МИНИСТЕРСТВО ОБРАЗОВАНИЯ И НАУКИ РОССИЙСКОЙ ФЕДЕРАЦИИ

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Report abstracts

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RENEWABLE ENERGY SOURCES UTILIZATION IN RUSSIA OPPORTUNITIES FOR SCIENTIFIC AND TECHNICAL COOPERATION

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Tasks on development of renewable energy are included in a number of federal target programs aimed on increase of power consumption efficiency, economic development of regions of the country, and also they are included in the scientific and technical program "Researches and development in priority directions of development of a science and technological complex of Russia".

Russia has good results in development of different methods of using new and renewable energy and the process equipment for development of local kinds of fuel that provides wide prospects of solving power and environmental problems in the future. However the volume of research and development works and furthermore the volume of manufacture of the equipment and installations of small and nonconventional power is not enough.

The realization of the international cooperation has a great value. So it is necessary to create favorable conditions for joint projects, to provide wide international support to development and introduction of renewable energy, to exchange available information and the developed technologies.

DEVELOPMENT OF NEW TECHNOLOGIES OF THE BIOMASS FUEL USAGE

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Russia possesses the greatest stocks of a biomass in the world. On the territory of our country it is concentrated about a quarter of the world's resources of wood and about 40% of the world's reserves of peat.

Alongside with producing of organic fossil fuels Russia can take the leading place in the world in the field of manufacture high calorific and ecologically pure fuel from a biomass. It is possible to use biomass for production of high-calorific gaseous and liquid fuels, pure carbon materials such as the coke, the activated charcoal, different sorbents, firm high-calorific power and household fuel. The development of modern complex technologies of biomass processing is necessary for this purpose. The mandatory requirement for practical realization of new technologies is the opportunity of usage of fuels produced from biomass in existing power units. Perspective direction of complex usage of a biomass is connected with technologies of joint processing of organic fossil fuels and biomass with production of energy carriers and carbon materials of high cleanliness which can be used in the form of high-calorific power fuel and raw material for industrial technologies.

Various directions of complex processing of a biomass are considered. The technology of pyrolysis of wood waste and peat and the technology of joint processing of vegetative waste (for example wood waste) and natural gas with productions of pure carbon materials and power gas with high content of hydrogen are presented. It is shown, that the complex technology of processing of a biomass and natural gas is allowed to solve the problems connected with hydrogen production for power use. The primary goal of hydrogen energy is a mitigation of dioxide carbon emission. Combustion products of hydrogen consist only from vapor steam and this is the main sense of using the hydrogen as a power fuel. The natural gas is considered as the basic source of hydrogen for power industry today. In the existing concept of hydrogen energetic the catalytic conversion of natural gas is accepted as a main process for hydrogen production. But in this process carbon dioxide is produced simultaneously with hydrogen and now it is proposed to create the global system of CO_2 storehouses for utilization of the carbon dioxide produced in natural gas catalytic process

In the process of joint processing of vegetative waste and natural gas a composite carbon material consisting of carbon from vegetative waste and carbon from natural gas is formed. The content of carbon in the producing composite is about 98-99 %. This material can be used as a raw material in various industrial technologies, and also as high-calorific power fuel. Instead of natural gas the outgoing burning gases of various industries and oil-well gases can be used in this technology

Ecological and economic aspects of developed technologies of joint processing of vegetative waste and natural gas are considered. It is shown, that the usage of the given type of technologies leads to reduction of harmful consequences of fuel-energy complex on the natural equilibrium and economically justified.

JOINT INSTITUTE FOR HIGH TEMPERATURES EXPERIENCE IN EFFECTIVE TECHNOLOGIES OF RES UTILIZATION, DEVELOPMENT AND IMPLEMENTATION

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The Joint Institute for High Temperatures of Russian Academy of Sciences (JIHT RAS) is one of the country's leading research center in the field of thermal physics and energy conversion processes. Energy conversion, energy conservation, utilization of renewable sources of energy are priority directions of it's R,D&D activities.

In the presentation examples of the JIHT RAS developments in field of RES utilization will be described, including:

- development of new types of solar collectors made of thermal and UV resistant plastics instead of metal and glass;
- development and theoretical studies of solar-wind autonomous energy installations with different energy accumulators, including hydrogen storage devices;
- studies of advanced geothermal power plants, in particular binary ones;
- development and implementation of heat supply systems with heat pumps.

Special attention will be paid to description of demonstration projects (reconstruction of the Special Astrophysical Observatory energy supply system located in North Caucuses mountains with implementation of RES and energy conservation technologies, etc.) and to analysis of RES resources and most effective niches and regions for their implementation in Russia.

Possible areas for international scientific and commercial collaboration will be formulated.

RUSSIAN GEOTHERMAL POWER TECHNOLOGIES AND EQUIPMENT

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Russian Federation possesses immense geothermal resources; more than 3000 wells have been drilled. For the first time power generation using geothermal resources was put into practice in 1967 on Paratunsky geothermal field (Kamchatka region). At the same time commercial exploitation of first Russian Pauzhetsky geothermal power-plant (GeoPP) (11 MWe) started.

Nowadays geothermal power-plant industry in Russia has been formed. It is capable to provide with necessary equipment geothermal power plants in process of their construction. Verkhne-Mutnovsky GeoPP (3 power generating units x 4 MWe) in Kamchatka has been in successful operation since 1999 and Mutnovsky GeoPP (2 units x 25 MWe) was put into operation in 2002.

Geothermal engineering company JSC “GEOENCOM” accomplishes engineering design of pilot binary geothermal power plant (2,5 MW)

RAO “UES of Russia” plans to construct Binary GeoPP (BGeoPP) using northern (in Kamchatka region) and southern (in Krasnodar territory) plant design.

Priority trends of Russian geothermal eneregetics development are geothermal district heating and integrated usage of geothermal fluid in diverse power technologies systems creation.

Advanced regions to develop geothermal technologies are Kamchatka, Kuril Islands, Northern Caucasus and Kaliningrad region.

HYDROGEN TECHNOLOGIES FOR RENEWABLE ENERGY SYSTEMS

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Hydrogen energy technologies are an important component of renewable energy systems for autonomous energy supply. One of the major components are solid-polymer electrolyte fuel cells and electrolyzers. Various variants of fuel elements with power of the individual module up to 5 kW are created and power plant for 10 kW is developed. Operating current density up to 1 A/cm^2 and efficiency of the batteries up to 60 % are realized. R&D on creation of new generation of PEM electrolyzers is carried out. Their advantage is high (more than 99,99 %) purity of hydrogen, low (less than 4,2 kWt*h/m^3) power consuption and an opportunity to receive hydrogen at high pressures (up to 13,0-16,0 MPa) without additional compression. Such electrolyzers are very perspective for autonomous renewable energy systems as they permit easily to solve hydrogen storage problem.

The problem of creation of highly effective and inexpensive PEM fuel cells and electrolyzers is complex scientific and technical task where nanomaterials and nanotechnologies play a significant role. Researches and developments have been executed in the field of polymer electrolytes (creation of membranes with nano-structural modification for high temperature operation and stable water balance), nanostructural electrocatalysts based on carbon carriers (platinum, platinum-palladium based on various types of carbon, nanotubes and nanofibers, including carbon carriers with chemically modified surface, possessing high chemical stability), technologies of nano-films (protective coatings) and so on.

Selective polymer and porous membranes developed in HEPTI permit to purify gases and liquids and concentrate gas components. Concentration of oxygen in air permits to increase PEM fuel cell efficiency.

Numerical modeling of optimum operation mode of electrolyzers and fuel cells in the renewables based power plants including safe operation modes are also carried out.

Developed in HEPTI hydrogen sensor and recombining (burning) systems are an important part on power plant safety.

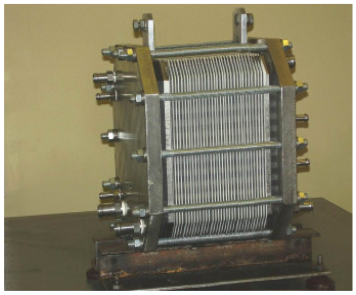

Fig. 1. Fuel cell with power up to 5 kW and electrolysis battery productivity up to 1 m^3/h (working pressure 3 MPa).Research was is executed at financial support of FASI (Rosnauka)

SOLAR CELLS AS HIGH-PERFORMANCE CONVERTERS OF MONOCHROMATIC ELECTROMAGNETIC RADIATION TO ELECTRIC POWER

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Known as solar cells semiconductor photovoltaic converters on the basis of silicon Si and gallium arsenide GaAs are one of the most relevant modern space power plants. Parallel with this solar cells are wide used in different terrestrial applications owing to their high reliability and ecological safety. Among these applications may be listed electric supply of houses, small ships, special solar cars, gauges of control systems for vehicular and pedestrian traffic in solar regions of the Earth, and others.

Unfortunately the main deficiency of photovoltaic converters is relatively low efficiency under solar illumination near 15% - 20% because only a small part of solar spectrum with energy higher then semiconductor bandgap energy ΔE is transformed into electric energy. One of the possible ways to increase solar array efficiency is the creation of semiconductor photovoltaic converters with multilayer structure where each bandgap is equal to energy of the definite part of solar spectrum. However this way has very great technological difficulties and so this type of solar array has a very high prize.

An alternative way to get more high efficiency of the standard solar cells is the use of monochromic electromagnetic radiation with radiation quantum hv is equal to bandgap ΔE for solar array illumination. In this case the efficiency of Si photovoltaic converters is of the order of 50% for the wavelength of monochromatic radiation λ equal to 1.06 μm and the efficiency of GaAs photovoltaic converters is of the order of 60% for the wavelength of monochromatic radiation λ equal to 0.8 μm. The increase of the bandgap ΔE leads to the abrupt increase of the solar cell efficiency that in one's part leads to very high nonlinear increase of the specific parameters of photovoltaic converters. If standard solar cells under solar illumination have specific parameters in the region of (200 – 250) W/m^2 of electric energy, in the case of monochromatic illumination their specific parameters increase to the region of (3 – 3.5) kW/m^2 of electric energy.

Preliminary analysis showed that standard solar cells under monochromatic illumination can be widely adopted in systems of centralized power supply of a spacecraft group. In this case it will be possible to provide an essentially irregular power mode of spacecraft with more efficiency than it can be provided by using onboard storage battery.

MULTICRYSTALLINE SOLAR SILICON PRODUCTION AS BASED FOR DEVELOPMENT OF PHOTOVOLTAIC INDUSTRY

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This report presents principal new technology direct production of multicrystalline solar silicon from high purity metallurgical silicon.

Multicrystalline silicon (MCS) is currently preferred for PV production: world-wide 60% of PV modules produced from MCS. This fact necessitates development of technologies to guarantee a sustainable supply of PV industry with a suitable silicon feedstock at acceptable costs. Therefore, the development of new technologies of solar silicon production, drastically reducing its cost, is the main problem to alternative technologies in the power industry. The mass production of solar energy systems requires development of new technologies of low cost solar grade silicon feedstock. High price of solar silicon itself hinders reducing the cost of a module. The requirements for purity of solar grade silicon materials are considerably lower than those for electronic grade silicon in microelectronics. Consequently, it is possible to produce solar grade silicon by the methods of oriented crystallization from refined metallurgical silicon produced by carbothermal reduction of super natural quartzite.

Primary experiment to receive high-purity refined metallurgical silicon with Si content about 99.9% was conducted with the purest quartzite in 25 MVA electric thermal furnace of “Kremny” Ltd. The furnace was specially prepared for experiments with a gradually forming skull to decrease the input of unexpected impurities into the reaction process. Low ash charcoal and high reactivity petroleum coke were applied for reduction process. The carbothermal reduction of silicon demands the silicon product to be enriched in heavy metals and carbon. Silicon produced in the furnace was tapped into a ladle, where the silicon melt was further refined by blowing oxygen or air. This procedure removes carbon from the melt nearly completely, as well as calcium and some other elements. Using the thermodynamic calculation of system Si-Fe-B-P-Ca-Al-H_2O-O_2-N_2, we determined the conditions to remove boron and other impurities from silicon by blowing gas through silicon melt. Our experiments verify the thermodynamic calculation results obtained.

The Stokbarger method was used for growing ingots of multicrystalline silicon. This process includes both refining metallurgical silicon from impurities and formation of silicon columnar structure. The diameter of columnar grains varies from 2 to 5 mm. Three main issues have been established. They are based on physical and chemical fundamentals of multicrystalline silicon production of solar cells. The silicon refining process is based on:

(i) low values of equilibrium coefficients of distribution of major impurities in silicon;
(ii) differential in vapour pressures of elements at the temperatures close to silicon melting point;
(iii) high vacuum. The paper describes in detail these issues and presents the basic features of multicrystalline silicon experimental samples.

The electro- physical parameters of the samples produced meet the requirements posed to silicon materials for solar cells (see table).

WASTELESS PLASMA MELT CONVERSION OF DOMESTIC WASTES TO SYNGAS

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NN	Properties	Value
1	Dimension	125*125*300; mm^3
2	Conductivity type	P
3	Resistivity, Ω*cm	1-3
4	Lifetime, μs	> 10
5	Block size of multicrystalline silicon, mm	> 2
6	Carbon concentration, cm^{-3}	$<10^{17}$
7	Oxygen concentration	$< 10^{18}$

Nowdays in Russian Research Center “Kurchatov institute” (in cooperation with Moscow State University of Ecology Engineering) a technology of wasteless refining of solid communal waste ballast fraction to synthesis gas (hydrogen) in the melted metal with the production of composition construction materials is being developed. Gasification of solid domestic and industrial waste, biomass, and black coal is a very urgent problem, because it provides not only the highly effective use of solid hydrocarbons as the energy (and) or chemical raw materials, it enables the possibility of the high standards observance, which are applied to energy technologies nowdays. Unfortunately, present gasification technologies have a number of shortcomings, that fact sufficiently restricts their broad application in technology.

It was shown that organization of the waste gasification process in which the gasification, biological sterilization, separation of flammable and non-flammable substances, as well as cleaning the acquired gas from the sulfur, sulfides and other contaminations carried out in one stage, with the synthesis gas mainly as a product of the gasification is possible. This can be achieved with the help of the plasma assisted gasification of hydrocarbons in the melted metal, when as a result of the oxygen and organic materials special interaction with the melted metal almost full gasification of organic materials and carbon with the formation of hydrogen and synthesis gas, melting and vitrification of mineral components and binding of the sulfur and other hazardous impurities takes place. Complete separation of flammable and non-flammable components facilitate the realization of the secondary processes of energy and composite construction materials production.

HEAT PUMP SYSTEMS IN RUSSIA
APPLICATION EXPERIENCE AND PERSPECTIVES OF DEVELOPMENT

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Report is devoted to evaluation of application perspectives of heat pump systems based on 15-year experience of JSC “Insolar-Invest” in installation and running of such systems.

- Accomplished projects review will be taken.
- Economical and energy aspects of heat pump systems use will be considered.
- Russian Federation territory zoning by efficiency of geothermal heat pump systems will be presented.

Cooperative actions on Russian heat pump systems market development will be proposed.

HYDROELECTRIC MICROPLANTS

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One of the most effective directions of nontraditional energetic development is usage of energy of small water flows by Hydroelectric Microplants (HMP). Hydroelectric Microplants are cheap and effective means of obtaining of the electric power. The cost price of the received electric power does not exceed 1.6 cents per kW/h. The costs of construction HMP pay off within 3-5 years.

Joint Stock Company INSET is specialised in development, quantity production, complete delivery and field installation of Hydroelectric Microplants with the outputs ranging from 3 to 100 kW and also of hydro-unites rated up to 5000 kW intended for small hydro power plants.

Hydroelectric Microplants supplied by INSET are reliable, environmental friendly, space saving, quick-repaid sources of power for villages, farms, suburban estates, mills, bakeries, small industries in hard-to-reach, mountain and remote areas, where it is cheaper to purchase and to install a hydroelectric microplant than to contract electric power lines.

The development of effective turbines concerns to the class of high technologies. Many technical solutions in this equipment have the patents and are developed by the scientists.

The equipment of INSET Co. is successfully maintained in many points of the world.