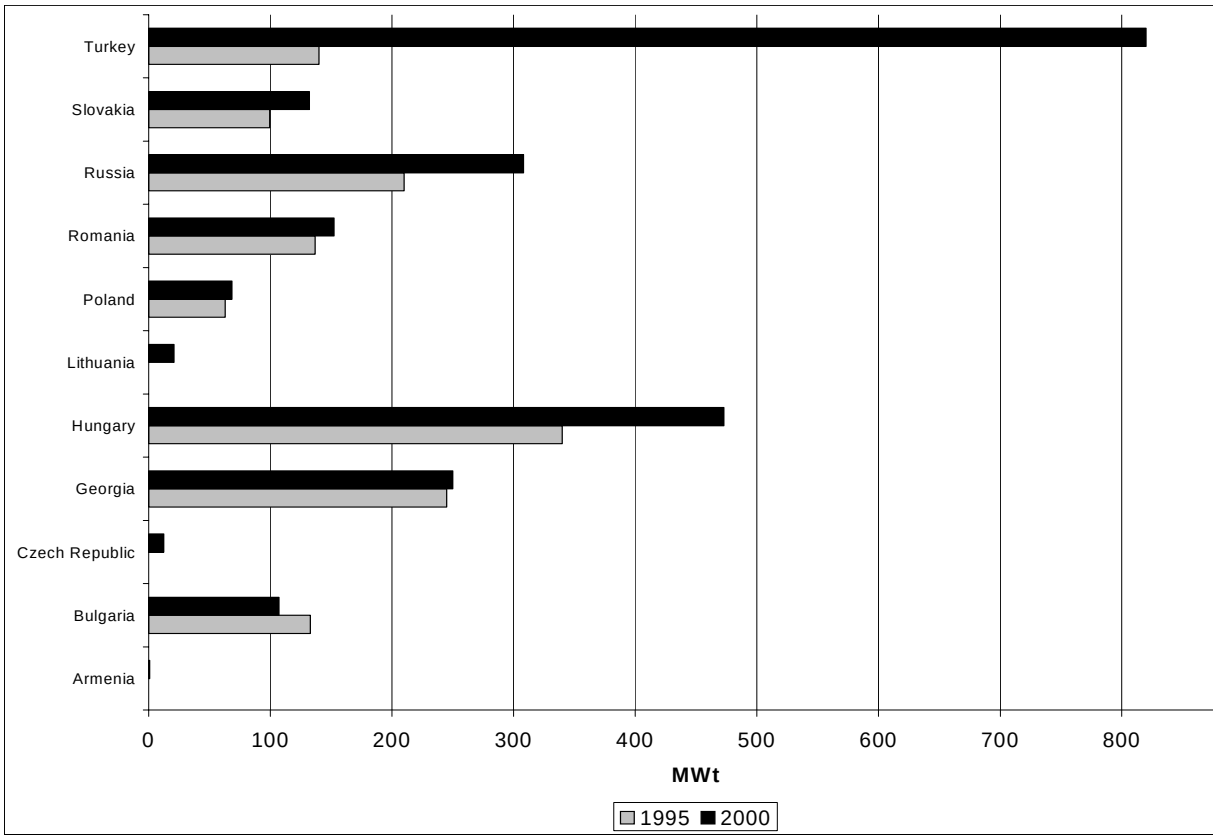

Figure 3: Geothermal energy capacity changes from 1995 to 2000.

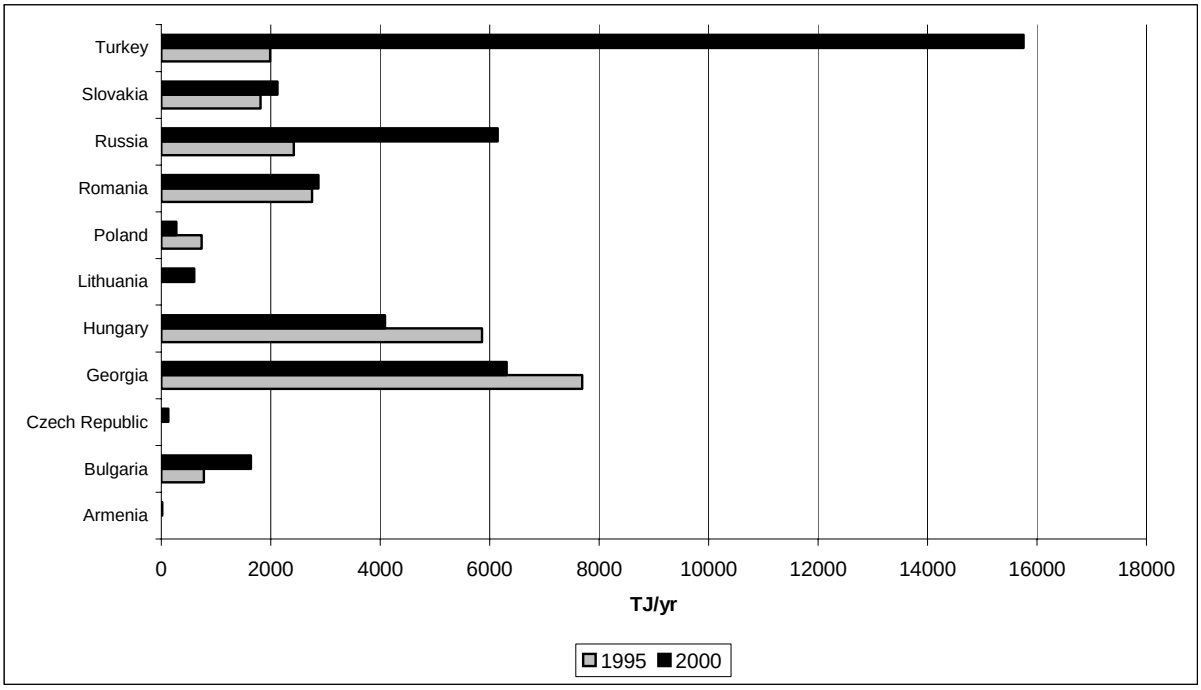

Figure 4: Geothermal energy capacity changes from 1995 to 2000.

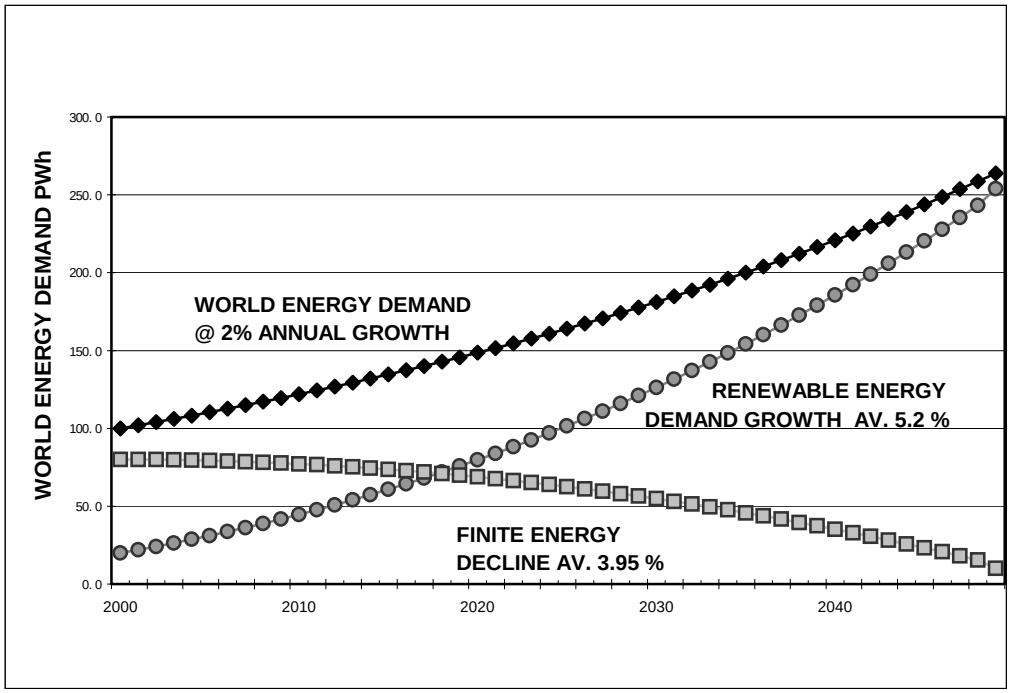

Figure 5. World energy scenario 2000-2050.

Figure 6,a. Verkhne-Mutnovsky GeoPP. First ecologically clean GeoPP. Photo of Svalova V.B.

Figure 6,b. Verkhne-Mutnovsky GeoPP. Snow in August. Photo of Svalova V.B.

Figure 7,a. Mutnovsky GeoPP. Many visitors always. Photo of Svalova V.B.

Figure 7,b. Mutnovsky GeoPP. Primary separators provide MGeoPP with the high-quality steam. Photo of Svalova V.B.

Figure 7,c. Mutnovsky GeoPP. The main entrance. Photo of Svalova V.B.