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NON-TRADITIONAL ENERGY SOURCES IN THE CIS: STATUS AND PROSPECTS

Prepared by the Russian Federation

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INTRODUCTION

This report has been prepared by a group of Russian specialists consisting of V. I. Dobrokhotov, A. I. Gritsenko and G. A. Zotov. The aim of the report is to analyse the status and prospects for the use of non-traditional renewable and non-renewable sources of energy and to estimate their resource base.

In preparing the report extensive use has been made of information obtained from the World Energy Council (WEC), the International Energy Agency, the United Nations Committee on New and Renewable Sources of Energy, journal articles, UN statistical handbooks, etc. A list of the principal publications consulted is appended to the report.

Separate sections of the report contain information supplied by the All-Russian Scientific Research Institute of the Gas Industry (VNIIGaz) and material obtained from Russia's scientific and technical "Clean Energy" programme, the Russian Energy Strategy (Basic Regulations, 1994) and the firm Al'ternativnaya Energetika (1992).

The World Energy Council - a very large non-governmental international organization with more than 100 member countries - is considering the following kinds of natural energy resources:

1. Coal (including lignite)
2. Crude oil and natural gas condensate
3. Heavy oil, oil shales and natural bitumen
4. Natural gas
5. Uranium
6. Nuclear energy
7. Hydropower
8. Peat
9. Firewood (including wood charcoal)
10. Biomass (other than firewood)
11. Solar energy
12. Geothermal energy
13. Wind energy
14. Tidal energy
15. Wave energy
16. Ocean thermal energy

The non-traditional renewable sources of energy include biomass (other than firewood), solar, geothermal, wind, tidal, wave and ocean thermal energy and small-scale hydropower.

The following are considered to be non-traditional non-renewable energy resources: heavy oil and natural bitumen; non-traditional sources of gaseous raw materials in the form of coal-bed gas, dissolved hydrocarbon gases, gas-hydrate hydrocarbon gases; complex structures with dense low-permeability reservoirs and low oil and gas recovery levels; depleted fields; oil and gas extracted from depths of more than 6 km.

The authors also found it necessary briefly to examine the problems of hydrogen power and technology since, with further technical advances, hydrogen,

which is found in nature in the form of various compounds, could become an important clean energy source.

The World Energy Council estimates the proven reserves and ultimate recoverable resources of fossil fuel to be as follows (in billions of tons of oil equivalent - TOE):

	Proven reserves	Ultimate recoverable resources
Coal and lignite	606	3,400
Crude oil	137	200
Natural gas	108	220
Non-traditional oil	-	595
including:		
heavy oil	-	75
natural bitumen	-	70
oil shales	-	450

Total nuclear fuel resources are estimated at 17 million tons, of which 3.7 million tons are "known". The energy equivalent of these nuclear fuel resources is estimated at 167 and 37 billion TOE respectively if used in thermal reactors, and at 8400 and 1850 billion tons if used in fast-neutron reactors.

The resources of non-traditional renewable sources of energy are usually estimated on the basis of their potential contribution to the energy balance. The World Energy Council’s "minimum" and "maximum" estimates for the contribution of non-traditional renewable sources of energy in the year 2020 are as follows (in millions of TOE):

	"Minimum" alternative	"Maximum" alternative
"Modern" biomass	246	563
Solar energy	109	355
Wind energy	85	215
Geothermal energy	40	91
Small-scale hydropower	48	69
Solar thermal energy	14	54
Total	542	1347

For comparison, we note that the present total use of non-traditional renewable sources is at most 200 million TOE or slightly less than 2 per cent of current annual world demand for primary energy resources. In terms of the "minimum" analysis of non-traditional energy trends, in 2020 the contribution of these sources to the input side of the world energy balance will be no more than

4 per cent, and according to the "maximum" analysis no more than 12 per cent. In terms of the four alternatives considered by the World Energy Council, in 2020 the contributions of the various types of energy sources to the input side of the world energy balance can be estimated as follows (in millions of TOE):

	High rates of growth of demand	Basic alternative	Basic alternative, but with low rates of decline of specific energy consumption in the economies of the CIS countries	"Clean" alternative
Solid fuel	4,852	3,035	3,814	2,128
Oil and condensate	4,594	3,769	4,532	2,898
Natural gas	3,648	2,977	3,561	2,486
Nuclear energy	982	793	981	693
Hydropower	999	920	987	661
Firewood	1,323	1,323	1,323	1,060
Non-traditional renewable sources	810	542	810	1,347
Total	17,208	13,359	16,008	11,273

During the preparation of Russia’s Energy Strategy, which was approved by the Government of the Russian Federation in December 1994, several scenarios of primary energy resource production in Russia in the year 2010 were worked out. The figures for two of these are set out below (in millions of TOE):

	Necessary scenario	Maximum scenario
Solid fuel	133	147
Oil and condensate	280	350
Natural gas	634	737
Nuclear energy	28	36
Hydropower	40	42
Non-traditional renewable sources	7	12
Total	1,122	1,324

It follows from these figures that, according to both scenarios, in 2010 the share of non-traditional renewable sources of energy in Russia's total production of primary energy resources will be less than 1 per cent. As regards their contribution to meeting the domestic demand for primary energy resources (706-839 million TOE), the coverage would be only a little over 1 per cent.

Given the current abundance of traditional fuel resources in Russia, it is unlikely that non-traditional non-renewable energy resources will make a serious contribution to the Russian fuel-energy balance in the near future. The most that can be expected is that they will be developed in individual regions to meet mainly local needs.

In general, for the foreseeable future, the use of non-traditional sources of energy in Russia should be regarded only as a means of satisfying the local requirements of areas remote from the centralized systems of fuel and energy supply. It might, however, provide one means of creating a competitive national environment for the supply of energy and fuel. Moreover, the extensive use of clean non-traditional renewable sources of energy could help to solve the problems of preserving the environment.

Section 1. Non-traditional Renewable Sources of Energy (NRSE)

In recent years, the development of non-traditional renewable sources of energy has been rapid, as a result of which their relative efficiency has increased considerably. According to estimates made by foreign specialists[1/], during the period from 1985 to 1993 the cost of generating electricity in the United States, where non-traditional energy sources have been most intensively developed, fell by a factor of 1.5-2. In the United States, the cost of generating electricity on the basis of NRSE is expected to continue falling in the future (cents per kWh in 1993 prices):

	1985	1993	2000
Gas-fired plants	10-13	4-5	3-4
Coal-fired plants	8-10	5-6	4-5
Wind power plants	10-13	5-7	4-5
Solar thermal plants (with gas standby)	13-26	8-10	5-6
Nuclear power plants (NPP)	10-21	10-21	(no orders for new NPP)

In determining the cost of generating electricity in the year 2000 reference was made to the following figures for the expected unit investment costs for NRSE-based plants in that year (US$:kW):

1/ Ch. Flavin and N. Lensen, Power Surge: Guide to the Coming Energy Revolution, N.J. 1994.

wind power plants	-	< 1,000
solar power plants, thermal	-	2,500
solar power plants, photoelectric	-	5,000
geothermal power plants	-	2,500
small-scale hydroelectric power plants	-	3,500

The previously mentioned "minimum" and "maximum" alternatives for the use of NRSE in 2020 have nothing to do with their potential which is practically unlimited. According to estimates contained in the Review of World Energy Resources published by the World Energy Council in 1992, at the earth's surface the solar radiation potential is approximately three thousand times greater than total world energy resource requirements. In the World Energy Council's report on non-traditional renewable sources of energy,[2/] the wind power potential on the earth's land surface is estimated at 20,000 TW of electrical power per year, which is almost twice as great as the current world annual output of electricity. Out of a world tidal energy potential of 22,000 TWh, the use of about 200 TWh might be economically justifiable. The geothermal and wave energy potential is enormous.

At present, about 350 geothermal power plants with a total capacity of more than 7 GW and about 20,000 wind generators with a total capacity of around 3 GW are operating or under construction worldwide.

According to the estimates of Russian scientists and specialists, in Russia the NRSE potential economic by current standards is equal to about 190 million TOE, which is only around 6 per cent of that which it is technically feasible to exploit (in millions of TOE per year, in round numbers):

	Gross potential	Technical potential	Economic potential*/
Geothermal energy**/	**/	**/	80
Small-scale hydropower	250	90	45
Biomass	700	40	25
Low-potential heat	370	70	20
Solar energy	1.6 X 10	1,600	10
Wind energy	18 X 10	1,400	10
Total	1.6 X 10	3,200	190

*/ The economic potential is assumed to be the reserves of thermal waters and steam hydrothermae earmarked for immediate exploitation using geocirculation technology.

**/ According to a rough estimate the potential resources of geothermal energy at depths of up to 3 km are equal to 125 trillion TOE/year, while the resources suitable for exploitation are equal to 15 trillion TOE/year.

2/ New Renewable Energy Resources, WEC, 1993.

In the opinion of a group of Russian specialists,[3/] the estimates of Russian NRSE utilization adopted for the purposes of the Energy Strategy are somewhat too low. In their view, in 2010 the economically feasible scale of exploitation of these energy sources could be around 20 million TOE (including 3.5 million TOE of low-potential heat). The principal contribution (about two-thirds) could come from solar energy, geothermal energy and biomass (in millions of TOE):

	1993	1995	2000	2010
Solar energy	0.001	0.1	2.0	5.2
Geothermal energy	0.2	0.5	0.7	3.5
Low-potential heat	0.04	0.1	0.6	3.4
"Modern" biomass	0.2	1.0	1.2	3.4
Wind energy	0.01	0.2	0.7	2.1
Small-scale hydropower	0.5	0.8	1.0	2.1
Total	0.951	2.7	6.2	19.7

These data correspond to the working version of NRSE development in Russia. Two other versions worked out by this group of specialists - the pessimistic and optimistic versions - assume that in 2000 NRSE will replace 12 and 28 million TOE respectively.

1.1. Solar energy (SE)

Approximately three-quarters of Russia’s total economic solar energy potential is concentrated in five regions of the country: in Eastern Siberia (28%), the Far East (20%), Western Siberia (15%), the Volga region, and the Urals (10% each). The other regions and, in particular, the North-West, Northern and Volga-Vyatskii regions have relatively little economic potential as far as solar energy is concerned. A somewhat greater potential is to be found in the Northern Caucasus (7%) and in the Central Region (5%).

Solar energy tends to be used mainly for conversion into electricity and to obtain heat for space heating, water heating, water desalination, drying and other technical purposes.

There are two main ways of converting solar energy into electricity:

- the thermodynamic method which is used to obtain electrical power on a relatively small scale;

- the use of photoelectric converters to supply electricity to scattered small consumers.

3/ Development and utilization of the potential of small-scale and non-traditional energy sources in the Russian energy balance, Russian Ministry of Fuel and Energy (Mintopenergo), 1994.

1.1.1. Thermodynamic solar energy conversion

Optical systems are used to concentrate the solar radiation in order to heat the working medium to the temperature necessary to enable heat engines to operate efficiently. Solar thermal power plants or solar power stations (SPS) are designed on this principle.

The following three types of SPS are those most frequently encountered:

- the tower type (TT) with a central receiver or steam generator on whose heat-absorbing surface the solar radiation is concentrated by means of plane mirrors or heliostats;

- the modular type (MT) with evacuated tubular receivers containing a heat transfer medium (steam generators) mounted at the focal point of parabolic cylindrical concentrators (PCC);

- the combined type (CT), i.e. solar-thermal power stations (STPS) in which a purely solar power plant of some type (TT or MT) is combined with a thermal power station.

Practical work on designing the first experimental TT SPS began simultaneously in a number of countries in the mid-seventies.

In the former USSR the basic technical principles for large experimental TT SPS were worked out in the fifties. However, the first 5-MW experimental TT SPS was started up only in 1987 (Crimea).

This SPS can generate about 7 million kWh of electrical power per year (equivalent to 2000 tons of comparison fuel), and the actual cost per installed kilowatt was 5400 rubles (1987 prices).

In the United States, Japan, France, Italy and Spain full-scale experimental research has been in progress since 1983 and various thermodynamic solar energy conversion technologies have been compared. So far the following thermodynamic SPS have been built: Solar-1 (Barstow, USA, 10 MW); Themis (Targassonne, France, 2.5 MW); Eurelios (Adrino, Italy, 1 MW); Cesa-1 (Almeria, Spain, 0.5 MW); and Sunshine (Nyo, Japan, 1 MW).

In the United States (Southern California) 7 large TT SPS with capacities ranging from 15 to 80 MW have been operating since 1988. All these stations feed into the main grid. The total SPS capacity is 243.8 MW. In 1989 the first phase of the construction of a 200-MW CT SPS - STPS was completed. Total SPS capacity in the United States is scheduled to reach 590 MW in 1995 and 4000 MW in the year 2000.

1.1.2. Solar heating (SH)

This is the commonest use to which SE is being put. The systems are based on devices that convert solar radiation into heat. The main component is a flat solar collector which absorbs the sun’s rays and converts them into thermal energy. The collector surfaces are usually painted dull black.

SH installations are used for water heating, space heating and air conditioning in private homes and public buildings and in sanatoria and spa establishments, for heating swimming pools and in various agricultural processes. It is possible to distinguish between:

- "active" installations in which collectors with a circulating heat transfer medium are used; and

- "passive" systems for heating buildings in which structural features are used as heat-absorbing elements.

Experience with the operation of these installations shows that:

- solar water heating (SWH) systems can replace 40-60 per cent of the annual fossil fuel consumption, depending on the location;

- solar space and water heating systems can replace 20-50 percent of fossil fuel consumption;

- "passive" space heating systems can reduce the consumption of traditional energy resources for home heating by 40 per cent and in some cases by 70 per cent.

At present, worldwide, there are more than 2 million solar water heating (SWH) and 250 thousand solar space heating (SSH) systems in operation.

Abroad, the construction of SWH systems began in 1973-74 and reached a peak in 1981-82 since when it has declined slightly.

The United States has the greatest total area of installed solar collectors, namely 10 million m^2, followed by Japan (8 million m^2), Israel (1.7 million m^2) and Australia (1.2 million m^2).

The annual output of SWH systems with a water temperature of (30-40)°C is estimated at 300-650 kWh/m, and 5-8 m^2 of collector is needed to obtain (200-300) litres/day of hot water. The output of swimming pool heating systems with a temperature of (20-27)°C is (250-270) kWh/m^2, and that of space heating systems with a temperature of (35-70)°C is (150-300) kWh/m^2.

In the CIS countries, the mass production of solar collectors based on stamped and welded steel panels has been organized (in the cities of Bratsk, Tbilisi and Kiev), and preparations are being made to set up the mass production of solar collectors based on rolled and welded panels of clad aluminium (Baku); quiet circulating pumps, heat exchangers, capacity storage tanks, etc. have also been brought into production.

In Russia, the latest solar water heating and photoelectric conversion technologies are being developed within the framework of the State’s "Clean Energy" programme.

Part 3 of this programme "Non-traditional energy sources" envisages five separate projects in the solar energy field. Two of these are aimed at developing and bringing into mass production modern solar installations for converting solar energy into low-potential heat for heating water, space heating

and other thermal processes. These are the applications which, technically and economically, are readiest for widespread practical introduction in various regions of the country. The other three projects are connected with support for developments in the field of photoelectric solar energy conversion. These projects are for the longer term, although photoelectric installations have already been used, mainly for local power supply requirements.

Passive solar heating systems are most widely used in Australia and Jordan, and active solar heating systems in Israel, Spain, Taiwan, Mexico and Canada.

In Australia, more than 400,000 homes have solar water heaters. In Israel, more than 70 per cent of all single-family dwellings (about 900,000) have solar water heaters with solar collectors having a total area of 2.5 million m^2. This is making it possible to save about 0.5 million TOE per year. In the United States, altogether over 8 million square metres of solar collectors have been installed.

In Russia, solar energy is used to produce hot water for hot-water supply and space heating purposes either by constructing individual installations comprising solar collectors (solar energy receivers) and storage tanks or by connecting such installations to fossil-fuel boilers (solar add-ons). Solar add-ons to boilers are effective in the above-mentioned regions; they make it possible to save up to 20 per cent of the fuel consumed by the boiler during the heating season.

Solar hot-water supply systems can be efficiently employed over a considerable portion of Russian territory.

On average, a solar collector produces <0.5 Gcal of thermal energy per year per m^2 of collector surface, and the unit comparison fuel savings (kg/m^2 solar collector per year) when solar water heating installations are used is: 80 for the latitude of St Petersburg, 87 for Moscow, 100 for Samara, 150 for Volgograd, 160 for Astrakhan, and 200 for Sochi.

1.1.3. Photoelectric conversion of SE

This method has become a priority solar energy application worldwide. This is because it provides:

- extremely clean energy conversion;
- the possibility of generating power almost anywhere;
- low maintenance;
- SE conversion efficiency that does not depend on the installed capacity.

Photoelectric sources are being used to supply consumers over a wide power range: from mini-sources for watches and calculators generating only a few watts to central power stations with a capacity of several MW.

More than 30 countries are now converting solar energy directly into electricity for various purposes. The total capacity of the world's annual production of solar photoelectric converters (SPEC) or solar batteries has now reached 65 MW, of which the United States and Japan are producing two-thirds (more or less equally divided) and Europe about one-fifth.

According to the WEC's data, at the beginning of the nineties SPEC were being used for generating electrical power in 24 countries, in just 7 of which, namely Spain, Mexico, Norway, France, China, South Korea and Canada, in 1990 more than 16 billion kWh of electrical power was generated by SPEC.

The greatest total solar thermoelectric power station capacity (279 MW with an annual output of 700 million kWh) is installed in the United States.

In the Russian Federation, there are regions particularly suited for the construction of photoelectric power stations where, assuming an efficiency of the order of 12 per cent, the unit power output would reach 200 kWh per year per m^2 of solar battery surface. These are the Astrakhan, Volgograd, Amur and Chita regions, the Sochi district, Kalmykiya, Dagestan, Tuva, Buryatiya, and the Primorye, Stavropol and Krasnodar territories.

Photoelectric installations on Russian territory could very profitably supply up to 3.5 million autonomous small-scale (2-4 kW) consumers (farms, horticultural and market garden enterprises, ranches, livestock watering stations, local irrigation systems) in zones with a decentralized power supply at distances of up to 5-10 km from the grids, depending on capacity. A 100-MW solar photoelectric power station built in one of the above-mentioned regions could generate over the season 120-150 million kWh without solar tracking or 200-250 million kWh with biaxial solar tracking, while occupying an area of the order of 2.5-3 km^2.

In recent years, there has been considerable technical progress in the photoelectric conversion of solar energy. This has made possible a substantial reduction in investment costs and in the cost of the electrical power produced. According to foreign sources,[4/] in 1993 the unit cost of SPEC was between $3.50 and $4.75 per watt, which means that power can be generated at between 25 and 40 cents per kWh. The rapid improvement in the economic indicators of SPEC, accompanied by increases in their efficiency and in productivity, have led to a sharp rise in photoelectric converter output: from 6.5 MW in 1980 to 29 MW in 1988 and 60 MW in 1993.

Every year, Japan produces up to 100 million solar-powered pocket calculators. These require 4.7 MW of solar photoconverter power, or 7 per cent of world production.

By the early nineties, the use of SPEC had become especially widespread in the developing countries, where they are used for lighting purposes and for driving water pumps. They replace kerosene lamps, lead batteries and diesel engines and are serving more than 200,000 homes in Mexico, Indonesia, South Africa, Sri Lanka and other countries.

4/ State of the World, 1995, p. 66.

In the mid-nineties, the commonest SPEC are those based on single-crystal silicon which represent as much as half of all the SPEC produced. SPEC based on polycrystalline silicon are also used. In Russia, as in other countries, thin-film solar converters are being developed. Individual specimens of these SPEC are achieving efficiencies of around 10 per cent, and in 1993 the cost of the power generated was not more than 10-12 cents per kWh. It is anticipated that by the year 2000 this indicator will have fallen to somewhat less than 10 cents and by 2020 to 4 cents per kWh.

1.2. Geothermal energy

Geothermal energy resources consist of thermal waters, steam-water mixtures, dry steam in underground reservoirs and porous strata (steam hydrothermae), and the heat from hot rocks, volcanic magma chambers and laccoliths (magma that has penetrated into sedimentary rocks).

Today, the commonest applications involve the use of thermal waters for space heating and water heating and steam-water mixtures for generating electricity.

Geothermal energy is being used in one form or another in the United States, Italy, Japan, Great Britain, Iceland, France, Germany and a number of other countries.

At the beginning of the nineties, electricity based on geothermal sources was being generated in 26 countries, mostly in the United States (total geothermal power station capacity 3300 MW), in the Philippines (about 900 MW), Mexico (700 MW), Italy (548 MW) and Japan (270 MW).

At present, the direct use of geothermal energy for space heating and water heating is most widespread in Iceland, Japan, the Philippines, France, China, Hungary and New Zealand. In Iceland, for example, about 83 per cent of the entire space heating load is supplied by geothermal systems.

In the Russian Federation, the potential thermal water reserves are estimated at 880 million Gcal per year, which is equivalent to almost 90 million TOE. The steam-water mixture resources suitable for the generation of electricity are enormous.

The main steam-water mixture resources are concentrated in the Kuriles-Kamchatka zone, where they could provide the basis for the construction of geothermal power stations with a total capacity of up to 1000 MW. However, the proven reserves of steam-water mixture would permit the construction of power stations with a total capacity of only 200 MW.

According to predictions made by the Leningrad Mining Institute, in the CIS countries the energy potential of the heat available for creating subterranean circulating systems (SCS) at temperatures of (100-150)°C could be of the order of 70 billion TOE.

Thermal water is used in the Russian Federation:

- for water heating in the cities of Makhachkala, Kizlyar, Izberbash, Groznyi, Cherkesk, Tobolsk, Goryachensk (Baikal), etc., and in the CIS in the cities of Tbilisi, Zugdidi and Samtradi;

- by hothouse and vegetable-growing combines in Dagestan, Western Siberia, the Magadan region and Kamchatka, and in Georgia and Kazakhstan in the CIS.

At present, the spontaneous flow or gusher method is mainly used for recovering thermal water. The transition to intensive technologies involving the pumping of the spent water back into the formation is taking time. Experimental intakes on an industrial scale are being constructed, in particular in the Krasnodar territory.

The utilization of thermal waters can be made much more efficient by making full use of the thermal potential of the water (for example, by using the residual thermal potential for pisciculture, etc.) and by extracting useful elements (iodine, cesium, lithium, bromine, etc.) for industrial purposes.

Low-permeability masses of bedrock and volcanic rock at temperatures of 200°C form extensive thermal-anomaly zones at depths of less than 4 km in Dagestan and also in Armenia, the Carpathians, Kopet-Dag, Tien Shan and the Crimea. This heat can be exploited by means of subterranean circulating systems (SCS). An experimental SCS has been constructed near Uzhgorod in the Ukraine for supplying heat to a hothouse and nursery complex and livestock farm (depth of SCS - 2.3 km, temperature - 124°C). The Leningrad Mining Institute has worked out a project for constructing a circulating system for supplying power to a tungsten-molybdenum combine (depth - 4 km, temperature - 223°C). This system should yield 100 GJ of heat per hour at an economic cost. There are plans for the future extension of the system to supply heat to the city of Tyrnyauz which has a population of 25,000.

In the Russian Federation, geothermal energy began to be used for generating electricity in 1968 when the first 5-MW unit started up at the Puzhetskii site in Kamchatka. By 1980 the capacity of the plant had reached 11 MW. This is the only geothermal power station operating in the RF. The cost of the power generated is comparable with that for a large heat and power plant and three times less than that for diesel power plants of the same capacity.

Unfortunately, the RF lags well behind most countries (14th place) in the use of geothermal power plants. The geothermal waters of the RF typically have a low energy potential. Whereas foreign geothermal power plants use a geothermal heat transfer medium with a vapour enthalpy of (200-650) kcal/kg, at the Puzhetskii geothermal power plant the corresponding value at the well outlet is only 170 kcal/kg.

In this connection, the main problem as regards the design of viable geothermal power plants is how to improve the thermodynamic efficiency of the heat conversion system. As early as 1967, at the Paratunskii pilot plant (Kamchatka) tests were conducted on a binary-cycle system in which thermal water at a temperature of 78°C heated liquid freon whose vapour was supplied to a turbine. In the United States and Japan this research was considerably extended and plants operating on isobutane, isopentane, propane, freon and their mixtures

were designed, which in practice presupposes the use of systems with temperatures of 200 to 250°C.

In the RF, schemes have been worked out for using geothermal heat in combined systems in which it is employed to pre-heat the feedwater for thermal power plants. This saves fossil fuel and improves the low-potential heat conversion efficiency. Moreover, these combined systems make it possible to generate power using heat transfer media at lower temperatures (70-80°C) than is now generally the case (over 150°C).

Planning is now under way for a 200-MW geothermal power plant at the Mutnovskii hot springs (Kamchatka).

The Leningrad Polytechnic Institute has designed hydro-steam turbines which, if used in geothermal power plants, would make it possible to improve the effective output of two-loop systems (second loop - steam) in the temperature range from 20°C to 200°C by, on average, 22 per cent.

The "Clean Energy" programme provides for the organization in the RF, in 1995, of the mass production of modular geothermal heat and power plants capable of competing on the world market. They are designed for a heat transfer medium with the following parameters: pressure 0.8 MPa, moisture content 0.2-0.65, gas content 0.2-0.5%, mineralization 0.5-2 g/kg. The plants have the following specifications:

- thermal substation (GPP) : 20 Gcal/h;

- power modules (GPP) : 20 MW.

In the first phase, power modules will be installed at the Mutnovskii geothermal power plant, together with thermal substations for supplying heat to the town of Severo-Kuril’sk.

One of the projects included in the programme involves the design of an experimental clean 2-MW geothermal power plant based on a SCS in the Stavropol territory. The heat transfer medium for this station is a high-temperature (165°C) geothermal brine with a mineralization of up to 100 g/l extracted from a depth of 4200-4400 m. Another project is aimed at building an industrial pilot plant designed to make full use of the geothermal waters of Dagestan by extracting both heat and valuable components.

1.3. Utilization of biomass

At present, biomass is supplying up to 14 per cent of the world’s total energy resource requirements. According to estimates made by the World Energy Council and the UN Committee on New and Non-traditional Renewable Sources of Energy, in the 21st century biomass will be one of the most important renewable sources of energy, although even now in the developing countries it represents 35 per cent of total primary energy consumption, and in some areas as much as 90 per cent. Biomass plays an important role as an energy source in the industrial countries also. For example, in the United States power stations with a total capacity of 9 million kilowatts are operating on various kinds of biomass (mainly production waste). Sweden uses biomass to meet 14 per cent of its energy needs. In Austria there are more than 70 small heat and power plants generating

enough electricity to cover approximately 10 per cent of total Austrian power requirements. The annual "economic potential" of biomass in the European Community countries is estimated at approximately 100 million TOE (almost 10 per cent of total energy requirements), and the "technical potential" at 306 million TOE.

It has been calculated that the energy supplies for roughly 800 million people in the world are linked to some extent or other with the use of biomass in the form of agricultural waste:

- protection of the environment as a result of treating manure on livestock and poultry factory farms and urban waste at disposal sites and burning it in special installations;

- use of reclaimable methane and solid organic waste as fuel;

- production, together with biogas, of high-performance organo-mineral fertilizers at bio-power plants operating on livestock-farming waste.

Programmes to generate power from biomass are being implemented in at least 17 countries around the world.

1.3.1. Use of wood biomass

On our planet trees cover an area of about 4 billion hectares, of which 2.8 billion hectares are accessible for practical use. The correct and rational utilization of this resource is of great ecological and social importance for both the present and the future.

In South Africa’s villages, where 85 per cent of the population live, up to 80 per cent of the energy is obtained by burning wood. Wood fuel represents (in%): 77 in Angola, 48 in Botswana, 47 in Lesotho, 64 in Malawi, 82 in Mozambique, 35 in Swaziland, 92 in Tanzania, 54 in Zambia, and 37 in Zimbabwe. Here, in the last 20 years there has been a sharp decline in the supply of wood fuel and the situation is becoming critical. A way out can be found by establishing plantations for growing fuel wood (short cycle - 3-14 years) capable of yielding 10-12 tons per hectare and located not far from population centres (5-100 km).

One promising method of utilizing the energy stored in wood is gasification. Research in this field is being carried out in Russia, France, Germany, Belgium, Canada and elsewhere. The aim of gasification is to obtain a gaseous or liquid fuel in a thermochemical process involving the decomposition of the solid components in the presence of active agents (air, oxygen, water).

Principal biomass technologies

Type of biomass	Process technology	Product
Dry		Thermal and electrical energy
	Gasification	Combustible gases. Methanol
	Pyrolysis	Combustible gases, tar, charcoal or semicoke
	Hydrolysis and distillation	Ethanol
Wet	Anaerobic digestion	Biogas
	Briquetting	Fuel briquettes
	Fermentation and distillation	Ethanol

The operating gas generators of low (up to 100 kW), medium (100-1000 kW) and high (more than 1000 kW) capacity are intended to produce electrical power, fuel gas that can be burned in combustion chambers and furnaces, synthesis gas and methanol, or to obtain liquid fuel. As fuel, gas generators use pre-treated (ground, pressed, briquetted) wood, charcoal, sugar cane, etc. Gas generators can be used as a basis for building steam-turbine power plants and diesel plants operating on generator gas.

In Great Britain, according to data published by the Ministry of Power, about 8-13 per cent (13-20 million TOE per year) of the country’s energy needs could be covered by energy from biomass and waste.

The United States is developing the idea of producing power and heat in bio-power plants burning wood waste. At present, 146 bio-power plants with capacities ranging from 5 to 50 MW are operating or planned. The fuel breakdown for bio-power plants is as follows: wood waste 72 per cent, urban solid waste 22 per cent, agricultural waste 6 per cent. According to estimates, in the United States by the year 2000 the use of wood as fuel may cover up to 10 per cent of all primary energy resource requirements.

In a number of countries proposals for creating so-called "energy farms" - intensive timber plantations for growing biomass - are being carefully analyzed. At present, however, using such plantations to produce energy is too expensive as compared with the use of traditional fuels.

In the former USSR, the preparation and processing of wood annually creates about 200 million cubic metres of waste and the waste from hydrolysis plants contains tens of millions of tons hydrolytic lignin; up to 400 million cubic metres of agricultural waste is produced every year. Altogether, the waste generated amounts to 500 million tons of dry matter. Full processing using the methods of biotechnology could yield up to 100 million TOE per year. At present, however, it is possible to make rational use of no more than 30 per cent of the waste.

The "Clean Energy" programme includes three projects involving the utilization of biomass to generate energy. The biggest is that to develop a bioenergy system for processing chicken manure from a factory farm in the Vladimir region. The main aim is to achieve a fundamental improvement in the environmental situation on and around the farm itself and to reduce its fossil fuel consumption by 10-12 per cent by utilizing biogas obtained from the manure.

Other biomass projects are aimed at building various versions of individual biogas plants for peasant households and designing a thermochemical gas generator for converting solid biomass into gaseous fuel.

1.3.2. Processing municipal sewage sludge

The sludge formed when municipal sewage is treated is one of the types of secondary resource whose recycling poses an important environmental, social and energy problem. The volume of sludge produced is on average 0.6-1 per cent of the sewage treated.

Sludge processing is most highly developed in the United States, Germany and France, among others. Anaerobic digestion of the sludge in sludge digesters with biogas recovery is widespread. The yield is 50-60 per cent. The sludge is dried on drying beds. There are more than 6000 aeration plants in the United States alone.

Spanish municipal treatment plants have a capacity of up to 25 million m^3 of biogas per year (maximum corresponding to 100 per cent sewage treatment - 145 million m^3 per year), 60 to 70 per cent of which consists of methane. The biogas produced is capable of supplying 70-80 per cent of the energy requirements of the plants themselves.

In Italy (Reus) an experimental plant is producing 1094 thousand m^3 of biogas per year, its own consumption being 664 thousand m^3 per year (61 per cent).

In the former USSR there were about 1000 municipal aeration plants in operation with a (water) capacity of about 60 million m^3 per day. A rough estimate gives the following figures for the total amount of sewage sludge:

in 1990: 250-280 million m^3 per year;
in 2000: 350-400 million m^3 per year.

In dry matter content (including 73-75 per cent organic constituents) these volumes correspond to 6.2-7 million tons per year and 9-10 million tons per year respectively.

The processing of this sludge could yield the following amounts of biogas: in 1990, 2-2.5 million TOE and in 2000, 3-3.5 million TOE per year.

The following methods are used for making the sludge harmless:

- thermophilic (52-55°C) anaerobic (in the absence of air) fermentation in sludge digesters with subsequent drying on sludge drying beds;

- mechanical dewatering of the raw sludge or digested sludge in the mesophilic regime (32-30°C) with subsequent thermal drying and combustion.

Sludge digested under thermophilic conditions can be used as fertilizer.

About 500 sludge digesters have been built. Of these 60 per cent are not operating for technical reasons. Sludge digesters with biogas recovery are operating normally in Moscow and Yaroslavl.

At present, in the Russian Federation fundamentally new equipment for carrying out biotechnological sewage treatment processes, with characteristics superior to those of similar equipment made by leading companies such as KHD and Flottweg (Germany) and Tsukishima (Japan), is being developed.

The table gives the total amount of fuel substitution that can be achieved by processing waste.

Possible volume of fossil fuel substitution in the RF from processing sewage sludge and solid household waste (in thousands of TOE)

Type of waste	Year			
	1990	1995	2000	2010
1. Municipal sewage sludge	63	100	175	310
2. Solid household waste	56	100	240	1050
Total	119	200	415	1360

The radical restructuring of sewage treatment and sludge recycling requires the development and organization of the production of equipment and materials for:

- bio-power plants, including compact units for treating drinking water, plants for purifying natural and waste water, and compact sewage treatment plants with high levels of nitrogen and phosphorus elimination;

- bio-sorber and bio-carrier systems to improve the capacity of operating treatment plants;

- the recovery of waste energy and its secondary use (heat pumps, heat exchangers, biogas engines);

- process automation systems.

1.3.3. Processing municipal solid household waste (SHW)

According to the forecasts of the Academy of the Municipal Economy (AME), in 1990 in the former USSR SHW was being produced at the rate of 61 million tons per year, while in 2000 this figure should rise to 74 million tons. The main

components of SHW are waste paper and food waste (60-65 per cent by weight), together with waste wood, textiles, leather, rubber, plastics, metals, bones, glass and stone.

The principal methods of dealing with SHW are as follows:

- storage at disposal sites (landfill);
- conversion to bio-fuel and organic fertilizer (compost);
- incineration with recovery of heat.

In 1990, in the USSR 87.5 per cent of SHW was dumped, 5.5 per cent was converted into compost, and 5 per cent was incinerated.

SHW is processed in special refuse processing plants (RPP). In 1990, in the former USSR there were only 18 such plants, of which 8 were for SHW conversion and 10 for incineration. These plants processed up to 3 per cent of waste. Most SHW is dumped at disposal sites which occupy an area of 70 thousand hectares.

RPP with a capacity of from 300,000 to 1.2 million m^3 SHW per year are being planned. All the plants are to be subsidized by the State.

According to the calculations of the AME, by the year 2000 in the RF the incineration of SHW with heat recovery should reach 10 million tons per year (13 per cent of the volume of SHW produced) which, assuming that the waste has an average calorific value of 2200 kcal/kg, could replace 2 million TOE per year.

Another problem associated with SHW is the biogas formed in large amounts at municipal refuse disposal sites (MRDS) which pollutes the atmosphere and the environment (soil, etc.).

In Germany, a 7-hectare quarry disposal site 24 m deep is being used to supply a brickworks with gas. Gas is extracted from 30 wells 1.5 m deep into which perforated plastic pipes are lowered; the wells have a 30-metre radius of action and produce 800 m^3 of biogas per hour.

An efficient process known as "Syngas" for obtaining methane from pulverized SHW has been developed.

The company Kaleppion has developed a project for equipping SHW dumps with a biogas collection system using impermeable polyethylene geo-membranes. The geo-membrane is laid at the bottom of the pit on top of the drains. Above it is another drainage system for removing rainwater. Biogas begins to form approximately one year after the dump is filled and continues to be released for about 20 years with an output of up to 250 m^3 of biogas per hour.

1.3.4. Processing animal husbandry, poultry farming and agricultural waste

Dozens of biogas technologies for obtaining biogas from organic biomass in special plants have now been developed. The biogas is then used to produce energy or is converted into methanol. It consists of 50-80 per cent methane and

20-50 per cent carbon dioxide and has a calorific value of 5000-6000 kcal/m^3. As a result of fermentation, from 1 ton of biomass it is possible to obtain 250 to 600 m^3 of biogas, one cubic metre of biogas being equivalent to 0.7-0.8 kg of comparison fuel. The efficiency of conversion of organic matter into biogas is 80-90 per cent.

Apart from energy problems, biogas production also makes it possible to solve no less important environmental problems. Agricultural and industrial waste and waste from livestock farms constitute a culture medium for the development of microbes and the causative agents of many dangerous diseases.

While eliminating the potentially dangerous properties of biowaste, the processes which take place in biogas generators (BGG) also make it possible, during methane fermentation, to obtain:

- biofertilizer with high nitrogen, phosphorus and potassium contents;

- feed supplements containing protein.

The use of BGG for obtaining fuel and high-grade sterile organic fertilizers is economically efficient. Biogas production is economic at gas yields of more than 2 m^3/day per m^3 of reactor. BGG pay for themselves in 3 to 10 years. The rate of biogas formation can be increased by a factor of 2 to 3 by going over from mesophilic fermentation (at temperatures of 30 to 40°C) to thermophilic fermentation (at 52-56°C). However, thermophilic BGG are still not being used very much because of the high cost.

Biogas is being produced from agricultural waste in many developing countries, but especially in India and China. In China, it is proposed to build 30 million BGG by the year 2000, while in India more than 800,000 BGG are in operation and it is intended to build 12 million BGG by the year 2000.

Among the ECE member countries, Italy is playing a leading role in biomass recycling. Two Italian national committees have developed a second energy plan which includes the intensive use of biomass to provide the country with energy.

According to the national experts, the total amount of energy contained in agricultural, animal husbandry and forest waste and recoverable by thermochemical and biochemical means is equivalent to the energy obtainable by burning 6342 thousand tons of comparison fuel per year.

In the Netherlands, the construction of 75 large BGG for processing manure is being studied.

In France, the possibility of obtaining biogas from whey is receiving attention. Thus, the cheesemaker Frangy (France) processes about 160 million litres of milk per year, between 80 and 90 per cent of which is converted into whey. Some of this whey is sold to pig farms and some is dumped after treatment. A BGG with a 25 m^3 reactor has been built to process about 7 m^3 of whey per day (first phase) and generate 130 m^3 per day of biogas.

The United States has developed a complete plant for obtaining biogas from manure by subjecting it to anaerobic microbiological decomposition in digesters.

Burning the biogas yields thermal and electrical energy; the surplus active sludge and alcoholic residues are converted into feed protein. The gas output is 280 m^3 per day, the power output 277 kW per hour, the heat output 760 mDt and the ethanol output 85 litres. The plant is intended for an animal husbandry complex with 60 head of cattle and 300 pigs.

In Russia there many large pig and poultry farming complexes, in particular with 30, 50 and over 100 thousand head of pigs. As a rule, on these complexes the problem of recycling the manure has not been solved. According to the research, liquid manure is an infectious bacteriological material (capable of causing brucellosis, swine erysipelas, salmonellosis, foot-and-mouth disease, tuberculosis, etc.). One ton of pig manure contains up to ten thousand weed seeds. At present, it is necessary to design BGG for farms with from 10 to 200 head of cattle.

Under Russia’s "Clean Energy" programme a clean pilot bioenergy system is being designed for processing chicken manure on the "Tsentral’naya" factory poultry farm in the Vladimir region. Its intended manure processing capacity is 400 m^3 per day. The system includes: three 500 m^3 digesters, a unit for separating the fermented manure into solid and liquid fractions, fish-breeding ponds and a 40-hectare botanical area. The annual yield of biogas is 3.5 million m^3, and 40,000 tons of concentrated fertilizer and 100,000 m^3 of industrial water are also produced. Each year the plant makes it possible to avoid releasing into the atmosphere 36,500 m^3 of nitrogen compounds and 120,000 m^3 of methane, to reduce the water intake by 100,000 m^3 (10.3 per cent) and to make savings of 10-12 per cent on fuel.

1.3.5. Obtaining motor fuel from biogas

Attention has turned to the use of NRSE in connection with the need sharply to reduce the harmful effects of traffic pollution on the environment. Advances have been made in a number of areas, including the replacement of environmentally hazardous petrol with clean fuel.

Brazil has a programme for using ethanol as an alternative fuel capable of replacing up to 22 per cent of petrol consumption (by volume). The ethanol is obtained by processing specially grown sugar cane. More than 70 per cent of the petrol sold contains 10 per cent added ethanol and 80 per cent of the country’s vehicle fleet uses this additive.

In the United States, too, there is a big programme for replacing petrol with ethanol obtained by processing surplus maize and other cereals. However, there is not much future for this raw material because of its high cost.

In the State of Indiana (United States) there is a plant for obtaining ethanol (200 million litres per year) from maize (700 million tons per year) and cattle feed and carbon dioxide from the waste. The following data are of interest.

In the United States, ethanol production is rising sharply, but the demand exceeds the supply and accordingly it is being imported from Brazil.

In the United States, there are subsidies for using ethanol (up to 25 per cent), which is making petrol-ethanol mixtures (gasohol) competitive with petrol.

A commission on alternative types of fuel has been set up. One of the tasks of this commission is to coordinate the federal programmes on the development of the use of various novel kinds of automobile fuel: methanol, ethanol, compressed gas and electricity.

The possibility of obtaining ethanol from solid waste, including SHW, is being investigated. By hydrolysis (temperature 230-350°C, pressure 30-32 atm) it is possible to obtain 60 per cent of glucose which is then converted into ethanol by fermentation.

Methanol is another alternative clean fuel. It can be obtained both from fossil fuels and from wood waste.

In the Russian Federation, a whole series of projects involving the use of cleaner alternative fuels (methane, propane-butane, methanol, etc.) as motor fuel is being carried out.

At the same time, the "Clean Energy" programme calls for the development of optimum technologies for recovering heat from the low-temperature (up to 25°C) wastewater from power engineering and industrial plants. For this purpose it is intended to use the waste heat from the Kursk nuclear power plant to run a non-traditional experimental complex producing foodstuffs on the basis of clean technologies.

Given a power unit capacity of 1 million kilowatts the complex will include:

- warming of 1000 hectares of open land and supplementary cooling of process water, thereby making it possible to obtain two crops per year (20,000 tons);

- heating of 100 hectares of hothouses (200,000 tons of marketable produce per year);

- fish farm with an output of 6000 tons of marketable fish per year;

- agricultural waste processing, mushroom growing - 1000 tons per year.

1.4. Wind energy

According to the data of the World Energy Council, wind energy is being used in more than 30 countries to generate power on the basis of modern technology. The total capacity of the approximately 20,000 modern wind power stations built worldwide by the beginning of 1994 exceeds 3 million kW, with more than half of this capacity in the United States and one fifth in Great Britain. Windmill-generated power is competitive with the power generated by a nuclear power station (according to the calculations of Danish specialists) and a coal-fired thermal power station (according to British specialists). Scientists and specialists in many countries are practically unanimous in

believing that with further technical progress the cost of windmill-generated power will continue to fall. It is also considered that to a large extent improvements in the economic indicators of wind power will be linked with an increase in the unit capacities of the wind generators.

In recent years considerable progress has been made with improving unit characteristics, both in the United States and in Europe. In Europe, the average unit capacity of wind power generators rose from 80 kW in 1986 to 300 kW in 1992.

The following data are used to determine wind energy resources at a height of 50 metres above ground in exposed areas:

average wind speed, m/sec	average energy potential, W/m^2
7.5	500
6.5-7.5	300-500
4.5-6.5	100-200
< 4.5	< 100

The energy potential of the wind is halved if the windmill is located in a sheltered spot and triples if it is located on high ground or a hill top.

In Europe, the strongest and steadiest winds blow on the coasts of Ireland and Scotland and in parts of Denmark, France, Spain, south-west England and Wales. Similar conditions prevail along most of the coastline of North and South America, Northern Asia and South Australia.

Assuming the annual average wind speed to be 8 m/sec, which is optimal for a wind generator, the energy potential of the wind can be estimated as approximately 5 MWh per m^2 per year. The average efficiency of a modern wind generator is about 25 per cent for a blade diameter of 35 m. For these initial data, the theoretical annual power output is 1.3 million kWh. At a wind speed of 6 m/sec the windmill’s annual power output falls to 500 MWh. On the basis of these figures, in order to replace a coal-fired thermal power station with a capacity of 1 million kW it would be necessary to build 5000 windmills with a blade diameter of 35 m.

At present, in Europe, the United States, India and certain other countries wind "farms" consisting of 100 or more closely spaced windmills are being built.

In Denmark, the approximately 3600 windmills installed are generating 3 per cent of the country’s power requirements. In California, there are 15,000 windmills which can generate enough electricity to supply the needs of all the homes in San Francisco.

In Germany, the mass construction of windmills began in 1988 when 25 units with a total capacity of 1 MW were brought into service on the Cuxhaven wind farm. In the same year 3 windmills with a total capacity of 750 kW were

introduced, while in 1989 the construction of 3 windmills with a total capacity of 1950 kW was completed. In recent years windmills with unit capacities of from 1200 to 3000 kW have been built.

In the first half of 1994, windmills with a total capacity of 98 MW were built in Germany. It was anticipated that by the beginning of 1995 total windmill capacity would reach 500 MW.

In Sweden, as early as 1982, the Maglarp windmill with a capacity of three megawatts and a two-megawatt windmill were brought into service. It is proposed to build 400 large windmills with an annual output of 3 to 5 billion kWh of electrical power on Sweden’s south coast.

The members of the European Union have set themselves the task of installing a total windmill capacity of up to 4 million kW by the year 2000 and 8 million kW by 2005, as compared with 1.4 million kW in 1994.

In India, the wind energy "boom" arrived in 1994. By the middle of that year windmills with a total capacity of 120 MW were in operation; there are plans to increase capacity further to 970 MW.

Large-scale wind energy projects are under way in China, Ireland, New Zealand, Switzerland and Canada.

In the early eighties, the unit cost of a windmill was about 3000 US dollars per kW, and the electricity cost 20 cents per kWh to produce. By the beginning of the nineties, these indicators had fallen to 1000-1200 dollars per kW and 7-9 cents per kWh respectively. In 1994, windmill makers were guaranteeing to meet orders for windmills that produced electricity at 4-5 cents per kWh.

Russia has lagged well behind the other industrial countries as regards the design of powerful windmills and the scale on which wind energy is being used. Recently, however, this gap has begun to close rapidly.

On the territory of the Russian Federation the energy potential of the wind is very high (in billions of kWh per year):

Economic region	Total potential	Technical potential	Economic potential
North	11,040	860	4.3
North-West	1,280	100	0.5
Central	2,560	200	1.0
Volga-Vyatka	2,080	160	0.8
Central-Chernozem	1,040	80	0.4
Volga River	4,160	325	1.6
Northern Caucasus	2,560	200	1.0
Urals	4,880	383	1.9
Western Siberia	12,880	1,000	5.0
Eastern Siberia	13,520	1,050	5.2
Far East	24,000	1,860	9.3
Russia as a whole:	80,000	6,218	31

Thus, in order to exploit what is now considered to be the economic energy potential of the wind it would be necessary to build 124,000 windmills with an average capacity of 250 kW. Windmills with precisely this unit capacity have been designed within the framework of the State's "Clean Energy" programme. Under the same programme, most of the windmills already designed and brought into mass production have a unit capacity of 8 or 100 kW. Financial support drawn from federal budget resources is being provided for setting up and organizing the production of small movable, transportable and dismountable wind power stations with a unit capacity of up to 1 kW, intended for supplying power and water to autonomous agricultural consumers.

Tests are now being carried out on an experimental batch of 250-kW wind turbines designed to operate in parallel with the existing local power system. The wheel diameter is 24 m. At a wind speed of 16 m/sec these machines will generate 400 kilowatts of power.

There are plans to design windmills with a higher capacity in the future.

It is interesting to note that, despite the economic disorder, the development of wind power is receiving much attention in the Ukraine, where in 1994 the electricity company Krymenergo, together with the American company Kenstich Corporation (San Francisco), undertook a wind power project in the Crimea with a total capacity of 500 MW.

1.5. Small-scale hydropower

Small-scale hydropower plants, defined by the World Energy Council as hydropower plants (HPP) with a capacity of less than 2 MW, are operating in approximately 100 countries around the world. In addition, several countries have plans to build such plants.

The total installed capacity of these HPP worldwide is estimated at approximately 12-16 million kW. The largest numbers have been built in Canada (700 MW), China (3700 MW), Bulgaria (850 MW) and Norway (800 MW).

Many small-scale HPP operate on the everyday flow of small rivers since the construction of large dams to create flow-regulating reservoirs for small hydropower capacities cannot be economically justified. Numerous small-scale HPP are based on existing reservoirs previously built for non-energy purposes.

This section also deals with the possibility of utilizing the energy of small rivers by building a number of types of micro HPP as energy sources for numerous individual consumers. According to the data of the All-Russian Institute of Agricultural Economics of the Russian Academy of Agricultural Sciences (VIESKh RASKhN), many such micro HPP could be built on small rivers in the Volga, Kama, Ural, Ob', Terek, Angara, Amur and Yenisei basins. Various types of micro HPP have been developed:

- the SPMGES-0.12 free-flow portable micro HPP which has a power rating of 120 W and a voltage of 12 V at the design water flow velocity of 1.5 m/sec. Such a micro HPP could be installed on a watercourse with a flow rate of 72 litres per second or more. It could be used to supply household electrical equipment (television, lighting, radio, etc.) and weighs 150 kg;

- a portable hose-type micro HPP for supplying the everyday power load of individual consumers, capacity 1.5 kV, voltage 350/220 V, required water flow rate 50 litres per second, weight 20 kg;

- a water hoist capable of raising a maximum of 277 litres per hour through a head of 2 metres (water velocity 0.65 m/sec).

The energy potential of Russian small watercourses is estimated at 1100, the technical potential at 380 and the economic potential at 200 billion kWh per year. At present, altogether less than 1 per cent of the technical potential is being utilized. These data on the energy potential are very arbitrary since they do not take into account the possibility of building HPP without dams or the potential of natural and artificial reservoirs. Nevertheless, it is worth noting the regional distribution (in billions of kWh):

Economic region	Total potential	Technical potential	Economic potential
North-West	81.6	31.5	24.1
Central	8.2	3.0	2.0
Volga-Vyatka	3.4	1.3	0.9
Central-Chernozem	1.5	0.6	0.3
Volga River	21.5	10.4	5.5
Northern Caucasus	37.5	19.3	11.5
Urals	34.6	17.2	11.5
Western Siberia	74.6	24.6	12.5
Eastern Siberia	390.8	128.4	66.8
Far East	452.0	146.0	65.4
Russia as a whole	1,105.6	382.3	200.0

Extensive development involving the design of micro HPP is being carried out under the "Clean Energy" programme. In particular, micro HPP ranging from a few hundred watts to several tens of kilowatts, capable of making efficient use of the energy of irrigation canals and mountain streams as well as of small rivers, are being developed.

1.6. Utilization of ocean energy

The world’s oceans constitute an enormous reservoir of renewable energy resources. At present, the development of ocean power is oriented towards the exploitation of:

- the energy of the ocean waves (tidal, wave action, swell) and currents;

- ocean temperature and salinity gradients.

From the practical standpoint, the use of ocean wave energy involves the design of wave power plants (WPP), tidal power plants (TPP) and ocean current power plants (OCPP).

Separate lines of research include:

- ocean thermal power plants (OTPP) which exploit the temperature gradient;

- hydrothermal power plants which exploit the temperature difference between the water of the ocean and the air in northern regions.

1.6.1. Tidal energy

The theoretical tidal energy potential of the world's oceans is 22 trillion kWh, but the economic potential is only 200 billion kWh. The main obstacle to exploiting tidal energy is the poor economic characteristics of tidal power plant (TPP) projects.

There are five places in the world particularly favourable for the construction of TPP:

- two adjoining bays in North America, one in Canada (Fundy) and the other in the United States (Passamaquoddy);

- the French Channel coast and the estuary of the river Rance;

- the estuaries of the English rivers flowing into the Irish Sea;

- the Kimberley coast in Australia;

- the White Sea coast in Russia.

Assuming that these five zones were fully utilized and 20 per cent of the tidal energy was recovered in the TPP, it would be possible to obtain 30,000 MW, i.e. approximately the capacity of 10 large modern nuclear power stations. This would be sufficient for local power supply requirements.

So far, only one TPP with a capacity of 240 MW and an annual power output of 500 million kWh has been built. The other existing TPP have much lower capacities: Annapolis in Canada (20 MW), a few small TPP in China with a total capacity of 5 MW and the Kislogubskaya TPP in Russia (400 kW).

As distinct from solar and wind energy, tidal energy is characterized by the constancy of its average monthly potential over seasonal and multiyear cycles, but on a daily basis it is intermittent.

The alternation of ebb and flood tides (every 6 hours and 12 minutes) means that the TPP hydroturbine must be capable of reversing its direction of rotation (enclosed turbine-pump type units).

In Russia, research in the field of tidal energy has been going on for a long time. The theoretical principles of tidal power engineering were established in the fifties. The Kislogubskaya pilot TPP (Murmansk) with a capacity of 1.2 MW (three 400-kW turbines) and an annual power output of 3.9 million kWh was built. Plans were also made for other large regional TPP: in the Bay of Mezen' (White Sea) - capacity 15.2 MW, annual output 41 billion kWh, and in the bays of Turgut and Penzhina (Sea of Okhotsk) - 8-31 MW.

It is estimated that the construction of the Mezen' TPP will be feasible by the beginning of the 21st century, and the construction of the Turgut and Penzhina TPP not before the year 2020. The main obstacle to the construction of TPP is the poor economics.

1.6.2. Wave power plants and other ocean energy installations

The energy generated by the wave motion of masses of water in the ocean is very great. The average amount of energy recoverable from a wave 3 metres high is about 90 kilowatts per metre of coastline. However, it is very difficult to put this energy to practical use. A number of devices which solve the problem with a certain degree of efficiency have now been patented. These include, in particular, the following energy converters:

- a system of floats known as "Salter's duck" (Edinburgh University, Scotland) with an efficiency of about 85 per cent (other systems about 50 per cent); it is estimated that 12 WPP, each 50 miles long, could supply Great Britain's power requirements;

- the "wave pump" (G.I. Denisenko, Russia) (a multimodule hollow-spher e structure);

- the Cockerell articulated raft consisting of floating pontoons.

No ocean thermal power plant (OTPP) has actually been built. Research in this field has been going on in a number of countries (United States and Japan) for more than 15 years and is aimed at designing OTPP that exploit the difference between the temperature of the water at the ocean surface (28-30°C) and at depth (4-7°C). In 1978, the United States tested a 50-kW floating OTPP off the Hawaiian islands. Since 1980 there has been a government programme to develop a 40-MW OTPP on the shelf off the island of Oahu (Hawaii).

In Japan, in 1977 a 1-kW tropical OTPP was tested (temperature difference 21°C), and in 1980 an experimental 100-kW OTPP was started up. Since 1982 development work on a 400-MW OTPP project has been going on.

Russia is the only country in the world to be developing an Arctic OTPP. The idea was first proposed by Academician A.F. Ioffe as early as 1932. Studies of freon turbines were made in 1979.

An additional form of energy for OTPP is the energy which can be obtained by exploiting the difference in the salinity of the water. The potential of this source is estimated at 1 billion kW, which is commensurable with the thermal potential of the ocean. The combined utilization of thermal and chemical energy is possible if the temperature of the less salty water is higher than that of the more salty water.

The efficiency of an OTPP can be improved by combining it with the use of solar energy to heat the OTPP's working medium (preheating of the fluid to boiling point or superheating of the steam ahead of the turbine in a solar heater).

Section 2. Non-traditional forms of hydrocarbon raw materials

Intensive research and industrial testing is now being carried out for the purpose of discovering, investigating and developing economically viable technologies for recovering and processing various non-traditional forms of hydrocarbon raw materials (NFHRM). In many parts of the world, the exploitation of NFHRM, previously unutilizable because of the lack of suitable technologies, the poor quality of the raw material or the sparsity or dispersal of the reserves, is now becoming a realistic and profitable proposition.

2.1. Heavy oil, natural bitumen, associated elements

Abroad, heavy oil (HO) is defined as oil with a density of more than 0.934 t/m^3, and in Russia as oil with a density of more than 0.904 t/m^3.

World reserves of HO and maltha (a hydrocarbon raw material intermediate between HO and bitumen) are estimated at 49 billion cubic metres. They have been found in 155 regions of the world, the largest deposits being in the Western Canadian and Eastern Venezuelan basins. These reserves make up about 20 per cent of the world's oil resources. The HO reserves in the United States amount to about 6 billion tons (12 per cent of world resources); there are altogether 722 deposits, including those in California (61 per cent of resources). Cumulative output to the end of 1985 was 2.16 billion tons. In 1987, world HO output amounted to about 366 million tons.

In the former USSR, heavy oil output was not more than 10 per cent of the total output of oil and was mainly concentrated in the Volga-Urals (Tatariya) and Timano-Pechora regions.

World reserves of natural bitumen (NB) are estimated at 398 billion cubic metres in 63 regions. The world annual output of NB was about 20 million cubic metres.

In Tatarstan, the experimental industrial exploitation of natural bitumen has been going for 14 years at two sites (Morodovo-Karmal' and Atal'chin) from which about 77,000 tons of NB has been extracted. Five recovery techniques are employed (in situ combustion; cyclical injection of steam, steam-gas and air; area steam-gas injection).

In the Timano-Pechora region, two deposits (at Yarega and Usinsk) are being worked on an experimental industrial basis using thermal mining and steam-injection well methods.

The future prospects for recovering HO and NB differ sharply depending on the data

According to the data of the Institute of Geology and Exploitation of Combustibles (IGiRGI), the predicted geological reserves of NB in the former USSR are about 17 billion tons, of which 88 per cent or 15 billion tons lies in

the Volga-Urals (6.0 billion tons or 36 per cent) and Eastern Siberian (9.0 billion tons or 52 per cent) regions.

Of these reserves only 7 per cent are "active", including 1 billion tons in Russia, divided equally between the Volga-Urals (Tatariya) and Caspian regions.

There are no active reserves in the Timano-Pechora and Eastern Siberian regions.

On the basis of these resources the prospects for NB recovery are as follows:

Year	1995	2000	2005	2020
HO and NB output, mill. t/year	0.3	1.0	1.5	4.6
of which:				
- NB output, mill. t/year	0.1	-	0.8	2.7

Despite the low output, HO and NB are very valuable raw materials for the petrochemical and chemical industries since they can be used to obtain sulfones, sulfoxides, resins, asphaltenes, high-index low-cold-test oils, low-cold-test fuel, bitumens, lacquers, mastic, etc.

Apart from hydrocarbon products, these raw materials are a source of metals (vanadium, nickel, mercury, etc.) and other valuable components which are present in HO and NB in higher concentrations than in ores. Thus, for example, the potential world reserves of vanadium in NB and HO amount to 125 million tons, of which 25 million tons is recoverable (together with hydrocarbons). So far, about 1 million tons of vanadium has already been extracted with the hydrocarbons and lost.

2.2. Non-Traditional Sources of Gaseous Raw Materials

In this category it is usual to include: coal-bed gases, natural accumulations of gas hydrates on land and offshore, and water-soluble and dispersed hydrocarbon gases (HCG) in stratal water, including thermal spring water.

Each of these sources is differently assessed by the experts.

2.2.1. Coal-bed gases

Coal-bed gases are present in the sorbed or free state. Methane absorbed by coal or dense rock is usually uniformly distributed in the bed and released when the bed is exposed by mining (captive gas).

In the free state (in deposits) methane accumulates in permeable traps associated with anticlines, domes, reduced-density zones on monoclines and other

structures and lithological complexes. The methane in the deposit is under high pressure and forms a mining hazard.

In order to prevent blow-outs and the uncontrolled penetration of methane into the coal-face zone and when it is not possible to guarantee by ventilation a 1 per cent concentration of methane in the mine atmosphere, a system of preventive measures is used. These include degassing the coal by drilling shafts both from the pit face and from the surface. Given a distribution system and a consumer, the gas recovered can be put to use.

The utilization of coal-bed methane is a promising modern technology. Coal mine degasification is used in 18 different countries. About 4.6 billion cubic metres of recovered methane is taken off through the degasification network every year.

Germany. The annual coal output for the country as a whole is 75.8 million tons and the total methane yield 1.95 billion m^3 (25.7 m^3/ton). Of this, 1.41 billion m^3 (72 per cent) of methane is extracted in the ventilation stream, 0.535 billion m^3 (27 per cent) is recovered, and 0.371 billion m^3 (19 per cent of the total yield or 69.3 per cent of the gas recovered) is used to produce energy. There are mines in which almost all the gas is used.

China. The total methane output is 430 million m^3 per year, and the utilization ratio 70 per cent.

In the United States, the industrial extraction of coal-bed gas began in 1997 with the use of active technologies (hydraulic fracture, injection, etc.). In 1990, 5.7 billion m^3 of gas (200 billion cubic feet) was obtained from 2500 wells. Altogether, about 11.3 billion m^3 has been extracted. The gas flow from the wells has varied from 2.8 m^3/day to 600 m^3 and the water flow from 0 to 160 m^3/day.

Coal-bed methane reserves are estimated at 8.5 to 14 trillion cubic metres.

According to other estimates, coal-bed methane resources in the United States amount to 11.2 trillion cubic metres, of which 2.5 trillion or 22.3 per cent is recoverable.

There are possibilities of recovering coal-bed gas in Australia, Canada, France, Great Britain, Hungary, India, Poland and South Africa.

In Russia, mine degasification is being carried out in the Kuznetsk, Pechora and Donetsk (Rostov) coal basins. The coal in these basins is estimated to contain potential gas resources amounting to 15.2 trillion cubic metres or about 7 per cent of natural gas resources, of which the Kuznetsk basin holds 13.1 trillion m^3 (including 0.1 trillion m^3 in gas accumulations), the Pechora basin 2.0 (0.02) trillion m^3, and the Donetsk basin 0.05 trillion m^3.

The methane resources in the known coal reserves amount to 904 billion m^3 (6 per cent), including 240 billion m^3 in fields with operating mines.

Coal degasification is being carried out in 58 mines. Every year 420 million m^3 of gas is being recovered, but only 60 million m^3 (14 per cent) is being used.

In the Kuzbass there is also a realistic prospect of working small (containing up to 1 to 1.5 billion m^3) deposits of free gas. These resources amount to 100 billion m^3 per year.

In the Pechora coal basin there are small deposits of free gas containing about 20 billion m^3.

In the Eastern Donbass the free-gas potential is estimated at 50 billion m^3.

The theoretical methane output of Russia's coalfields is estimated at 7-10 billion m^3 per year (or 10-12 per cent of natural gas output), of which 57 billion m^3 per year would come from the Kuzbass and 2-3 billion m^3 per year from the Pechora basin. This would require about 2000 wells 500 to 800 metres deep.

The drilling volumes have been estimated with allowance for a success factor of 5-6 thousand km.

In the Asian part of Russia there are known to be more than 10 large coal basins whose deep seams are estimated to contain 5 trillion m^3 of potential gas resources (Tungus, Taimyr, South Yakutsk, etc.). Most of these basins lie in the polar zones far from industrial centres and their gas resources are unlikely to be exploited in the foreseeable future.

2.2.2. Dissolved hydrocarbon gases (DHCG)

The planet's subterranean stratal waters (subterranean hydrosphere) contain hydrocarbon gases in the dissolved and dispersed state. The global volume of dissolved hydrocarbon gases (HCG) has been estimated at 10^{16}-10^{17} cubic metres, which is an order greater than the volume of HCG in deposits.

The dissolved HCG resources in the underground waters of the former USSR have been estimated at 400 trillion m^3 (1980) with a gas saturation or gas-water factor (GWF) of 0.5-18 m^3/m or more. Many specialists consider this estimate too low, although it is 12 times greater than the natural gas potential.

Some experts (VNIIGaz) estimate Russia's potential DHCG resources at 50-60 thousand trillion cubic metres.

In principle, the DHCG resources could be exploited commercially along the following main lines:

(a) Incidental recovery during the exploitation of oil and gas fields. For example, according to certain expert estimates, in the Cenomanian deposits of the Vyngapur and Medvezh'i fields when the gas deposits have been completely worked out about 2 per cent of the initial gas reserves will flow into them as a result of the release of gas from formation water;

(b) Incidental recovery in connection with the extraction of balneological and thermal mineral waters. At present, in Russia, every year about 100,000 m^3 is released into the atmosphere in this way. In some countries (Japan and Italy among others) these resources are partially utilized at depths of not more than 2 km;

(c) Direct recovery of gas-saturated water for the purpose of extracting DHCG and other valuable components (iodine, bromine, calcium, etc.). It is generally proposed to make combined use of the energy and chemical resources of highly saturated thermal waters present at great (> 5 km) depths in formations with abnormally high rock pressures.

Deposits of this kind are being exploited in the United States.

In Russia, water-bearing strata in which the geological conditions ensure a high rate of spontaneous outflow of clean stratal water are of practical interest for gas recovery purposes. These conditions are satisfied only in certain small areas north of the Caucasus (Krasnodar and Stavropol territories, Dagestan). Here, the potential geological DHCG resources are estimated at 100-120 billion cubic metres.

Calculations show that for the foreseeable future the economic recovery of DHCG will be possible only in extremely limited areas. An example is offered by the Upper Cretaceous complex of the Taman' peninsula in the Krasnodar territory, where from the abnormally high pressure zones (abnormality factor 1.6-1.9) water at a temperature of 130°C with gas factors of up to 60 m^3/m^3 flows at rates of up to 200 m^3 per day. The gas consists of methane (64-68 per cent) and carbon dioxide (9-31 per cent). The existing stock of drilled but suspended wells could yield 2.5-3 thousand cubic metres per day and 40 thousand cubic metres per day of gas, 30-40 per cent of which would be utilizable.

Thus, in Russia, both now and in the foreseeable future, DHCG could be recovered in limited quantities for local needs without, however, making a significant contribution to the fuel-energy balance.

2.2.3. Gas hydrate hydrocarbon gases (GHHCG)

The gas hydrate deposits and accumulations of free gas in the marine sediment hydrate-forming zones are global hydrocarbon formations of the earth's non-lithified sedimentary mantle, since they are found virtually throughout the world's oceans, i.e. over most of the surface of the globe, and range in age from tens to the low hundreds of millions of years. The resources of (10^5-10^6) trillion cubic metres exceed the earth's resources of all other mineral fuels combined.

The natural gas accumulations in the dry-land hydrate-forming zones are regional hydrocarbon formations. They extend through the upper horizons of the polar sedimentary basins and take in about 27 per cent of the land. The gas resources of the dry-land hydrate-forming zones (HFZ) amount to (100-1000) trillion cubic metres, which is comparable with the resources contained in ordinary gas fields.

At present, the scientific problems associated with the discovery and exploitation of hydrocarbon resources in HFZ are in the data-gathering stage.

Direct evidence of the presence of gas hydrates has been found at more than 40 points in the world's oceans. On dry land they have been observed only in Northern Alaska (Prudhoe Bay) and Western Siberia (Messoyakha). The latter hydrates are a subject of debate since some scientists (All-Russian Scientific Research Institute of Ocean Geology, St Petersburg, RF) consider that they are of technogenic origin (well bottom-hole zone).

In the RF, HFZ are to be found in the surrounding seas (Bering, Okhotsk, Japan) and in the polar zones (Pechora platform, Western and Eastern Siberia, the North-East of the RF - Anadyr' basin). According to some data (N. V. Cherskii et al.), the potential geological resources of the RF's marine HFZ are 2900 trillion m^3 within an area of 2900 million km^2 (a gas resource density of 1 billion m^3 per square kilometre).

The gas resources of the dry-land HFZ are estimated at 21.4 trillion m^3 in partially located structures and 87 trillion m^3 in unlocated structures (altogether 108.4 trillion m^3).

The area of the HFZ is estimated at 4.9 million m^2, i.e. an average density of 22.1 million m^3/km^2.

On the other hand, according to estimates made by the All-Russian Scientific Research Geological Prospecting Institute (VNIGRI, V.P. Yakutseni, 1993), the actual gas reserves in HFZ amount to 1-1.2 trillion m^3 (200-240 billion m^3 recoverable), concentrated in an area of 1.6-1.7 million m^2, i.e. an average density of 0.6-0.7 million m^3 per square kilometre.

Thus, in the present stage of investigation of the problem of gas hydrate deposits the gas resource data cited cannot be used as a basis for even long-term forecasts. It will be necessary to carry out further research on gas hydrate prospecting and commercial evaluation and on economically viable technologies for exploiting these resources. The commercial recovery of gas from gas hydrates, even on a limited scale, is a problem for the distant future.

Thus, of the non-traditional sources of gaseous raw materials considered above it is possible to predict the limited use for individual local consumers of coal-bed gas (7-10 billion m^3 per year) in the Kuzbass and Pechora basins and the multipurpose use of gas-saturated hydrothermal waters at experimental test sites north of the Caucasus. Hydromineral energy technologies (L. N. Kapchenko, VNIGRI, 1992) should be devised for exploiting underground stratal water.

2.2.4. Complex formations with dense low-permeability reservoirs and low oil and gas output, depleted fields, oil and gas recovery from extreme depths (more than 6 km)

The following are additional sources for expanding the raw material base of the oil and gas industry:

- residual reserves of liquid (oil, hydrocarbon condensate) and gaseous hydrocarbons in depleted fields (flooded zones, retrograde condensate, etc.);

- HC reserves contained in dense low-permeability reservoirs (less than 1 millidarcy) in complex oil and gas fields with a low

hydrocarbon output; a new class of complex reservoirs has now been identified (Sakhalin shelf);

- hydrocarbon accumulations at great depths (more than 6 km).

Within the oil and gas provinces, these resources (except for the resources at extreme depths) can be only conventionally referred to the non-traditional sources of hydrocarbons. They have been taken into account in estimating potential gas resources (off-balance sheet, nonrecoverable, etc.) and could be exploited as geotechnologies and recovery techniques are perfected.

2.2.5. Natural gas

The gas resources in the dense rocks of the RF amount to 25-30 per cent of potential gas resources, i.e. altogether on dry land 40-50 trillion m^3.

In the United States, the proven reserves of gas in dense rocks are estimated at (2.5-12) trillion m^3, while gas output is 28-34 billion m^3 per year. To a considerable extent, these resources are associated with developed fields and occupy in them a space which is at present excluded in calculating known reserves (lower limit of porosity).

There has been little study and no quantitative estimation of the presence of gas at large depths (more than 6 km) or in the sedimentary rocks of the folded basement of the recent (young) plates.

According to the estimates of some experts (Yu. P. Korotaev, Yu. I. Bokserman, and others) the corresponding gas resources (worldwide) amount to about 200 trillion m^3. On the other hand, it should be noted that the present level of investigation of these resources (the thermodynamic situation in the interior of the various geostructural elements of the sedimentary mantle at extreme depths and the effect on the processes of generation and formation of hydrocarbon accumulations and their composition) is not such as to enable them to be used for the long-term prediction of hydrocarbon output.

Special consideration should be given to the problem of recovering retrograde condensate from gas condensate fields developed without pressure maintenance (for example, in the RF the Iuktyl field, which has retrograde condensate reserves of more than 100 million tons). In the RF, various methods of recovering retrograde condensate (tertiary methods) have been developed and are being commercially tested.

2.2.6. Oil from depleted fields

A range of methods and means of recovering the residual oil from flooded zones (tertiary methods) is now being used.

On the industrial scale, systems of horizontal wells are being used for these purposes in combination with direct action on the productive formations (viscoelastic sediment-forming injectable-agent compositions, thermal and thermochemical action).

In the RF (Tatariya, Bashkiriya and Western Siberia) since 1983 biogeotechnology for recovering oil from flooded zones has been undergoing

experimental commercial testing. In Tatariya, during the period 1987-1991, an additional 21,000 tons of oil was extracted, in Bashkiriya 190,000 tons and in Western Siberia (combination of physico-chemical and microbiological methods) 600,000 tons.

Thus, non-traditional forms (sources) of hydrocarbon raw materials are serving as a basis for the development of commercially viable geotechnologies for the purpose of broadening the raw materials base of the oil and gas industry and the range of products obtainable from those raw materials.

In the foreseeable future they will not have much effect on the structure of the world’s and, in particular, the Russian Federation’s fuel-energy balance. At the same time, the independent use of these resources for local energy supply and for obtaining valuable components may prove profitable from both the economic and the social-environmental standpoints. This applies especially to coal-bed gas and hydrothermal energy.

We conclude this section by noting that the present period of use of traditional primary energy resources (TPER) is characterized by an intensive search for and development of technologies, equipment, technical agents and materials that will radically reduce the negative effect on the environment of extracting, converting, processing, treating, transporting, storing and utilizing TPER, increase power plant safety and reduce the level of nonproductive losses of energy resources in the fuel and energy complex.

To this end, the Russian Federation’s "Clean Energy" programme provides for the implementation of a number of large-scale projects. These include:

(a) projects directly related with reducing the negative effects of the extraction and use of fossil fuels on land, air and water resources: clean coal-mining enterprises for processing fossil fuel (clean gas processing plants, plants for producing clean motor fuel, thermobriquette and peat briquette products, etc.); the production, transportation and use of coal in suspension; the design of clean solid-fuel thermal power stations; underground coal gasification;

(b) projects designed to solve problems by creating the preconditions for replacing fossil fuels in the national energy balance with alternatives having a much less negative effect on the environment, including: developing clean power generation based on nuclear fuel (safe nuclear power stations, underground nuclear power stations, naturally safe non-traditional nuclear power stations, environmentally safe disposal of radioactive waste) and hydrogen power.

These approaches also embrace non-traditional renewable sources of energy (NRSE). In the non-traditional energy context, direct savings in energy resources are also being achieved by utilizing low-potential environmental heat by means of heat pumps and other devices.

In general, the implementation of these projects will not make much of an impact until after the year 2000. Nevertheless, new energy projects will begin to be introduced even in the next few years.

Section 3. Hydrogen power and technology

Hydrogen is a very clean energy source with a broad field of application extending from power and heat supply to use as a motor fuel and as an industrial raw material.

Hydrogen is used indirectly in oil refinery processes (hydrocracking, hydrotreating) and is beginning to be used for obtaining synthetic liquid fuels. In the RF, the total consumption of hydrogen (indirect use) is about 8 million tons c.f. and needs to be increased by 2 to 3 times.

Hydrogen is being used directly as an energy source or fuel in experimental commercial low-power electrochemical generators (up to 100 kW).

According to the estimates of the authors of the "Clean Energy" programme in the near term hydrogen will be used more and more widely in energy conversion, storage and transport processes.

In the last 10 to 25 years, active scientific research and experimental design work has been carried out in more than 30 countries, including the United States, Germany, Japan, the European Union, Russia and China. The United States, Germany and Japan have each spent 150 to 200 million dollars a year on implementing national hydrogen power programmes.

Abroad, a number of full-scale demonstration and experimental commercial installations employing new technologies have been built to obtain, purify, store and transport hydrogen for use in different branches of industry: power engineering, metallurgy, oil refining, the chemical industry, road transport, aviation, etc.

Experimental installations designed to produce hydrogen using solar energy (electrolytic hydrogen gas) or "solar hydrogen" are being built in Germany, Saudi Arabia and elsewhere. The biggest such installation is that in Saudi Arabia (Ar Riyad, 1991) which with a photoelectric plant capacity of 550 kW is producing 279 m^3/day of hydrogen for use in automobiles.

The Russian Federation’s "Clean Energy" programme provides for the development and introduction of new, highly efficient methods and processes for obtaining hydrogen from water and non-traditional raw materials, as well as of processes for using hydrogen in power engineering.

In the field of hydrogen production technologies it is proposed:

- to develop a non-waste clean plasmochemical membrane technology for processing natural gas with a high hydrogen sulphide content (Astrakhan and Orenburg fields): the plasmochemical membrane process module at the Astrakhan field will work on raw material containing up to 50 per cent hydrogen sulphide, carbon dioxide, etc.; the technology yields 99.9999 per cent pure hydrogen, will process 20,000 n. m^3/hour and extracts sulphur from the gas (up to 99.99 per cent);

- to build an experimental industrial demonstration plasmochemical plant for obtaining 99.99 per cent pure hydrogen from

methane (natural gas). The output will be 5,000 m^3 of hydrogen per hour with a power requirement of 5 MW, an energy input of 1 kWh per cubic metre of hydrogen and no toxic emission into the atmosphere;

- to develop a non-waste technology for the integrated processing of technological gases containing hydrogen, with the separation of concentrated (up to 98 per cent) and highly pure hydrogen, based on the use of nonporous polymer and metal membranes;

- to develop a high-performance aqueous-alkaline electrolysis technology with modernized diaphragms and a hydrogen output of up to 500 n. m^3/hour, a power input of not more than 4.2 n. kWh per cubic metre of hydrogen and a hydrogen purity of not less than 99.8 per cent;

- to develop and build new types of water electrolyzers with a solid polymer electrolyte for obtaining hydrogen from water: hydrogen output 5, 25, 50 and 100 m^3/hour, hydrogen purity not less than 99.9 per cent, energy consumption not more than 4 kWh per cubic metre of hydrogen. Intended for energy storage and distribution systems, for power station (including nuclear power station) basic-duty operation, and also for supplying hydrogen for use in various branches of industry (installation points - Krasnoyarsk gas chemical complex, nuclear power stations, electronic industry enterprises);

- development of an autonomous clean hydrogen power plant with a capacity of up to 30 kW (thermal capacity up to 200 kW) based on renewable sources of energy (wind generators, solar thermal converters) for supplying the complete energy requirements of independent consumers. The plant includes hydrogen storage batteries based on intermetallic-compound hydrides with a hydrogen capacity of up to 10 kg; heat storage systems, aqueous, metal-hydride and based on phase-transition heat-storing materials, with a specific energy capacity of up to 400 kJ/kg; an electrolyzer with a hydrogen output of 6-10 n. m^3/hour; secondary energy converters in the form of a hydrogen internal combustion engine and/or a hydrogen gas-turbine plant; for providing comfortable communal living conditions in remote regions of the RF;

- to develop electrochemical power generators (ECG) with a capacity of up to 100 kW (electrical) and 70 per cent efficiency, based on a thin-film solid electrolyte (100-300 μ) and operating on 99.9 per cent pure hydrogen and 99.5 per cent pure oxygen (hydrogen-oxygen ECG) or on hydrogen and air (hydrogen-air ECG); installation points - nuclear power stations, means of transport, emergency power systems, etc.;

- the conceptual design of steam-turbine and steam-gas cycle clean high-temperature hydrogen power plants, and the development and construction of experimental versions of steam generators for these power plants, such as a 10 MW high-temperature hydrogen-oxygen or hydrogen-air steam generator.

The fulfilment of these various tasks will make it possible to proceed with the widespread introduction of hydrogen technologies in the Russian Federation.
