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THE PROSPECTS FOR THE DEVELOPMENT OF NEW AND RENEWABLE SOURCES OF ENERGY IN THE U.S.S.R.

(THE SOVIET UNION'S NATIONAL REPORT FOR THE UNITED NATIONS CONFERENCE ON NEW AND RENEWABLE SOURCES OF ENERGY)

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I. INTRODUCTION

With the existing structure of the energy balance and the present-day level of technology, the provision of the world economy with energy is becoming an increasingly more difficult and costly problem. These difficulties can only be overcome and the technical, economic and political outlines of the power industry of the future delineated by pooling the efforts of all states along the path of broad and equitable international co-operation.

The United Nations Conference on New and Renewable Sources of Energy is to become an important positive step in this direction. The Soviet Union sees it as a broad and representative forum at which all the interested states can exchange experiences and formulate scientifically-grounded guidelines in national and international energy policies.

The technical and economic aspect of the energy problem involves a number of factors among which the foremost is the inadequacy of current technology and the resource base to satisfy the new needs of world economic development. The uneven development of the scientific and technological revolution has resulted in a situation where energy generation throughout the world has become a "lagging sector" of technological progress. Despite the outstanding successes scored in the harnessing of atomic energy, many practical questions pertaining to nuclear power development have still not yet been solved. The situation is further aggravated by a gradual deterioration in the natural and geographical conditions of fuel extraction caused by the depletion of deposits that are easy of access and relatively rich. Although it cannot be excluded that new, abundant oil and gas fields will be discovered in the future, today it is largely deep-lying oil and gas horizons that are put to commercial use and the search for new fields is gradually shifting into offshore areas and remote, partly uninhabited regions. This aspect of the energy problem affects all countries to varying degrees.

Its social aspect, however, manifests itself in different ways in countries with different social systems. Socialist countries see the solution of the energy problem in the management of the integrated problems involved in the development of fuel and energy supplies according to plan, in the pursuit of an energy-saving policy in every echelon of the national economy.

In the non-socialist part of the world the acuteness of the energy problem is caused, along with the technical and economic factors, by the irrationality of the energy balance structure in the Western countries, by its inconsistency with the structure of the national energy resources and unregulated relations between the countries extracting and consuming oil which engenders the instability of the entire system of energy supply in the world capitalist economy. The irrational character of the energy balance in the advanced capitalist states and some developing countries has evolved in large part spontaneously under the influence of the shifting correlation of forces among different groups of energy monopolies. In their pursuit of profits they have artificially fostered an atmosphere encouraging wasteful energy consumption, especially in the home. This has resulted in an irrational system of energy consumption in the capitalist world, with imported oil playing a hypertrophic role.

At the base of the system lay the monopoly control that the Western oil and gas companies exercised over the resources of the Asian, African and Latin American countries which involved an artificial depression of oil and gas prices in comparison with their real value. The establishment by the oil-producing countries of effective sovereignty over their natural resources in a situation marked by a relative shortage of energy resources on the world market and the discrepancy between the price and value of oil led to a sharp increase in the prices of the primary energy resources. In late 1973 the energy problems became greatly aggravated in the capitalist world. This exacerbation assumed the form of a profound energy crisis having grave consequences for economic development.

Even after the oilfields were nationalised the channels of oil shipment, processing and marketing were still under the control of the same international oil monopolies that shift the burden of the rising prices on petroleum products onto the consumers on a scale greatly exceeding the rise in the selling prices fixed by producers on crude oil. The sharp increase in the price of oil imports in industrially advanced capitalist countries and the even higher oil and gas prices on their home markets have exerted further pressures on the entire world capitalist economy and served to intensify inflation, disrupt money circulation, increase payments and trade deficits and substantially retard economic growth rates overall. The shifting of the burden of the economic difficulties experienced by industrially advanced capitalist states onto the shoulders of developing countries, coupled with soaring world prices on the primary energy resources have done much to worsen the status of most newly-free states. Their total indebtedness to state and private credit institutions in the West exceeds 300,000 million dollars. This has brought on a situation in which some of them have been forced to either abandon or freeze the economic and social development plans adopted earlier.

The world public is also concerned over the fact that under the increasingly complicated conditions surrounding the supply of energy to the world capitalist system some Western countries have proclaimed their "right" to enjoy precedence in the acquisition of the oil resources of other countries. By their actions in the Persian Gulf area they show their readiness to use force in order to secure a continuous supply of oil, to arm the countries following in the wake of their foreign policy, to kindle old and new conflicts in the Middle East, thereby prejudicing the interests of states throughout the world.

Obviously, the solution to oil supply problems cannot be found from positions of strength. Technical progress in the fields of the production, conversion and consumption of energy, including the commercial utilisation of new and renewable types of energy and the consistently changing energy balance structure that has evolved, can be basic to this solution.

Technological progress has more than once extricated mankind from energy difficulties and it is quite capable of creating a new and fundamentally more advanced technical base for energy generation in the future. In this endeavour an immense positive role could be played by the termination of the arms race and demilitarization of the nuclear power industries which hold a colossal financial, technological and resource potential necessary for such restructuring. In this connection, it would be pertinent to recall that to date the Soviet Union has introduced about a hundred proposals in the UN, aimed at averting threat of war and curbing the arms race. More specifically, at the latest, 35th, session of the UN the U.S.S.R. has again put forward a proposal on the cessation of the manufacture of nuclear weapons and the elimination of its stockpiles, which is directly related to the prospects of wider development of new energy sources.

Recognizing the complexity of the quest for the solution of the global energy problem in the contemporary world, including the political circumstances compounding it, the Soviet Union expresses its firm intention and readiness to take a constructive part in the work of reaching such a solution. In particular, the U.S.S.R. will do its utmost to ensure the success of the Conference on New and Renewable Sources of Energy and enable it to produce concrete results in the endeavour to promote international co-operation with the object of resolving energy problems.

2. THE SPECIFIC FEATURES OF ENERGY PRODUCTION IN THE U.S.S.R., THE PROSPECTS FOR ITS DEVELOPMENT AND THE ROLE OF NEW AND RENEWABLE SOURCES OF ENERGY IN THE FUTURE

The U.S.S.R. has great reserves of natural nonrenewable energy resources accounting for about 40 per cent of the world fuel reserves and a significant hydropower potential of which a mere 16 per cent has been put to work to date. This provides the conditions for basing the development of the country's fuel and energy complex on the domestic energy resources in the foreseeable future.

The structure of energy consumption that has evolved in the U.S.S.R. determines the short-term development of the fuel and energy complex. Under the five-year economic development plan for 1981-85 provision has been made to bring electricity output up to 1,550,000-1,600,000 million kWh including 220,000-225,000 million kWh at the atomic power-stations and 230,000-235,000 million kWh at the hydro-electric power-stations. The increased electricity generation in the European part of the U.S.S.R. will be secured in the main due to the construction of atomic power plants. The building of large hydro-electric power-stations will be continued on the rivers in Siberia, the Far East and Central Asia with due account being taken of the integrated utilization of water resources. The construction of thermal power-stations will be carried on at accelerated rates on the basis of the Ekibastuz and Kansk-Achinsk coal basins and also natural and associated gases from fields in Western Siberia. Work is being pursued to further develop the country's integrated power grid and district heating.

The output of oil and gas condensate is planned to be increased to 630-645 million tons. The oil industry is to be developed at increased rates in the regions of Western Siberia, the Kazakh SSR and the north of the European part of the country.

The gas industry will be developed at accelerated rates: in 1985 natural gas output is to amount to 600,000-640,000 million cubic meters. The construction of high-capacity gas pipelines, automated to a large extent, and with high operational reliability, is to be continued. The capacities of underground storage facilities are to be increased signigicantly. The capacities for a comprehensive processing of oil gas and natural gas so as to recover from them ethane, sulphur and other associated components are to be stepped up, too.

Oil output will be brought up to 700-800 million tons due to the accelerated development of the Kuznetsk, Kansk-Achinsk and Ekibastuz coal basins. Open-cast coal mining will go ahead at priority rates.

Right up to the end of the twentieth century and in the early twenty-first century the U.S.S.R. fuel and energy complex will be characterized by the following trends and uniformities:

- enhanced effectiveness in the utilization of energy resources in the national economic sectors due to the introduction of new energy-saving technologies and the increased efficiency of power-generating and power consuming equipment and facilities, the large-scale utilization of secondary energy resources, the reduction of the energy intensity of production, the evolution of a life-style towards the more economical consumption of energy;

- an accelerated growth of the share of electricity in the country's energy balance due to the relatively stable indicators of its value with the increase in world oil and gas prices which engenders the prerequisites for the extensive introduction of electric energy into the national economy, not only as a crucially important method for improving labour productivity but also as a way of reducing the share of oil consumption in the energy balance;

- substantial shifts in the country's energy balance structure towards a greater proportion of effective energy carriers in energy consumption (electric energy and natural gas, first and foremost). This being so, the growth of the country's energy capability will mainly proceed due to the use of gas and then nuclear fuel and low-cost coals;

- a substantial increase in oil extraction costs which, coupled with growing oil prices on the world market, will result in the expediency of obtaining synthetic liquid fuel (SLF) from low-cost coals (primarily those of the Kansk-Achinsk coal basin);

- the need to displace liquid fuel, and later gas, from the sphere of the heat supply and first of all from district heating by using nuclear energy to assure the annual base-load curve for heat supply, and by using quality solid fuel for meeting seasonal variations in heat consumption;

- an increase in the share of district heating due to the use of nuclear energy in the form of pumped-storage electric heating and thermal pumps, and also the replacement of liquid fuel and gas by solar and geothermal energy for dispersed heat users;

- high growth rates of atomic power limited, in the short term, by the possibilities of the machine-building base, and expansion, in the long term, of the fields of effective utilization of atomic energy;

- provision of the prerequisites for the extensive commercial utilization of renewable sources of energy: hydropower, solar energy, wind energy, geothermal waters, biomass and other nontraditional sources of energy and energy media;

- the further concentration of production of energy resources and electricity and the centralization of their distribution;

- continuing non-uniformity in the location of energy resources throughout the country which makes it necessary to resolve questions of power transmission over long distances, especially for supplying the needs of the European part of the U.S.S.R.;

- the increased impacts exerted by energy production upon the state of the environment which necessitates the implementation of a large complex of diverse measures in order to prevent and neutralize the undesirable ecological consequences of energy development.

The bulk of the increase in energy consumption will be assured by a growth in the production of natural gas and coal and the development of nuclear energy. In the 1990's a certain contribution to the energy balance can be expected from new and renewable energy sources (solar, geothermal, wind, etc.), although their aggregate share together with hydropower will not perhaps exceed 5-6 per cent of the total energy production in the U.S.S.R. towards the close of the century. On the whole, the proportion of new and renewable sources of energy, including nuclear energy will grow from roughly 4 per cent at present to 15 per cent towards the end of the century. New and renewable energy sources are expected to make a much greater contribution after the year 2000.

According to some estimates, towards the end of the first quarter of the twenty-first century this category of energy resources (including nuclear energy) will already account for 35-40 per cent of the aggregate production of primary energy resources in the U.S.S.R.

Notwithstanding the relatively small contribution of new and renewable sources of energy to the solution of the problem of supplying the U.S.S.R. national economy with energy up to the end of this century, intensive scientific investigations and experiments on the development of practically inexhaustible sources of energy are being conducted in the country. Much prominence in these investigations is accorded to the development of technologies for their effective utilization. Hence the interest that the U.S.S.R. is showing in exchanges of experience and international co-operation in the field of the development and commercialization of new and renewable sources of energy is quite understandable.

In the final count the large-scale utilization of these sources of energy will be determined by their economic effectiveness compared with traditional resources of fossil fuel and nuclear energy. However, the steadily rising prices of fossil fuels (especially of oil and natural gas, the most effective of them all) and also the uncertainties surrounding the commercial use of thermonuclear energy, and the fact that a number of questions pertaining to nuclear power development are as yet unresolved make it urgent and vital to develop more effective methods of utilizing new and renewable sources of energy.

3. THE CURRENT STATUS OF THE DEVELOPMENT OF TECHNOLOGIES FOR UTILIZING NEW AND RENEWABLE SOURCES OF ENERGY

3.1. The Possibilities of Expanding the Utilization of Traditional Energy Resources

3.1.1. Tertiary Methods of Oil Production and High-Viscosity Oil

Increasing oil recovery is an all-important way of augmenting the resource base of the U.S.S.R. petroleum industry; in the future it may become a significant source of maintaining production in regions where there has been a tendency for it to decline. In the development of new oilfields the use of these methods will, from the very first, make it possible to appreciably increase the total volume of production and its maximum level.

High world oil prices create economic conditions propitious to developing that part of the resources of "ordinary" oil fields which are not extracted by conventional oil production methods.

In the U.S.S.R. preparations are under way to use several methods commercially for improving oil recovery. In 1980 pilot-plant work for mastering tertiary methods of oil recovery was carried on at more than 45 oil fields.*) The first positive results have been achieved in the application of these new methods.

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*) N. A. Maltsev. New Frontiers of the U.S.S.R. Oil Industry. (In Russian). "Neftyanoye Khozyaistvo" (Oil Economy), 1979, No. 9, p. 7.

Efforts are under way to develop deposits of heavy high-viscosity crude oil whose proven reserves in the U.S.S.R. are fairly large. The bulk of these reserves occur at relatively great depths and are situated in regions with inclement climatic conditions.

The thermoshaft method for extracting heavy crude oil involving a combination of shaft sinking and exposure of the oil pool to the action of steam and heat under conditions of underground workings was developed in the U.S.S.R. and introduced on a commervial scale for the first time in world practice in the Yareg oilfield (Komi ASSR), It is important to stress that the high oil recovery in the Yareg oilfield is achieved under the conditions of very high oil viscosity - 11,000-15,000 centipoise.[x)]

3.1.2. Oil Shale

At present, favourable conditions are taking shape for the commercial production and processing of nontraditional sources of hydrocarbons, including combustible shales. This is due first of all to the signigicant rises in world oil prices. In this connection, the conversion of the richest (in kerogen content) resources of oil shale into artificial liquid fuel becomes economically justified and expedient.

Oil Shale Reserves in the U.S.S.R. Since the shale-bearing capacity of the territory of the U.S.S.R. has been insufficiently studied, it is only possible to give a tentative evaluation

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x) M. A. Berstein, et al. Employment of Different Methods for Increasing the Recovery of Oil Pools. Moscow, 1977, p. 14, p. 22.

of the oil shale reserves as being of the order of 2,000,000 million tons, from which it is possible to produce about 200,000 million tons of shale resin. The largest oil shale deposits are the Baltic shale basin, the Volga shale basin, the Timano-Pechora basin and the reserves of the Domanikovy shales located in the area of the Southern Timan and along the western slope of the Urals. The yield of resin from shales from these deposits is sufficiently high and amounts to 10-20 per cent (in weight).

Thanks to the peculiarities of their organic matter (the H:C ratio close to high-viscosity oils) and the significant content of the mineral part, oil shales represent a valuable organo-mineral feedstock suitable not only for electricity production, but also for obtaining synthetic liquid fuel, shale gas and a number of valuable chemical products and different building materials.

In this connection, the more important avenues of commercial utilization of oil shales being pursued in the U.S.S.R. are as follows: energy-generating, technological and energy-technological.

Energy-generating shale utilization involves the combustion of oil shale in the furnaces of power-plants. Currently, over 70 per cent of all the shale mined in the U.S.S.R. is used to generate electricity. The world's most powerful thermal power-plants burning oil shale (the Baltic and the Estonian State Regional Thermal Power Plants with a combined design capacity of 3,224 MW) have been built. The thermal power-stations burning the shales of the Baltic basic operate in a stable and efficient way. These plants consume a total of over 20 million tons of oil shale per annum. The experience gained by the U.S.S.R. in the field of using oil shales for energy generation is unique and can be of much interest to countries with reserves of low-cost shales poor in kerogen content. The U.S.S.R. is already rendering assistance to a number of countries in this field.

About 25 per cent of all the oil shale mined in the U.S.S.R. is subjected to technological processing in special facilities (shaft generators) where the thermal decomposition of the shale takes place under relatively "mild" conditions (at temperatures ranging from 480 to 700 degrees C) which results in the liberation of liquid and gaseous products (resin, low-calorific gas and pyrogeneous water).

Resin produced in the thermal decomposition of shale is a valuable feedstock for obtaining different synthetic liquid fuels: motor petrol, motor kerosene, diesel fuel, furnace fuel oil.

At present, in practice shaft generators alone are used in the U.S.S.R. to produce shale resin. The capacity of shaft generators is 240-250 tons of oil shale per day, the resin yield being in the region of 170 kg per ton of shale. The construction of shaft generators with a capacity of 1,000 ton/day is under way.

However, it should be noted that gas-generators are only effective in the processing of lumpy shale. Because of the tendency for the mechanized production of shale to continuously grow, the problem arises of refining shale down to fines (lump size less than 25 mm) which develops when this mechanized method of mining is used (about 50 per cent). In this connection, of considerable interest is the energy-technological processing of shales which involves heat treatment of shale having lump size of up to 25 mm with a solid ash heat carrier at a temperature of 480 degrees Centigrade resulting in the production of high-calorific and low-sulphur power-generating fuels and feedstocks for the chemical and building industries, and agriculture.

The method has been tested and optimized in two pilot installations with a shale output of 200 tons per day and 500 tons per day. The latter installation has processed two million tons of shale and produced 270,000 tons of shale oil and 100 million cubic meters at NTP of high-calorific gas.

In 1980 the first of the two commercial installations for energy-technological processing of shale with a shale output of one million tons per year (3,330 tons per day) was put into operation at the Estonian Regional Power-Plant. It is to produce a total of 130,000 tons of shale oil, 54,000 tons of high-calorific gas including 7,500 tons of gas-derived gasoline annually from shale mined in the Baltic basin. The commissioning of another such installation is expected in 1981-82. The combined efficiency of the process (calculated with respect to the low heat value) amounts to 86.3 per cent with due account being taken of production losses; however, the yield of resin, with the energy-technological processing of Estonian shale, under the conditions of low-temperature carbonization is not high and makes up about 55 per cent of its organic part.

In recent years the development of other effective processes for the technological conversion of shales has been in progress in the U.S.S.R. One such process is the method of thermal dissolution of shale.*)

The process is carried out at a pressure of 30-50 atmospheres and at temperatures ranging from 410 to 430°C with the use of a special solvent which is a liquid fraction with a boiling temperature range between 210 and 340°C, obtained in the process of the thermal dissolution of shale. In these conditions, without the use of a catalyst, the destruction of the organic part of shales takes place, its transition into a soluble state and cracking accompanied by the liberation of gas and a liquid fraction which separates into a gasoline fraction with a boiling temperature range of 180-200°C, a regenerated solvent and an extract with a temperature range higher than 320-370°C.

At present, the simplest variant of this process has been tried out, the one producing a high-boiling extract which can find application as an ash-free power-generating fuel and also as a feedstock for obtaining electrode pitch coke, bitumens and an organic binding material for highway construction, and a liquid fraction. With the further processing of the liquid fraction, evaporated by boiling up to a temperature of 350°C, it is possible to obtain a high-octane motor fuel by the methods of hydrogenation and catalytic reforming. Depending on the process temperature, the yield of products, relative

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*) A. B. Vol-Epstein. Thermal Dissolution of Oil Shales and Coals. (In Russian). "Khimiya Tverdogo Topliva", 1980, No. 6.

to the shale organic part (with the solvent's full regeneration and discounting losses), is as follows: gas - 3 to 11 per cent, crude petrol fraction with boiling temperatures of up to 200°C - 8 to 30 per cent, and ash-free extract - 40-70 per cent.

Major advances have been made in the U.S.S.R. in the conversion of solid fuels by the method of high-speed pyrolysis which permits the following pyrolytic products to be obtained, owing to superquick heating (for 10^{-4}-10^{-1} seconds, to the temperatures of 500-900°C): coke breeze, gas, pyrogenic moisture and resin which upon further processing furnish a valuable feedstock for the production of high-octane motor fuel and a number of chemical products (phenols, aromatic hydrocarbons, etc.).

The energy-technological method of high-speed pyrolysis of coals developed at the Krzhizhanovsky Energy Institute has best been developed for commercial utilization. At a later stage, this technology will also be employed for shale conversion. Several pilot installations with capacities of 30 to 90 thousand tons of coal per annum which have converted tens of thousands of tons of coal are already in operation in the U.S.S.R. The new method of pyrolysis is distinguished from the conventional low-temperature carbonization by the simplicity of the process schemes, high intensity, high unit capacity (175 and 500 tons per hour), high energy efficiency (up to 85 per cent) and a large yield of resin and gas.

Currently, a lead full-scale facility is being built according to an "energy-technological scheme". The facility will have an output of 1.2 million tons of coal per annum (0.65 million tons reference fuel*) (t.r.f.) per annum)

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*) Reference fuel = 7,000 kcal/kg

and turn out 0.62 million t.r.f. of other products including: 0.22 million t.r.f. of resinified coke breeze, 0.12 million t.r.f. of coal briquettes, 0.15 million t.r.f. of resin and 0.13 million t.r.f. of pyrolytic gas.

The energy technological conversion of solid fuels is a highly effective process whose principal elements have by now been sufficiently well optimized and tested in industrial conditions. In the long term this method is to become the main trend in utilizing oil shales in the U.S.S.R. It is likely that the commercial-scale production of synthetic liquid fuel will begin in the country with the processing of the shales sufficiently rich in kerogen, the reserves of which are significant in the U.S.S.R., and also on the basis of high-speed pyrolysis and hydrogenation of coals.

3.1.3. Peat

Much experience has been accumulated in the U.S.S.R. in the field of peat utilization for energy production. The country has large reserves of peat. The potential peat reserves amount to 157,200 million tons including the proved reserves of about 48,000 million tons. Over 70 per cent of all the potential peat reserves are situated in the Urals and Western Siberia.

In 1980 peat output totalled 84 million tons of which amount 35 million tons were allocated to meet agricultural needs as fertilizer and also litter for cattle, etc. A total of 27 million tons of peat (9.18 million t.r.f.) was used for energy production. The production of peat briquettes as a quality fuel for communal and household uses is going ahead; 9.2 million tons of peat were used for these purposes; this amount yielded 5.3 million tons of briquettes (3.18 million t.r.f.).

The U.S.S.R. is one of the few countries where the combustion of peat for heat and electric energy generation is organized on a fairly large scale.For instance,in 1980 peat consumption by thermoelectric plants and district heating plants amounted to 5.6 million t.r.f. including 4.1 million t.r.f. by thermoelectric plants and 1.5 million t.r.f. by district heating plants.

At present, power-generating units each with an output of 200 MW operate at the Shatura,Cherepovets and Smolensk electric power-plants. The installed capacity of each of the three plants is 600 MW (3X 200 MW).

In the long term a significant expansion of peat utilization in energy production is not envisaged; however, since the U.S.S.R. has unique experience in peat development and utilization it can render aid to other countries (mainly developing ones) having significant peat reserves and a surplus of labour.

3.2. Renewable Sources of Energy

3.2.1. Hydropower

Hydropower development, the way we understand it now, was started in the country only after the Great October socialist revolution. At present, hydropower plays a prominent part in the country's electricity generation of the country both in the installed capacity of the hydroelectric power-stations and in the volumes of electricity generated by them. The aggregate installed capacity of hydropower stations as of early 1980 stood at 49.9 million kW (20.8 per cent of the installed capacity of all of the country's electric power-stations). In 1980 the hydroelectric stations generated a total of 183,000 million kWh of which 80,400 million kWh falls to the share of the European part and 102,600 million kWh to that of the Asian part of the U.S.S.R.

In the scale and technical level of hydraulic power engineering and the construction of hydropower facilities the U.S.S.R. ranks with the world's most advanced countries.

The utilization of the water power of U.S.S.R.'s main rivers is being pursued with emphasis laid on the building of cascades of hydroelectric power-stations which makes for the fuller and more effective utilization of water resources. The consistent "river system" construction of electric power-stations facilitates the organization of construction and installation work, and in a number of cases it is only a cascade of integrated hydro-schemes that accomplishes the tasks involved in the integrated utilization of rivers for hydropower generation, irrigation, water supply and water-borne traffic.

The largest integrated cascades of water power projects built in the European part of the U.S.S.R. are the Volga, Kama and Dnieper river systems.

The high-capacity hydroelectric stations of Siberia are highly-effective sources of energy, especially the Angara-Yenisei cascade which consists of four high-capacity hydroelectric power-stations - Bratsk, Ust-Ilim, Krasnoyarsk and Sayano-Shush stations - with a combined output of 88,000 million kWh under annual mean flow conditions.

A number of hydroelectric power-stations in Central Asia, besides generating electricity, are crucial to the utilization of annual river runoff for irrigation.

Long-term hydropower development will be marked by a qualitative change in the structure of the country's fuel and energy balance; the gradual development of the hydropower potential in the industrially advanced European regions of the U.S.S.R.; the need to regulate the runoff towards the integrated utilization of water resources and a simultaneous tightening up of the regulations pertaining to environmental protection.

The guidelines for long-term hydropower development in the country's different regions are as follow:

- in the European part of the country - the maximum utilization of hydropower resources with the object of moderating stresses in the fuel and energy balance in this region of the country and the construction of special mobile hydroelectric pumped storage power plants for enhancing the efficiency and reliability of the operation of energy-generating systems;

- in Siberia - the construction of large hydroelectric power-stations on the Angara, the Yenisei, the upper reaches of the Ob, regarded as a crucially important element of the largest fuel-and-energy base being created in the country's East.

The utilization of the abundant hydropower resources of Siberia is linked with the development of a production, social and institutional infrastructure, the establishment of territorial and production complexes and the accelerated pioneering of new regions;

- in the Soviet Far East - the construction of hydroelectric power-stations on the Vitim, the Olekma, the Bureya and the Kolyma in order to create an energy-generating base for economic development in the area of the Baikal-Amur railway and in remote regions of the north-east;

- in Central Asia and Kazakhstan - the construction of multi-purpose hydropower-schemes ensuring river runoff control and for electricity generation and the development of irrigated farming.

The overall level of the possible utilization of hydropower resources in the U.S.S.R. in the foreseeable future may attain 450,000-500,000 million kWh, with the economic potential amounting to 1,095,000 million kWh.

Thus, in the foreseeable future the proportion of utilization of the economic hydroelectric power resource potential will reach 40-45 per cent of the total.

Soviet hydraulic engineering science and designing practice have reached a level which has made it possible to get down to the construction of unique hydroelectric power-stations and water-development projects under the most complicated natural conditions.

Hydraulic power engineering in the U.S.S.R. traditionally occupies a leading place in the world in the construction of major hydroelectric power-stations upon non-bedrock foundations. All the hydroelectric power-stations on the Volga and the Kama have been raised on such foundations.

Some dams erected in the U.S.S.R. rank among the world's highest: the Nurek earthen - rock-fill dam standing 300 m high;

the Inguri arch dam standing 271 m high; the Sayan-Shush arch-gravity dam standing 242 m high; the Chirkey arch dam standing 295 m high.

It should be stressed that most of these unique structures have been built, and/or are being built, under complicated engineering and geological conditions in high-seismicity areas.

The massive gravity dams used at the Bratsk, Krasnoyarsk and Ust-Ilim hydro-schemes have proved to be the simplest to build and the most effective economically under the conditions of the copious Siberian rivers.

In the past few years the building of pumped-storage hydroelectric power-stations has been started in the U.S.S.R. These stations are to manoeuvre capacity in the Interconnected Power System of the European part of the country.

The power plant industry of the U.S.S.R. develops and manufactures hydraulic turbines of different systems: propeller and axial-flow (Kaplan) turbines; adjustable blade (Darrieus) turbines, radial-axial (mixed flow) (Francis) turbines, Pelton turbines of different capacities, and also horizontal enclosed units.

The largest in size, the propeller turbines (Kaplan) with turbine-wheel diameters of 10.3 m and 10.0 m operate at a number of hydroelectric power-stations in the Volga-Kama cascade.

Adjustable-blade (Frencis) turbines are highly effective for hydroelectric power-stations with heads of up to 125 m and with wide-ranging head fluctuations. In 1976, adjustable-blade

220 MW turbines with a wheel diameter of 6.0 m designed to operate over the head range of 40 through 97 m were put into operation at the Zeya hydroelectric power-station. The question of using adjustable-blade turbines for a head of up to 150 m is under consideration.

Radial-axial (mixed-flow) turbines suitable for the 40-600 m head range have become quite common. The largest of them are the hydroturbines installed at Sayan-Shush Hydroelectric power-station (640 MW, radial head - 194 m, wheel diameter - 6.5 m).

Impulse (Pelton) turbines are used for heads exceeding 400 m.

Turbine pumps, each with a capacity of 200 MW and a wheel diameter of 6.3 m, have been developed for the high-priority Zagorsk and Kaishyador pumped storage hydroelectric power-stations.

Much experience has been gained in the U.S.S.R. in the construction of "small-scale hydro projects ranging in capacity from several dozen kW to several MW. A large number of such hydroelectric power-stations were built in the 1930's through the 1950's all across the country's territory. True, over the past twenty years the construction and operation of most small-scale hydroelectric power-stations have been discontinued because of their low efficiency, and in connection with the development of the power grid which has encompassed virtually the entire country. The harnessing of small streams and the utilization of head differentials in unitized automated hydroelectric generating sets which do not require attendant personnel can provide an additional several thousand million kilowatt-hours of electricity per annum and thus replace up to a million tons of fuel.

The step-by-step development of hydropower resources in the U.S.S.R., and especially in the country's eastern regions, is part of the general trend towards the development of renewable energy resources in the long term.

The U.S.S.R. has significant tidal energy resources (a total of 350,000 million kWh per annum) which accounts for about half the world's technical potential.

Since the sites for the possible construction of tidal power plants are located in uninhabited areas along the White Sea and the Sea of Okhotsk, coasts with inclement climates, a floating construction for the building of the Kislaya Guba (bay) tidal power-station was developed and realized in the U.S.S.R. for the first time in the practice of building hydroelectric power-stations. This construction has been adopted for all the tidal power schemes designed in the U.S.S.R. and abroad, in Canada, Great Britain and South Korea.

3.2.2. Solar Energy

Possibilities for the large-scale utilization of solar energy are relatively limited in the U.S.S.R. This is due to a number of objective natural and socio-economic factors whereby solar energy in the U.S.S.R. can find application mostly in supplying heat to scattered users in the country's southern regions and electricity to small remote facilities which, given suitable development, can secure, towards the close of the century an economy of fossil fuels in the amount of several tens of millions of tons of t.r.f. per annum.

Low-grade heat and refrigeration supply. This trend in solar energy utilization is the most promising for the U.S.S.R. The southern regions of the U.S.S.R. (south of latitude 50^{o} north) lying in clear-sky zones are characterized by the insolation of one square meter of a solar collector, optimally oriented in space, in an amount ranging from 1.5 to 2.0 GCal/sq.m per annum. Thus, assuming the average efficiency of solar radiation conversion into low-grade heat to be equal to 40-50 per cent (flat-plate solar collectors heating the heat-transfer medium to a temperature exceeding the ambient temperature by 50-60^{o}C), one square meter of the solar collector will make it possible to obtain 0.6-1.0 GCal/sq.m per annum which is equivalent to a saving of 0.1 to 0.3 t.r.f./sq.m per annum.

These figures are approximate for they are obtained without account being taken of, say, variations in the seasonal graphs showing heat demand and the amount of incoming solar radiation. Seasonal variations mainly make themselves felt in the optimal proportion of annual heat consumption, made good by solar radiation.

With the standard investment efficiency rate being 12 per cent and depreciation costs - 5 per cent and given 20-year long service life, irrespective of the current costs of running a solar plant, the minimal marginal fuel costs at which the introduction of solar installations is economically expedient are as follows:

with an installation costing 150 rouble/m^2 - 130 rouble/t.r.f., with an installation costing 100 rouble/m^2 - 85 rouble/t.r.f.

It we take the price of oil on the world market which now stands at about 40 dollars per barrel (about 250 dollars/t.r.f.) to be the determining factor, then the operation of solar systems for the production of low-grade heat is justified in a number of cases even now especially if they displace liquid and gaseous fuels.

To date, about 30 pilot facilities with systems for solar heat supply have been built in the U.S.S.R.

A number of scientific institutions conduct research for the purpose of developing economical heating and air conditioning systems powered by solar radiation.

Air conditioners powered by solar energy to be used in premises in arid and hot climates have been developed.

There are certain possibilities for utilizing solar energy in agriculture. The seasonal nature of agricultural production and a large number of small and scattered users predetermine the favourable possibilities for using solar systems for various agricultural purposes.

In Kazakhstan and Central Asia there are numerous desert and semi-desert pastures occupying an area of over 200 million hectares which have sufficient reserves of fodder but lack fresh water for watering livestock because of the high mineralization of the groundwater (up to 35 g/l). The use of these pastures would allow the sheep population to be increased substantially. The operation of solar prototype desalination plants developed and tested under the conditions of the Turkmen

SSR, the Uzbek SSR and the Kazakh SSR has shown their fresh-water output to be 1 t/m^2 per annum, capital construction costs - 45-50 roubles/m^2, the cost of fresh water - 2.5-3 roubles/cu.m which is in many cases cheaper than delivering it in tankers.

A new idea of organizing the supply of water to remote pastures through the construction of heliocomplexes in the desert has been put forward in the U.S.S.R. Such a helio-complex will comprise a solar-powered desalination plant with a water elevator, a house for shepherds with heat and electricity provided by the sun,[x)] a helio-hothouse for vegetable growing and a vat for growing chlorella as a feed additive. Currently, such complexes are being tested for feasibility.

Helio-hothouses are extremely promising. Depending on the purpose and climatic conditions, a fuel saving up to 70 per cent can be obtained and in a number of cases the backup fuel economy[xx)] oan be dispensed with as demonstrated in the operation of pilot helio-hothouses in Uzbekistan and Turkmenia where at night temperatures drop to - 20°C.

It is difficult to forecast the scale on which solar plants will be introduced for generating low-grade heat and for agricultural uses up to 1990. However, it appears quite feasible that by the year 1990 the use of solar energy will

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x) In some cases it is expedient to use wind-generated installation for water elevation and electricity supply.

xx) Due to heat storage by the hothouses and the possibility of lowering the hothouse temperature below the optimal one.

have allowed the saving of up to one million t.r.f. of fossil fuels per annum. This will require the installation of up to 5-7 million sq.m of collectors provided they are operated the whole year round; considering the seasonal nature of heat consumption, 7-10 million sq.m of collectors will be necessary. Over 100 million sq.m of solar collectors will be required to save about 20-30 million t.r.f. of fossil fuels by the year 2000.

The thermodynamic method of converting solar energy into mechanical energy and electricity. In the Soviet programme for solar energy utilization much emphasis has been laid on establishing relatively large solar electric power plants which will operate on the basis of machine thermodynamic cycles and produce electric and thermal energy on a commercial scale.

The economic efficiency of such stations integrated into power systems is determined by the recoupment of the capital outlays for their construction resulting from the saving of fuel and costs of environmental protection measures.

According to design evaluations the unit cost of installed kW of a large steam-turbine solar power plant (in 1979 prices) may fluctuate between 750-900 roubles per kW with marginal costs of 8-10 kopecks per kWh which exceeds several times electricity production costs at thermal power-stations on fossil or nuclear fuel.

Research and development in this field will be aimed at technological and technical economic quests to enhance the efficiency and competitiveness of solar power plants.

In the long term the schemes of power solar plants of a tower type could utilize photocells capable of operating at increased temperatures (over 300°C) and at high radiation densities. One may assume that the use of photocells on the surface of solar power plant collectors will make it possible to increase the overall efficiency of converting solar energy to electricity up to 35 per cent and over. This may become economically justified if relatively low-cost photovoltaic converters are developed.

In accordance with the programme for the further study of the possibilities for using solar power plants in the U.S.S.R. energy sector, provision has been made to build and test the country's first experimental solar power plant in the Crimea with an output of 3-5 MW which will comprise all the basic elements of a commercial solar power plant of the tower type.

Photovoltaic conversion of solar energy. Of all the known methods of direct conversion of solar energy into electricity, the photovoltaic method of energy conversion with the aid of semiconductor photovoltaic solar power systems (PSS) is the best tested one under the conditions of longtime operation on Earth and in outer space.

The merits of photovoltaic systems are linked with the possibility of using them virtually in any geographical region, their high reliability, long service life (over thirty years), independence of operation and ecological purity of the energy source.

The main drawback of photovoltaic systems is their high cost which is the chief factor hindering their wide application in the future.

The cost reduction programme includes the following measures: (1) the utilization of low-cost silicon in the form of a tape or film obtained with the help of low-cost, high-speed processes - casting, zone melting, extrusion or rolling of polycrystal silicon; (2) the development of a continuous automated production process all the way from the production of pure material to the assembly of solar cell batteries; (3) the employment of simplified methods of printed contact making; the application of low-reflection coatings by atomization, vacuum deposition, etc.

In the U.S.S.R. the solution of problems involved in the reduction of costs of photovoltaic converters is based, apart from the above ways, on the programme (advanced in the early 1970's) of utilizing the concentration of solar radiation, involving the saving of high-cost semi-conductor materials and the use of relatively low-cost concentrators.

Long-term programmes are being drawn up in the U.S.S.R. for the development of ground-based solar power facilities; groups of leading scientists and research staffs are engaged in doing relevant research. The main aim of the programme is to drastically reduce the costs and the power consumption involved in the production of semi-conductor materials and solar cells, to develop modules and power units for high capacity photovoltaic systems and heliocomplexes for their testing. In the event of a technological breakthrough in this field capable of reducing solar cell costs by approximately a factor of 10^2 one can expect radical changes in the structure of the energy supply.

Currently, in ground-based applications of photovoltaic converters emphasis is laid on silicon solar cells. Economic calculations show that even at a cost of 50 roubles per watt the use of photovoltaic converters is expedient for supplying energy to small remote users operating units of up to 500 W. Currently, about 120 solar electricity-generating facilities using photovoltaic modules in gas-filled glass protective shells are in operation. They are installed on lighthouses, navigation marks, on gas pipeline cathode protection setups in the Azerbaijan SSR and in Central Asia, etc. Their aggregate capacity is 10 kW, with efficiency ranging between 8-10 per cent and the service life over thirty years.

The large-scale utilization of solar energy is in the initial stages in the U.S.S.R. By now some experience has been accumulated in the development and experimental utilization of solar energy. For the immediate years ahead, provision has been made to launch the pilot-plant operation of facilities, using solar energy in the country's more promising regions. The results of these tests will furnish grounds for an ultimate evaluation of the expediency and scope of solar energy development.

3.2.3. Geothermal Energy

According to data released by the U.S.S.R. Academy of Sciences and the U.S.S.R. Ministry of Geology the prospected reserves of thermal waters at depths of 3-3.500 m with temperatures ranging from 40 to 200^{o}C and a mineralization of up to 35 g/l can assure a longtime recovery at a rate of 20-22 million cu.m per day. Most of these waters find their way to the surface by spouting. Over 70 per cent of the prospected subsurface hot water storage fall to the little-developed regions of Siberia and the Far East. Almost 90 per cent of all the thermal waters have temperatures below 100°C.

These two circumstances do not hold promise, even in the long term of supplying, a significant proportion of the country's demand for low-temperature heat and electricity by thermal waters, although it is beyond question, that better-endowed regions geothermal energy will be used first of all to provide local household and agricultural users with heat.

Great thermal energy reserves are trapped in permeable water-bearing strata and in "dry" rock masses lying at significant depths. The schemes for the effective utilization of this heat on a commercial scale are in the stages of scientific and technical evaluation and experimental testing. In order to obtain petrogenic heat it would be necessary to involve great volumes of rock masses with a multitude of natural and man-made fractures uniformly encompassing the entire volume between the boreholes for pumping down cold water and recovering hot water or steam; otherwise, the rock mass will become coll quickly in the zone of the most active circulation, and this zone will deliver slightly heated water although the bulk of the mass will still be hot. In the case of water-saturated strata the same difficulties may arise because of the uneven permeability of the entire volume of a stratum. The question of exploiting man-made circulation systems is extremely complicated due to the fact that the chemistry of the interaction between the waters containing oxygen and carbon dioxide and the rocks has been insufficiently studied. For this reason, heat from water-saturated strata and hot dry rock systems, immense though it is, has not yet been included in the recoverable geothermal reserves.

For the most part, thermal water resources are noted for the exceedingly high content of salts dissolved in them as well as other chemical compounds which virtually exclude the possibility of discharging spent waters into natural water bodies. The most rational scheme as regards environmental protection is to pump spent water down the stratum again which, however, increases costs of utilizing geothermal heat and can become an impediment even in the most richly endowed regions.

Low-grade geothermal resources (thermal waters with temperatures of up to 100°C) are used in our country for heating frozen rocks and dredging grounds in the development of placer deposits of minerals in the North-East of the U.S.S.R., for supplying water to livestock complexes, for hot water irrigation, for sporting and health-building purposes (e.g. swimming pools, showers, etc.), for the intensification of fish breeding, for the provision heat and hot water to residential and industrial buildings and for the heating of hothouse and hotbed complexes.

The main constraint limiting the use of thermal waters with temperatures below 100°C is the lack of suitable users on the spot and, what is more important, the ecological limitations on the discharge of spent waters, either highly-mineralized or containing harmful impurities, into surface water bodies.

The second category of geothermal resources comprises thermal waters and hot springs with temperatures ranging from 100 through 200°C. This heat can be used most effectively in many sectors of the national economy. Overheated thermal waters can find, and do find, application in electricity generation by small-capacity installations using low-boiling working fluids (isobutane, freon, etc.). At a later stage, they could be used as thermal waters of a low-grade type for processing and power-and-heat supply purposes. And, finally, hot springs with temperatures ranging from 150-200°C can be used to generate electricity.

Geothermal heat supply. Inasmuch as the bulk of the thermal water reserves in the U.S.S.R. belong to the low-temperature category, their main users, in the forseeable future, will be agriculture and communal heating and water supply.

Natural heat utilization holds the greatest promise and economic advantage for agriculture.

Greenhouses have been set up all across the country, from the subtropics to the arctic regions.

The problem of developing vegetable growing in hothouses in many regions of the country, provided traditional fuels for their heating are replaced to a maximum extent, can be resolved successfully by way of switching hothouse complexes over to geothermal heating either fully or in part. The economic effectiveness of thermal water utilization is well illustrated by the example of the hothouse combine of a state farm located not far from the city of Grozny. The outlays for the construction of one film-covered hothouse there, covering an area of 500 sq.m, were recouped within a year.

Much attention is being given in the U.S.S.R. to the provision of fresh vegetables to regions where climatic conditions do not permit their cultivation. Many such regions lack local fuel and its delivery over long distances is fairly costly; therefore, geothermal energy in such regions is regarded as virtually the only way of developing vegetable growing.

Large geothermal agricultural complexes are being set up in many regions of the country. For instance, one such complex is effectively functioning in the Northern Caucasus, in the Mostovsky region of the Krasnodar Territory. The hothouse complex covering an area of ten hectares is heated with thermal water with an initial temperature of 74°C whereupon the spent water with a temperature of 35-40°C is channelled to a livestock farm and a pond with an area of 200 hectares where mirror carp is bred.

Geothermal hothouse-and-hotbed complexes are being widely introduced all over the Northern Caucasus region and Trancaucasia. For example, in the Georgian SSR the Kindgsky hothouse combine with an area of 54 hectares is being established on the basis of the local hot water springs.

Geothermal heating and hot water supply. Schemes for geothermal heating and hot water supply have been developed for a number of the regions in the country.

Let us dwell briefly on just one such scheme for the comprehensive utilization of thermal waters within an urban heat supply system. The same thermal water well can serve different numbers of users, depending on the temperature of water coming to the surface and the climatic factors. For instance, one thermal water well with a flow rate of 1,500 cu.m per day and an outflow temperature of 50°C supplies heat to seven houses each having 70 flats in the city of Makhachkala and allows a saving of a total of 1.200 t.r.f. if there is a parallel delivery of thermal water for heating and hot-water supply. However, with a combination of additional water heating for peak power load, and warm-air and hot-water heating, the fuel economy increases to 3,100 t.r.f. and the number of 70-flat houses served by the well - to 16-17.

The heating of thermal water for peak load can be done in conventional boiler rooms (houses) equipped with steam generators and hot-water boilers and by means of electricity. In the latter case the "peak-load" boiler room (house) is fully automated and operates without any attendant personnel. Fuel consumption is very low because the peak-load boiler room has to function only during an insignificant part of the heating season.

At present, small separate districts of the cities of Tbilisi and Mákhachkala, and also a number of small towns and settlements, are provided with geothermal heating and hot-water piped to residential and industrial buildings.

In the next few years major cities such as Alma-Ata, Tashkent, Tyumen, Omsk and Petropavlovsk-Kamchatsky are to be switched over to a geothermal heat supply.

The development of thermal waters is proceeding not only along the line of a heat supply, but also to produce low temperatures with the aid of refrigerating machines.

A bromine-lithium absorption refrigerating machine producing cold at the rate of 2.5 million kcal per hour has been tested and is being used commercially in the U.S.S.R. It not only operates on electricity but also using subterranean hot waters and waste water from industrial enterprises and thermal power-stations. This facility is remarkable in that it not only produces cold but is also a heat transformer. It can operate all the year round, producing cold in summer and heat in winter.

Low-grade geothermal resources are a large energy reserve in the mining industries; they are used to heat frozen rocks in the gold, diamond and tin fields of the North-East of the U.S.S.R., melt ice, and heat the metalwork of dredges over dredging grounds and marine alluvial deposits of the continental shelf.

More than 70 chemical elements occur in thermal waters, in a dissolved state. They are often in high concentrations which makes such waters an important feedstock for the chemical industry as well.

The accompanying recovery of chemical components in heat utilization not only affords additional economic gains (just as associated heat utilization in the recovery of chemical components from water) but is an imperative necessity for protecting the natural environment against pollution with the harmful substances contained in the recovered fluids which are disposed of after heat utilization.

In many artesian basins and in mountainous-folded regions of the U.S.S.R. there are large reservoirs of thermal waters which are effectively used at health resorts and in swimming pools.

Geothermal Electric Power Generation. The possibilities of using geothermal resources for electricity generation are limited in the U.S.S.R. The most promising regions for this are those of modern volcanism: Kamchatka and the Kuril Islands.

In Kamchatka hot springs with temperatures of 200-250°C have been discovered already at depths ranging from 500-1,500 metres. The forecast reservoirs of thermal waters and hot springs in Kamchatka are capable of fully meeting the region's demand for electricity and thermal energy.

The experience gained in operating the Pauzhetskaya geothermal power-station has shown its reliability and economic efficiency. The cost of electricity is 3-5 times less than that at diesel electric power plants of equal capacity which are the most common type in different regions of Kamchatka.

Thermal anomalies of up to 170-200°C have been discovered at depths of 4-5 km in regions of mountainous-folded formations (the Caucasus, the Crimea, the Carpathians, the Pamirs). Small-scale pilot-plant geothermal power-stations with capacities of up to 10 MW are to be built on the basis of these anomalies.

On the whole, geothermal energy will be utilized for a low-temperature heat supply and only in the zones of recent volcanism will geothermal energy be used to generate electricity.

At the same time, a large amount of research and exploration work is to be undertaken to utilize the heat of water-saturated strata and dry rock systems which, given favourable results, can become a source of virtually inexhaustible energy.

3.2.4. Wind Energy

The development of research and practical work in the field of wind power for energy generation in the Soviet Union was started in the very first years of Soviet government. In the 1920's E. E. Zhukovsky and his pupils developed the theory of an ideal and real windmill systems; investigated loads developing on a windwheel and tested various designs for high-speed windmills. The Central Wind Power Institute was founded in 1930. The world's largest (at the time) wind-operated power station with a capacity of 100 kW was built and put into operation in the Crimea in 1931; it successfully operated up to 1942 delivering energy to the local power grid.

Recently interest in wind-power utilization and in other renewable energy resources has revived in the U.S.S.R. The building of wind-operated units is considered promising for supplying energy to dispersed user installations in regions where there are no sources of centralized energy supply. As a rule, units of low and medium capacities (up to 100-200 kW) will be used.

Regions with large wind-power resources are the Arctic zone, the southern Black Sea-Sea-of-Azov zone, the Aral Sea-Caspian zone, the Baltic Sea coast and the Pacific coast. These zones are noted for the highest wind velocities and frequent recurrence intervals. Within the lowest surface layer annual wind velocities average 5-10 m/sec, wind flow duration ranges from 270-320 days per annum with a wind velocity averaging 8 m/sec and over, and winds blowing from 30 to 60 per cent of the time.

However, in selecting zones for rational wind energy utilization it is necessary to take into account the following specific conditions: nonuniformity of the energy over time, the nature of energy consumption, the influence of lanscape factors, etc.

The best prospects for operating wind powered units are in agriculture and land amelioration. The need for wind power plants is especially acute in the provision of watering places for livestock breeding on remote pastures in the country's southern arid and semi-desert regions far removed from power systems. The maximum design load of such a user, depending on the depth of the water source in the form of a shaft well or an artesian well varies from I to 4 kW. The water-lifting stations allow requisite water storage in reservoirs for periods of calm which permits the use of wind-powered units without backing them up with other sources of energy.

The results of the calculation of costs for lifting one cubic meter of water made for various methods of water supply under the conditions of Kazakhstan, have shown that wind systems allow the annual cost of watering one sheep to be reduced by almost 66.7 per cent and simultaneously effect a significant saving in fuel, preserve the purity of water-supply sources and exclude the possibility of fuel finding its way into water-supply sources.

Definite prospects open up in oasis irrigation where there is a need for wind-driven power plants with electricity outputs of tens and hundreds of kW.

Water desalinating plants are suitably integrated with wind-powered plants. The continuity of a desalinated water supply is in this case assured by its storage in a standby reservoir. A 4 kW wind-operated plant in assembly with an electrodialysis desalting installation can provide small population centres with a daily consumption of 4 cu.m with drinking water, with an average wind velocity of 5 m/sec and the salt content of starting water - 6 g/l.

The use of wind systems for supplying energy to meet the household needs of shepherds, reindeer breeders, hunters, geologists and people in similar occupations is acquiring growing cultural and social significance.

In a number of cases the continuous supply of users with electricity necessitates the equipment of wind-powered plants with energy storage devices and sources of backup power supply.

The main factor hindering the development of wind power generation is the relatively high cost of aerogenerators.

The most promising trend in the work of raising the efficiency of wind energy generation is that of increasing the speed of windwheels, raising their aerodynamic efficiency, improving and simplifying their fabrication and using novel materials.

The pilot-plant production of wind energy-generating machines has been organized in the U.S.S.R.

The ABEU-6 (Russian designation) is a high-speed double blade horizontal-axial wind electro-unit, with a windwheel diameter of 6 m and a power rating of the synchronous generator of 4 kW, at an estimated wind velocity of 9 m/sec, a maximum working wind speed of 50 m/sec, designed to utilize wind-rose winds, with the tower height up to the axis of rotation - 7 m. The ABEU units are in trial operation in the country's different climatic zones, serving different users.

Even now wind electro-generators of medium and small capacities can be employed and yield a substantial economic gain, especially in remote areas difficult of access; on the other hand, the large-scale utilization of wind-power station (WES) appears problematic because electricity demand on the Arctic coast of the U.S.S.R. is limited and the power networks of other regions with a high recurrence of strong winds are integrated into the country's power grid where the bulk of electricity generation will in the long term come from atomic power plants. This being so, wind power stations, which only allow the fuel component of electricity generating costs to be saved, prove practically ineffective.

Thus, for economic reasons the use of wind-driven electric plants will be confined first and foremost to coastal regions, the desert regions of Central Asia and little-developed regions of Siberia and the Soviet Far East where low energy consumption loads do not warrant the construction of thermal or hydraulic power-stations or the switching of remote users into the operating power networks. In these regions it is possible to combine various types of renewable energy resources (solar, geothermal wind) to meet user needs for electricity and heat.

3.3.5. Biomass and Organic Wastes

Biomass comprises organic fuels of diverse origins: firewood, agricultural residues and other types of fuel obtained on the basis of plant raw materials. This category also includes biogas obtained in the process of the anaerobic digestion of organic wastes.

The use of biomass as a fuel accounts for an insignificant amount in the U.S.S.R. (about 60 million cu.m or 15 million t.r.f., i.e. under 1 per cent of the total energy consumption).

And yet, in the past few years keen interest has been shown in the utilization of various organic wastes originating in industry, agricultural production and cities, which is due first of all to considerations of environmental protection and lately to the possibility of partially replacing high-grade liquid and gaseous fuels.

Of greatest interest in this connection is the process of anaerobic digestion of organic substances with the object of reprocessing them and obtaining high-quality fertilizers and biogas (methane).

It is proposed that the residues left over after anaerobic digestion of wastes be used as primary material for obtaining protein-rich fodder additives. As distinct from developing countries where biomass and organic wastes are utilized in small installations, thus allowing the local problems of energy supply and the employment of the population to be solved, in the U.S.S.R. attention is focussed on the building of large centralized plants.

The process of anaerobic digestion is mainly used in the U.S.S.R. in the treatment of sewage water sludge and the processing of agricultural residues.

<u>The anaerobic treatment of sewage waters</u>. The organic substances obtained from effluents discharged by enterprises of the food industry and the microbiological industry are a reserve for saving primary energy resources. The effluents of these enterprises belong to the category of highly concentrated ones

which calls for a special approach to their neutralization and treatment. In the next-few years the construction of a large number of treatment facilities is planned at the enterprises of these sectors. In most cases treatment technology involves anaerobic digestion of organic substances, i.e. their complete conversion into carbon dioxide and water without utilizing oxidation energy. More effective is the fermentation of methane during which the hydrogen and carbon of the oxidized substances do not react with oxygen, as they do during anaerobic digestion, but are expended on the generation of methane biogas. The following data indicate the amount of methane that can be obtained by this method. A medium-capacity meat-packing plant produces 4,000 cu.m of effluent per day. The yield of biogas per cubic metre is about 5 cu.m. All in all, over 20,000 cu.m of fuel gas can be produced everyday. A molasses-distillery integrated plant produces effluents at the rate of 500 cu.m. It is possible to obtain over 10 cu.m of gas from every cubic metre, or over 5,000 cu.m per day from one such enterprise. In the Ukraine alone there are over a hundred meat-packing plants and several dozen distilleries. Each of them can produce millions of cubic metres of gas per annum. Similar capabilities are available at sugar mills, starch-and-molasses mills, dairy plants and various enterprises of the microbiological industry.

The employment of the process of methane fermentation for industrial effluent treatment in combination with the existing method of anaerobic oxidation is not only possible but necessary for this assures a high degree of purification at lower costs, even if the utilization of methane and the biomass forming in the process is not taken into account. This is due to the fact that the concentration of organic impurities in effluents exceeds by dozens of times the values at which the existing aerobic method yields a sufficiently high economic gain. At high concentrations of organic substances aerobic treatment results in increased costs caused by the growing oxygen demand, the need for secondary water treatment (recirculation, etc.). The employment of the method of methane fermentation permits the concentration of the organic substances in runoffs to be lowered by 80-90 per cent and the advanced effluent treatment is easily carried out by the aerobic method. In that case, the total treatment costs will be substantially lower compared to costs involved in a purely aerobic process. For instance, the economic gain from the employment of the process of methane fermentation within the scheme of waste-water treatment at meat packing plants exceeds 400,000 roubles per annum for each enterprise. In utilizing the methane forming in the process which can replace high-grade liquid and gaseous fuels costing about 100 roubles per t.r.f. the economic gain is increased to 900,000 roubles whereas the simultaneous utilization of the microbic biomass as a protein-vitamin concentrate for livestock feeding will permit savings of up to 1.5 million roubles per annum.

It is held that the use of anaerobic waste-water treatment in industry could assure the production of 4,000 million cu.m of biogas per annum which is an equivalent of 3 million t.r.f.

Of great interest is the use of anaerobic treatment of sewers in large cities. For instance, in Moscow, at the activated sludge plants a total of 25,000 cu.m of sludge are formed everyday, with a moisture content of 97 per cent and an overall volume of dry matter of 280.000 t per annum. The whole amount of sediments is subjected to anaerobic sludge digestion in methane tanks. The amount of biogas evolving in the process is 10-12 cu.m per 1 cu.m of sludge. The biogas liberated in the process of digestion contains: 60-65 per cent of methane, 16-34 per cent of carbon dioxide, 0-3 per cent of nitrogen and 0-3 per cent of hydrogen. The normal calorific value is 5,000 kcal/cu.m. The gross yield of biogas at the Moscow activated sludge plants amounts to 180 t.r.f. per day or over 60,000 t.r.f. per annum.

Biogas produced in the heated digestion (methane) tanks of the Moscow activated sludge plants is utilized to meet the energy needs of the city's sewage handling facilities.

The construction of activated sludge plants using anaerobic digestion of wastes only in large cities, each with a population of about one million and over (at present such cities in the U.S.S.R.have a combined population of over 35 million) makes it possible to produce at least 0.25-0.30 million t.r.f. per million of people which, by present-day standards, amounts to 10-12 million t.r.f. per annum.

Anaerobic digestion of agricultural production wastes. Agricultural production is a large-volume producer of renewable energy resources as yet insufficiently utilized. These resources consist of the organic wastes of crop and livestock farming (straw, the tops of root bearing plants, the stalks of cotton, maize and other plants as well as excrements and other organic wastes from agricultural production).

These wastes pollute the environment (especially sewage waters from livestock complexes and wastes from poultry farms). The direct introduction of these wastes into the soil as fertilizer entails significant losses of nutrient substances.

Modern microbiology has at its disposal technical solutions allowing a considerable reduction in the nutritive losses in fertilizers, helping to settle the question of the sanitary treatment of waste waters and allowing fuel to be obtained in the form of biogas. The basis of this technology is the digestion of organic wastes under anaerobic conditions by means of cellulose-fermenting and methane-producing bacteria.

To date, several designs for systems of anaerobic fermentation of agricultural residues have been produced in the U.S.S.R. An integrated process scheme for treating waste water in discharge channels of livestock complexes is of interest. Under the scheme wastes from the pens occupied by animals come to the sewage screens, then on to the press filters whence the residue squeezed out is routed to the dry feed shop where it is mixed with activated sludge from methane tanks and is pelletized whereupon dry feed is sent to fish-breeding complexes. One livestock complex is capable of producing annually a total of some 2,000-3,000 tons of dry feed saturated with biotin from activated sludge from methane tanks which allows up to 800-1,000 tons of fish to be bred on this feed.

The biogas forming in the methane tanks is collected into a gas-holder and utilized in heating, the steaming of feeds, etc.; excess gas is used for the heating and production of feeding meal. A livestock farm of 5,000 head of cattle is capable of producing daily up to 3,500-4,000 cu.m of methane through the digestion of 1,000 cu.m of waste water.

An energy-supply scheme for a large agricultural complex and an urban-type settlement for the temperate zone of the U.S.S.R. has been drawn up. A comparison of this scheme with the long-established technology of organic waste utilization shows that out of a total of 68,900 tons of organic wastes with a moisture content of 75 per cent which the farm obtains from crop and livestock farming, a mere 28,500 tons per annum are applied for fertilization. This means that under the established technology a mere 43 per cent of the starting amount of organic residues is applied as fertilizer. If all the organic residues and wastes were used as stock for the operation of a bioenergy plant, they could produce 63,800 tons of high-quality disinfected fertilizers and 4.4 million cu.m of biogas with a total energy content of 3,400 t.r.f. This energy, including its consumption, of up to 20 per cent, of the total output, in the operation of the bioplant would suffice to ensure all the heating processes on which at present the farm spends natural gas and coal.

An analysis of the transporation costs involved in the delivery of organic residues from fields and farms to the bioenergy plant and in bringing to the fields the digested mass has shown that given average haul distances of 12 km the fuel consumption for these purposes does not exceed 20 per cent of the energy derived from the biogas produced.

With regard to the farm considered above (4,360 hectares of ploughland) costs for the construction of a bio-energy generating plant with a storage facility of 70,000 cu.m will total

1,260.0 roubles with annual operation costs of 36,000.0 roubles. The plant will have the capacity to produce 220,000 t of organic fertilizers and 4,038,000 cu.m of biogas (3,173 t.r.f.) with costs for production and storage of one ton of organic fertilizer being 22 kopecks and for generation of one cu.m of biogas - 1.8 kopecks per cu.m (23 roubles/t.r.f.).

Higher-capacity plants used on farms with 40,000 hectares of farmland will allow unit costs for fertilizer preparation and biogas generation to be cut by 20-30 per cent compared with the similar indicators of the bioenergy generating plant examined above.

In the long term the utilization of the organic residues and wastes originating in industry, agriculture and the housing-and-communal sector is to become a reliable renewable source of energy whose commercial utilization will make it possible to resolve the important problem of protecting the environment, obtaining millions of tons of high-quality fertilizer and saving significant quantities of liquid and gaseous fuels.

4. THE SOVIET UNION'S TO INTERNATIONAL CO-OPERATION IN DEVELOPING NEW AND RENEWABLE ENERGY SOURCES

4.1. Forms and Trends in the Development of the Soviet International Co-operation Effort

The XXVIth Congress of the CPSU has reaffirmed the steadfast nature of the policy of the Soviet Union aimed at the further promotion of mutually advantageous economic, scientific and technical co-operation between states with different social systems.

The Soviet Union is well aware of the fact that energy production has developed into a global problem nowadays and can only be resolved on the strength of a thorough study of international experience and comprehensive, mutually advantageous and equitable international economic, scientific and technical co-operation.

This co-operation should be pursued in different fields of energy production, including the development and commercial use of new and renewable sources of energy, joint research into efficient energy-generating technologies, the development and implementation of methods of conserving fuel and energy resources.

The Soviet Union regards co-operation in the field of energy production as an integral element of its foreign policy based on the principles of peaceful coexistence, respect for sovereignty, non-interference in the internal affairs of other states, equality, voluntariness, and mutual benefit. This policy accords precedence to the task of promoting the amelioration of the international political climate, the advancement of detente and an assurance of lasting peace. The Soviet Union is convinced that the mobilization of the necessary financial, labour and material resources to ensure mankind a reliable supply of energy is only possible provided there is effectual control over, and then termination, of the arms race which diverts productive forces and society's significant capabilities from the solution of urgent problems. This is precisely why detente is vital to effective co-operation in the field of energy production.

The Soviet contribution to international co-operation in the field of energy production is multifarious in nature and is being developed along the following lines: bilateral co-operation with socialist countries, multilateral co-operation within the framework of the Council for Mutual Economic Assistance, bilateral co-operation with developing and industrially advanced capitalist countries, co-operation within the framework of UN agencies and international nongovernmental organizations.

Co-operation between the U.S.S.R. and other countries of the socialist community is being pursued within the framework of the Council for Mutual Economic Assistance (CMEA) in accordance with the long-term special-purpose programme aimed at ensuring that the scientifically founded requirements of the CMEA member states in the basic types of energy, fuel and raw materials for the period ending in 1990 are met. This programme provides for the joint activities of the CMEA member states in the spheres of production, conversion and transportation (transmission) of energy resources and in the development of energy-generating technologies. Much is also being done by the CMEA in the field of atomic energy development and the commercial utilization of other sources of energy for which purpose such joint research and economic organizations of these countries have been set-up and are operating as, for instance, the Interatomenergo. The "Druzhba" (Friendship) oil pipeline, the "Mir" (Peace) electric power grid and the "Soyuz" (Union) gas pipeline, built by joint efforts, exemplify the effective promotion of integration in the fuel and energy sphere.

At present, economic, scientific and technical co-operation within the CMEA framework is ever more closely being combined with bilateral relations between the U.S.S.R. and other socialist countries. Thus, it is with Soviet assistance that such large-scale energy-generating projects as the Iron Gate (Derdap) hydropower complex on the Danube, on the border between Romania and Yugoslavia have been built. A number of thermal power-stations with a capacity exceeding 1 million kilowatts, including those burning brown coal and lignite are being built in Yugoslavia with Soviet technical assistance. Co-operation with other socialist countries (Cuba, Mongolia, the Democratic of Vietnam and the Korean People's Democratic Republic) is being promoted on a growing scale, and more specifically in the prospecting and development of oil and gas fields on land and the continental shelf, in the exploitation of local bituminous and brown coal deposits, oil shales and tar sands, in the construction of thermal and hydroelectric power-stations, and in the utilization of new and renewable sources of energy.

In delivering the Report of the Central Committee of the CPSU at the XXVIth Congress of the CPSU, Comrade Leonid Brezhnev pointed out: "We are developing wide-ranging, mutually beneficial economic, scientific, and technical co-operation with the newly-free countries. The building of large projects in these countries with some form of Soviet participation figures prominently in our relations with them".

Co-operation between the U.S.S.R. and developing countries is being pursued on a bilateral basis and is marked by a comprehensive approach to the development of the national fuel-and-energy bases of those countries. It involves prospecting for mineral resources and their development, the construction of fuel-extracting and energy-generating projects, the establishment of the requisite infrastructure, technology transfer, national manpower training and assistance in the maintenance of projects commissioned. The multifarious aid provided by the Soviet Union is based on the utilization of the country's abundant experience gained in building up and developing the energy sector.

The promotion of co-operation between the Soviet Union and developing countries in the field of energy generation appears to be increasingly crucial in the energy situation which has evolved for some time past in the world economy. At present, energy-generating facilities account for about a quarter of the total volume of the assistance the U.S.S.R. renders to developing countries. The combined installed capacity of the power-stations designed, built or being built with Soviet aid in these countries exceeds 36 million kilowatts; half that capacity has been commissioned.

Hydropower stations have been built, wide-ranging prospecting work carried out and significant reserves of energy resources have been identified with Soviet assistance in Afghanistan, Zambia, India, Iran, Pakistan, Syria, Somalia, Turkey, Morocco, Egypt, and other countries.

Speaking about renewable energy resources, hydropower undoubtedly stands foremost in the co-operation between the Soviet Union and developing countries. The unique experience accumulated in the building of hydropower facilities and the manufacture of highly effective power-generating plants enables the Soviet Union to carry on an extensive programme of technical assistance involving the fulfilment of numerous orders for surveying, designing and procuring various equipment for hydraulic engineering facilities abroad, and for building and commissioning them. A total of 25 hydropower stations with a combined capacity of 9,670 MW, including the Aswan hydropower complex (2,100 MW) erected in 1971 (ARE) and the Euphrates hydropower complex (800 MW) (Syria) have been built and/or are under construction with Soviet technical assistance.

Such hydraulic engineering facilities as the 400 MW "Bhakra" hydroelectric power-station in India have also been built with Soviet assistance. Construction of the Hao Bin large integrated hydroscheme with a designed capacity of about 2,000 MW has been launched on the river Da in Vietnam.

With the world prices on oil and other traditional fuels rising, many developing countries are turning to unconventional energy resources, including oil shales. As shown by Soviet experience, shale utilization as fuel for electricity generation is becoming more and more economically justified.

In 1979, a contract was signed with Morocco for the conducting of feasibility studies regarding the construction of a thermal power plant involving the method of direct combustion of shales from the "Timakhdit" deposits. The contemplated capacity of the thermal power plant will be 1,000 MW. It will satisfy a third of the country's electricity requirements. The Soviet design envisages the integrated utilization of shales and waste (shale ash).

Currently, Soviet organizations are working out the design of a shale-based fuel and energy-generating complex in Jordan, comprising a shale mining enterprise (open-cast mine), an upgrading facility, and a 300 MW thermal power plant using the method of direct combustion.

Thus, the principled approach of the Soviet Union to rendering assitance to developing countries in the power sector not only consists in financing and building individual energy-generating projects but, mainly, in aiding the establishment of national power economies. In the long term such an approach makes for the self-sufficiency of a national economy in the energy sector and facilitates the accomplishment of other economic and social tasks in those countries' development. Therefore, Soviet aid to developing countries in the working and making commercial use of new and nontraditional sources of energy should be viewed within the overall context of aid rendered to build up their economies.

One condition crucial to the progress of newly liberated states is the availability of skilled national scientific and technical personnel. The training of these personnel is a high priority problem, for unless it is resolved, it is impossible to gain genuine national independence. Convinced that the facilities and technology being transferred to them yield a maximum effect only if there are national personnel who have completely mastered the use of new facilities, the Soviet Union makes a big contribution to the training of a wide range of specialists for developing countries.

Among the diverse forms of assistance rendered in training national personnel the greatest emphasis is laid upon the training of skilled workers of the most common trades and middle-level technical personnel during the construction and operation of co-operation projects; the training of engineering personnel and skilled workers at higher and secondary specialized educational establishments and centres of vocational training set up in developing countries with Soviet assistance; industrial training and advanced training of foreign specialists and workers at enterprises in the U.S.S.R. and the instruction of foreign citizens at higher schools, specialized secondary schools and vocational schools in the Soviet Union.

As for the scale of personnel training in the power economy it is well illustrated by the training of over 10,000 power specialists in the course of constructing the Euphrates hydropower complex.

Over the past twenty years the enterprises and training centres of the Soviet Union have trained more than 70,000 specialists, power engineers of different specialities. A significant number of skilled workers have been given training at the 18 training centres of the energy sector set up in developing countries with assistance from the Soviet Union. All told, the 200 training centres have trained over 300,000 workers of different specialities for national sectors including 31.000 workers for the power economy.

International co-operation between the Soviet Union and the advanced capitalist countries is pursued both in the field of traditional and nontraditional energy resources, including the development of new sources of energy. The instruments for bilateral co-operation are, first of all, intergovernmental agreements and programmes for trade, economic, industrial and scientific and technical co-operation entered into by the Soviet Union and the majority of developed countries for periods of 10 to 15 years in the field of the exchange and development of fuel and energy resources.

A feature of this type of co-operation is that it does above all envelope the large-scale projects involving the development of novel technologies (e.g. co-operation among specialists from the U.S.S.R., the USA, France and other countries in the investigation of the problem of thermonuclear fusion, the development of breeder reactors, MHD-generators, etc.). Forms of co-operation include the conducting of joint research, the exchange of trainees, the exchange of scientific and technical information and documentation.

The Soviet Union actively co-operates in the energy field with many international nongovernmental organizations and UN Agencies.

Under the aegis of the UN ECE work is under way to implement the proposal put forward by the Soviet Union on the holding of an all-European summit conference on energy problems. The accomplishment of this work and the convocation of the conference will, in the view of many authoritative experts, make a strong impact on the promotion of regional co-operation and help resolve a number of pressing problems in the energy field.

The international seminar "The Role of New and Renewable Sources of Energy for the Solution of Global Energy Problems" was held in Moscow in preparation for the UN Conference on New and Renewable Sources of Energy.

Soviet scientists also make their contribution to the holding of international conferences, seminars and workshops on the problems of the commercial use of solar energy and other types of renewable energy organized under the aegis of the UNIDO, UNESCO, UNEP and regional UN commissions. In particular, the Soviet Union contributed several papers at the seminar on new and renewable sources of energy sponsored by the UN Economic Commission for Europe and held in Jülich, FRG, in 1980. The seminar is the ECE's contribution to the preparation of the UN Conference on New and Renewable Sources of Energy.

Soviet scientists are taking part in the work of the International Institute for Applied Systems Analysis in Vienna, of different committees of the World Energy Conference and other major nongovernmental organizations concerned with power questions.

At the International Institute for Applied Systems Analysis much prominence is given to the "Energy Project", the implementation of which is being aided by leading Soviet scientists. The main objectives of the project are to develop alternative ways of energy development, evaluate and compare various energy supply variants, and select optimal power strategies for countries, regions and the world as a whole.

It should be noted that international co-operation in the energy field is integral to the state economic development plans of the U.S.S.R. Thus, for instance, "The Guidelines for the Economic and Social Development of the U.S.S.R. for 1981-1985 and for the Period Ending in 1990", endorsed by the XXVIth Congress of the CPSU, sets, among other things, the following task: "To develop, on a long-term and equitable basis, the mutually beneficial exchange of goods and the all-round economic, scientific, technical and other ties of the Soviet Union with developing countries, to continue rendering these countries economic and technical assistance in constructing industrial enterprises, and power, agricultural and other projects conducive to strengthening their economic and political independence".

4.2. Proposals for Promoting International Co-operation in Developing New and Renewable Sources of Energy

The socio-economic and scientific and technical mechanisms that have evolved in the UN have significant capabilities for organizing effective co-operation in the energy field, including the development and commercial use of new and renewable sources of energy.

The following avenues can be suggested for achieving these objectives:

(a) Improvement of the effectiveness of the system of UN agencies and special organizations for the development of new and renewable sources of energy through the better overall co-ordination of activities and the elimination of parallelism and duplication.

(b) The elaboration and implementation of energy programmes in the field of development and the use of new and renewable sources of energy.

(c) The implementation of co-operation programmes within the framework of the UN with the aim of aiding developing countries in utilizing new and renewable sources of energy. These programmes should be based on an interdisciplinary approach to the development of fuel and energy resources with due account being taken of the following directions of possible national development:

- the accelerated development of a national energy sector as a foundation for industrialization and the advancement of agriculture, first of all through mobilization of internal resources and, also, by seeking out external aid on a multilateral and bilateral bases;

- the exercising of full national sovereignty over a country's natural resources and state control over the development and use of fuel and energy resources;

- the elaboration and consistent implementation of state interdisciplinary programmes in the energy field as part and parcel of national plans for economic and social development;

- an economically-founded combination between the development of the traditional power industry on the basis of thermal, hydroelectric and atomic power stations and that of an autonomous power industry providing for the utilization of local energy resources and renewable sources of energy (solar, wind, etc.);

- the development of electrification as a factor enhancing labour productivity in industry and agriculture and conducive to the accomplishment of socio-economic tasks;

- the pursuit of co-operation between industrialized and developing countries alike on the basis of co-ordination of activities to master new technologies assuring production and obtaining of renewable resources. These forms of co-operation may include the exchange of information, and the conducting of joint investigations and tests on experimental facilities, etc.