



LITHUANIAN ENERGY INSTITUTE



Annual report 2005

LITHUANIAN ENERGY INSTITUTE

is a state scientific research organization, created for carrying out the long-term scientific research projects important for Lithuanian economy, culture and international cooperation. The main activities of the Institute are scientific R&D activities.

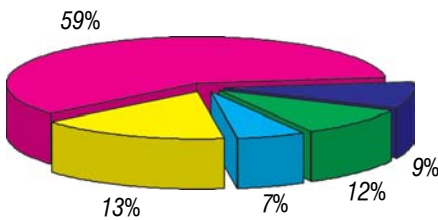
Strategic objective of the Institute is to act as the highest qualification expert in treating issues of science, engineering, metrology, safety of power industry and economics linked to efficient development of the Lithuanian energy sector.



Scientific activities in the Institute were carried out according to five research directions approved and financed by the Government of the Republic of Lithuania:

- I.** Development of energy economy planning methods, investigation of safety and reliability of power plants, their impact on the environment, efficient energy consumption and renewable energy sources.
- II.** Investigations in the fields of thermal physics, fluid mechanics and metrology.
- III.** Simulation of complex systems, development of their control methods and technologies.
- IV.** Investigation of energy systems' construction elements aging and development of new multifunctioned materials.
- V.** Investigations of combustion and plasma processes in the fields of fuel saving, reduction of environmental pollution and thermal decontamination of materials.

Distribution of researchers according to basic research directions



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Laureates of 2005 Lithuanian science prize – Eugenijus Uspuras, Kazys Kestutis Almenas, Algirdas Kaliatka, Sigitas Rimkevicius, Juozas Augutis. Prize awarded for fundamental and applied science research works “Deterministic and probabilistic research, engineering solutions and their implementation increasing safety and reliability of the Ignalina NPP (1994–2004)”.



Lithuania has been a member of the European Union for two years, therefore, Lithuanian researchers have more possibilities to participate in EU financed projects. Primary objectives of Lithuanian Energy Institute (LEI) have not changed. The most important ones are as follows:

- successfully integrate into European Research Area (ERA);
- ensure a high quality of fundamental research and technology works, which – would allow successfully collaborate with national and international business and industry representatives;
- improve quality management system of the institute.

In 2005 researchers of Lithuanian Energy Institute carried out 20 state funded research projects. Nine of them were successfully completed and approved. These works were financed by the Ministry of Education and Science of the Republic of Lithuania. Researchers of the institute actively participated in the calls of the Lithuanian State Science and Studies Foundation – more than 950 000 Litass were granted for

the implementation of science research projects.

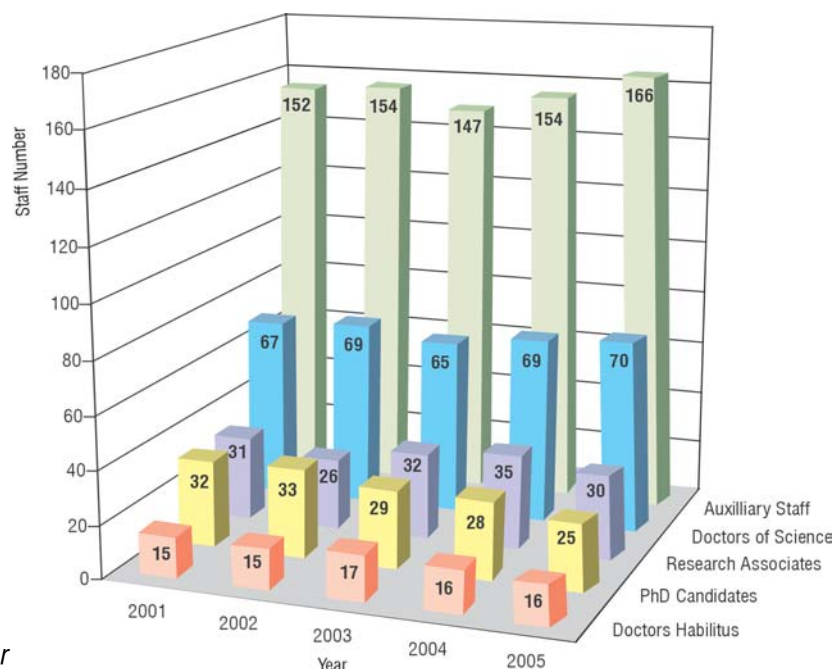
Researchers of the institute closely co-operate with Lithuanian authorities, institutions and private companies.

The main partners among them are: the Ministry of Economy of the Republic of Lithuania, the Ministry of Environment of the Republic of Lithuania, Ignalina Nuclear Power Plant, SC *Lietuvos energija*, SC

Lietuvos dujos, SC *Achema*, State Nuclear Power Safety Inspectorate (VATESI), Klaipėda State Seaport, and Kaunas city municipality. Some of those projects were implemented together with the scientists from United Kingdom, France, Germany and other countries.

Lithuanian Energy Institute together with Lithuanian science institutions and industry and business organisations car-

Title of the completed project financed from the state budget	Direction of scientific activity	Leading researcher
<i>Risk Assessment and Control for Energy Plants</i>	<i>I</i>	<i>Prof. Dr. Habil. J. Augutis</i>
<i>Investigation of Condensation Implosion Event Initiated by Hydrodynamic Instability</i>	<i>I</i>	<i>Dr. M. Seporaitis</i>
<i>Efficiency Evaluation of Solid Biomass Usage for Energy Production in the Country</i>	<i>I</i>	<i>Dr. S. Vrubliauskas</i>
<i>Investigation of Heat and Mass Transfer Processes in Metal Oxides Coating</i>	<i>III</i>	<i>Dr. V. Valincius</i>
<i>Evaluation of Social and Economical Factors Integrating Renewable Energy Projects into Regional Development Programmes</i>	<i>I</i>	<i>Dr. Habil. Klevas</i>
<i>Research of Optimisation and Functioning of Power Systems Control Algorithms and Information Systems with Respect to Electricity Market Performance</i>	<i>IV</i>	<i>Dr. R. Andruskevicius</i>
<i>Investigation and Assessment of Implementation and Usage of Advanced, Energy Efficient Technique, Means and Technologies in Industry and Buildings</i>	<i>I</i>	<i>Dr. R. Skema</i>
<i>Modelling of Power Plants Effective Operation, Taking into Account Local Conditions and Wind Energy Parameters Investigation Data</i>	<i>I</i>	<i>Prof. Dr. Habil. V. Katinas</i>
<i>Modelling of Sustainable Energy Development</i>	<i>I</i>	<i>Dr. Habil. V. Miskinis</i>



Variation of staff number

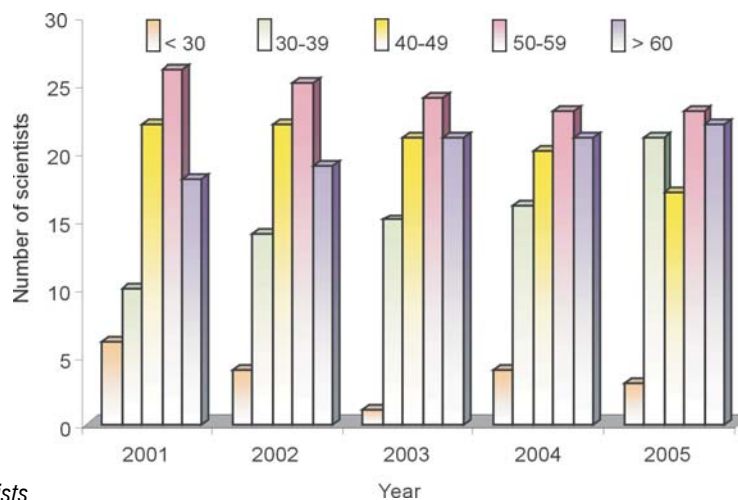
ried out over 100 projects and this comprised approximately 75% of finance resources of contracting projects. Together with the contractors the most relevant issues of nuclear safety, energy strategy creation and its development of the Republic of Lithuania, energy control, energy economy model of municipalities, and usage of renewable energy sources were solved. Issues of future technologies development of hydrogen storage, high-temperature thermoisolation materials, materials utilization by plasma, industrial plants safety, and Ignalina NPP decommissioning issues were tackled as well. The institute has developed and maintains four state metrological standards, and tackles issues of climate change, Lithuanian rivers hydrology, Baltic Sea nearshore, the Curonian Lagoon and the Kaunas Sea.

Researchers of the Institute as in previous years actively and successfully participated in the EU financed programmes. Up to the end of 2005 researchers of the institute with partners from different countries completed ten large-scale projects financed from the funds of the EU Fifth Framework Programme. One project of this programme is continued. Moreover, LEI implements three projects of INTERREG III, two projects of SAVE II, several projects of EUREKA, COST, and PHARE, and even seven projects of *Intelligent Energy for Europe* programme. Contracts of eight projects of *Intelligent Energy for Europe* programme are signed and work will be initiated in

2006. These are rather good results. However, the integration of the institution into the most significant EU research programme – Sixth Framework Programme speaks of the true scientific potential and perspectives of science and studies institution. The institute has been successfully participating in the implementation of this programme. In accordance with information of Agency for International Science and Technology Development Programmes, LEI researchers submitted 38 projects proposals for the Sixth Framework Programme, out of which 12 projects received the EU funding. In such way, a success index of the submitted projects proposals of the institute for the Sixth Framework Programme is rather high – 32%. In comparison: Lithuanian science and education institutions for this programme were coordinators and partners for 1026 project proposals, 209 out of which received the funding, thus, their success index is approximately 20%. The institute was one of the most active Lithuanian science and education institutions according to the submitted projects proposals for the Sixth Framework Programme, and one of the leaders according to the granted Sixth Framework Programme funds. In accordance with the number of implemented Sixth Framework Programme projects, LEI is an unquestioned leader among Lithuanian science and education institutions, and according to this index, only Kaunas University of Technology and Vilnius University surpass LEI. Scientists of the institute together with

partners from best European research centres implement Sixth Framework Programme projects, devoted for the research of NPP severe accidents phenomenology (SARNET), hydrogen energy (NENNET, FET-EEU, HYTRAIN and NESSHY), new and renewable energy sources (CEERES), and energy social-economical (NEEDS, EIFN, SOLID-DER and CASES) issues. It should be noted that in 2005 the institute was the first Lithuanian science and education institution to join the EU Sixth Framework Programme thermonuclear synthesis research programme FUSION, the aim of which is to develop an operating industrial thermonuclear reactor. Currently researchers of the institute successfully implement two FUSION projects, devoted for the assessment of hydrogen release during the accident in experimental thermonuclear reactor ITER and for the research of properties of materials used for the production of thermonuclear reactors. More detailed information on the above mentioned projects, their implementation and results are presented in other sections of this annual report.

Aiming at high quality of science and technical works, a close synergetic connection between fundamental research and science applied works is required. Fundamental research results cannot be achieved without state-of-the-art measurement equipment and special software of the highest level. In 2005 the institute spent approximately one million Litass for the ex-



Dynamics of age of scientists

pansion of research equipment, i.e. 2.5 times more than in 2004. From these funds Laser Doppler anemometer, vacuum thin film deposition system, wind parameters measuring equipment, steam generation system, standard precision balance, and other experimental and special software, were purchased. However, state-of-the-art experimental equipment and software itself do not determine significant research results. Therefore, considerable attention was given to the increase of qualification and competence of scientists and to young gifted researchers. The average age of the institute researchers reduces, but at the same time the optimum balance between experience and youth enthusiasm is preserved. In other words, ratio between researchers, the age of who is over 50 and younger, remains 'fifty/fifty'. The above mentioned factors allowed ensure a high quality of science and technical works, in accordance with the agreements with national and international business partners, eight million Litass of income was received. It should be noted that since 2002 the insti-

tute has received income for 1.5 times more from the contracts with industry and business enterprises and from international contracts than grant from the State budget. Denying the myth that Lithuanian Energy Institute earns the greatest part from contracts with Ignalina NPP, we should highlight that income of contracts with other Lithuanian and foreign enterprises in the structure of contract works has never been smaller than 70% of total income from contractual projects.

Currently research institutions as well as industry enterprises cannot expect contracts without having certificates from supervising institutions to implement a certain activity and not implementing quality management system in an institution, corresponding to the requirements of ISO 9000 series standards. Lithuanian Energy Institute was the first Lithuanian science and education institution to implement the quality management system. Lithuanian Standardization Department on February 17, 2004 issued a Certificate *Institute's Qual-*

ity Management System, which corresponds to the requirements of LST EN ISO 9001:2001. This system is constantly improved, therefore, the repeated quality management audit on November 17, 2005 was successful as well. Implementation of quality management system in the institute as well as high qualification of researchers made it possible to get licence from Lithuanian State Nuclear Safety Inspectorate, which empowers to perform nuclear safety analysis and safety assessment in the field of nuclear energy of the Republic of Lithuania. Moreover, on June 20, 2005 state enterprise Ignalina NPP issued a certificate to Lithuanian Energy Institute, which empowers to perform safety analysis and safety assessment in state enterprise Ignalina NPP. The certificate is valid till June 20, 2008. In accordance with the decision of Lithuanian State Energy Inspectorate on August 20, 2005, the institute was granted certificates to implement works, related to the operation of heat equipment and turbines, oil and oil product

In 2005 Kaunas University of Technology together with Lithuanian Energy Institute conferred Doctor of Science degree in the field of power and thermal engineering for six researchers of the Institute:

- on March 9, Arturas SMAIZYS for his work **Analysis of the Nuclear and Radiation Characteristics of the Spent RBMK-1500 Nuclear Fuel Storage Casks and Radioactive Waste Storage Facilities.**
- on May 5, Vilma SNAPKAUSKIENE for her work **Research on Properties of Catalytic Coatings Formed by Plasma Spray Technology for the Acceleration of CO Oxidation.**
- on May 5, Egidijus NORVAISA for his work **Modelling and Analysis of Sustainable Development of Lithuanian Power and Heat Supply Sectors.**
- on June 30, Jurgita GRIGONIENE for her work **Investigation of District Heating for Residential Sector.**
- on June 30, Andrius KAVALIUSKAS for his work **Straw Combustion in a Packed Bed.**
- on November 25, Ramunas GATAUTIS for his work **Mathematical Modelling of Cogeneration Power Plants and Energy Transmission Networks in Electricity and District Heating Markets.**

Senior Research Associate Dalia Streimikiene prepared the overview of works **Solution of Environmental and Social Problems by Overcoming Energy Market Failures** and successfully complete habilitation procedure at Vilnius Gediminas Technical University on December 21, 2005.



facilities, natural gas facilities and liquid gas equipment.

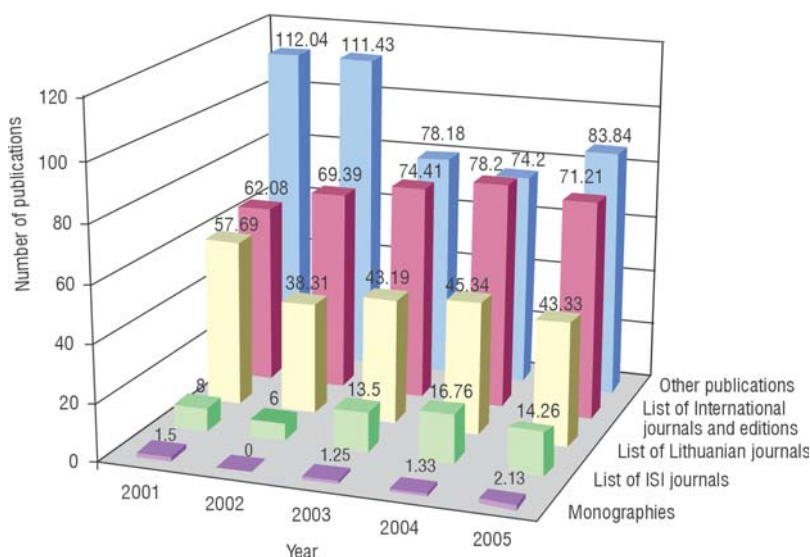
2006 is the completion year of the EU Sixth Framework Programme. In the period 2007-2013 new Seventh Framework Programme, the budget of which is 2-3 times larger than the budget of the Sixth Framework Programme, will be implemented. In order to successfully integrate into the Seventh Framework Programme,

LEI together with other Lithuanian science and education institutions must properly analyse the experience and lessons of the Sixth Framework Programme. It is relevant to participate actively in formation of Technological Platforms and propose institute representatives for the already existing Technological Platforms, which will be one of the most significant instruments of the Seventh Framework Programme.

Finishing with year 2005, it should be noted that the forthcoming year 2006 for the Institute is an anniversary year, marking the 50th anniversary of the establishment of the institute.

All these years were full of hard work, formation of research directions as well as expedient adjustment and dynamics of those directions, taking into account the challenges and time relevance. For the institute they were famous for significant and highly worldwide recognized research results in the field of thermal physics, energetics, hydrology, materials science, technical cybernetics, other. All this, and ultimately, profound experience – competence undoubtedly had impact on the relevance and trends of today research as well as on the successful development of nuclear power and solutions of its safety issues, on Lithuanian energy usage, its management, ecology and renewable energy sources usage. Key mission of the institute is to deal actively with this wide spectrum of issues in the context of the country and the European Union.

Variation of publications number
(Author's contribution evaluated)



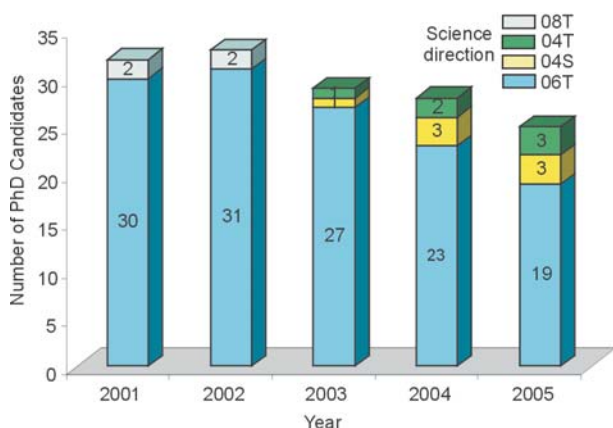
Director of the Institute
Prof. Dr. Habil. Eugenijus Uspuras

PHD STUDIES

Since 1992 up to 1998 Lithuanian Energy Institute had an authority to award doctor's degree in the following science directions:

- Energetics and thermal technology (7D);
- Materials science (08T);
- Geography (hydrology) (2D).

Distribution of Lithuanian Energy institute PhD Candidates according to the science directions



Since 2004 annual conference *Youth Energy* of PhD Candidates and young scientists has been organized. It is aimed at educating young researchers' ability to present their ideas and research results in public, defend them reasonably and discuss, listen to remarks and recommendations of other scientists, prepare articles and get acquainted with works of their colleagues.

PhD Candidates of other universities and institutes are invited to participate in the conference. In 2005 the conference was attended by 24 PhD Candidates: 18 – LEI, 2 – Kaunas University of Technology, 2 – Vytautas Magnus University, 2 – Vilnius Gediminas Technical University.

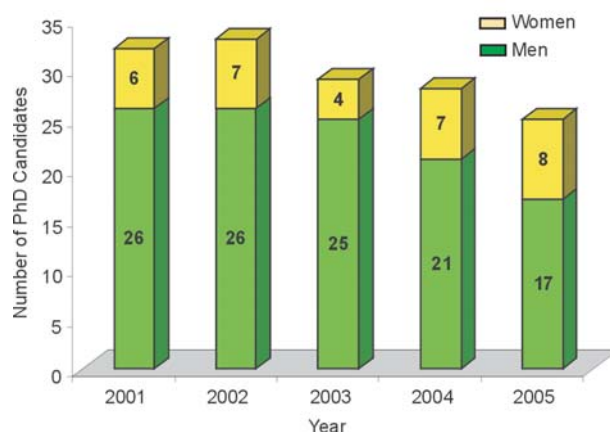


At the conference "Youth energy 2005"

Since 1998 after the change of the Regulation of PhD studies in the Republic of Lithuania, Lithuanian Energy Institute together with Kaunas University of Technology has had an authority to award doctor's degree in the field of technology sciences, energetics and thermal engineering direction (06T). Since 2003 Lithuanian Energy Institute has the integrated PhD studies together with Kaunas University of Technology in the following science directions:

- Economics(04S);
- Environmental engineering and regional management (04T);
- Power and thermal engineering (06T).

1992–2005 45 PhD Candidates completed PhD studies, doctoral theses were defended by 32. Thus, performance of PhD studies – 71%.



Considerable attention in the institute is given to the increase of employees' competence and qualification, favorable conditions are created for PhD Candidates and young scientists to go on traineeships abroad or attend conferences, to improve English language. In 2005 out of 303 international traineeships trips of MSc and PhD Candidates comprised 59. The same amount of traineeships trips had young scientists (up to 35 years age). 17 PhD Candidates and 10 young scientists participated in seminars and traineeships abroad. Two scientists had longer internships: R. Krikstolaitis at the Institute for Transuranic Elements, Karlsruhe, Germany (for 6 months) and V. Matuzas at Brussels University, Belgium (for 2 months).

Main directions of the Laboratory research:

- research of solid biomass usage for energy production;
- research of wind power parameters' change as well as wind power plants modelling taking into account local conditions;
- analysis of contemporary technologies application using local and RES, – technical economical assessment of their usage, research of environment issues;
- preparation of accredited training courses, formation of data basis, services and consultations for users.

In 2005 research, related to RES (of biomass, sun, wind, other) usage in heat and electricity production, was performed at the laboratory. National and international programmes, related to the usage of local energy sources as well as improvement of environment safety conditions, taking into account the Directives of the EU Council and Parliament, also solving tasks as foreseen in the Kyoto Protocol, the EU White Book and in other international documents, were implemented. In Lithuania RES comprise approximately 8.2% of the total primary energy balance, whereas electricity production out of these sources comprises only approximately 3.7% from all the amount of electricity energy consumed in the country. In order to implement the requirements of the EU Directive 2001/77/EC (in 2010 to produce 7% of the consumed electricity energy from RES) it is necessary to use various types of RES types at a large scale. Most of attention is paid to the

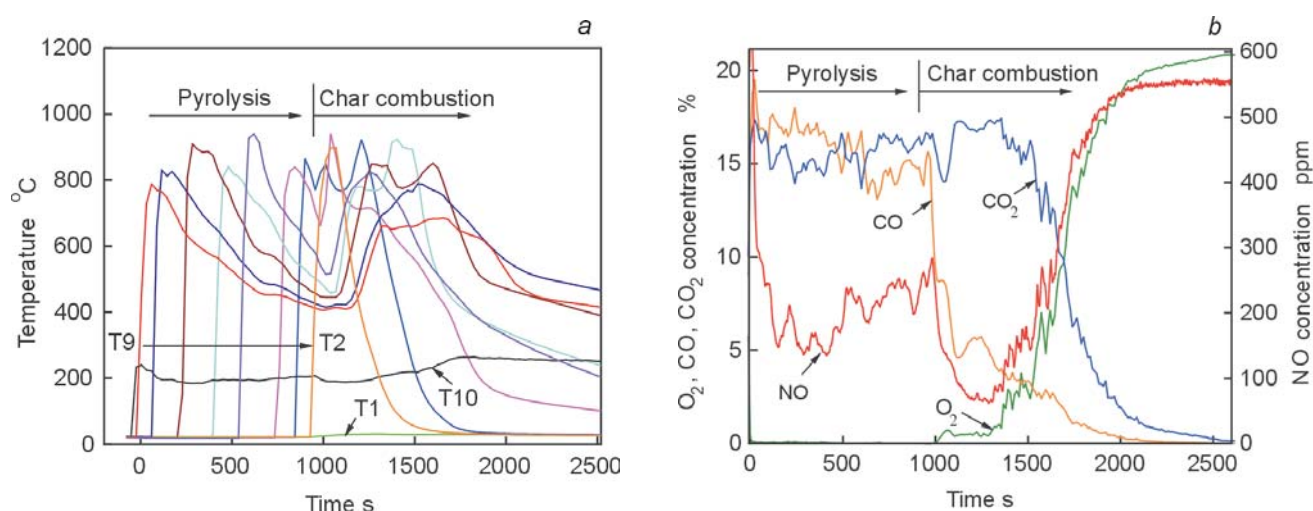
research of efficiency of solid biomass usage for energy production since solid biomass has lately been widely used in the country's energy sector. Consumption of solid biomass, especially wood, in large boiler-houses of district heating supply and industry enterprises constantly increases and in 2004 was equal 694.4 ktne (thousands of tons of oil equivalent), and this comprises approximately 80% from the existing wood sources.

Research of efficiency of solid biomass usage for energy production

At the Laboratory research is performed, related to the rational usage of biomass sources for biofuel production as well as to the possibilities of efficiency increase in its process of conversion into energy. Information on biomass sources and their usage in biofuel production, covering all cycle from raw material collection, prepa-

ration, reproduction into solid biofuel and burning in furnace of different types of boilers, are accumulated and analysed. Considerable attention is given to the issues of solid biofuel quality and standardization.

Laboratory personnel actively participates in the activity of 71st Technical Committee *Solid Biofuel*, translating into Lithuanian the EU standards and validating them at the national level. Methodology of solid biofuel quality assurance system, taking into account the requirements of projects of standards prepared by the European Standardization Committee, is prepared. Experimental research of solid biomass combustion processes under laboratory conditions and real boiler furnaces are performed. Using the equipment of Combustion and Harmful Emission Control Research Center, Technical University of Denmark (Department of Chemical Engineering), experiment of straw combustion in a grate furnace, using cut and whole



Distribution of flame temperature (a) and combustion products concentration (b) in the fuel bed during straw combustion process



Bioreactor of JSC "Lekeciai", Lithuania biogas power plant

straw and its pellets, is carried out. Impact of the amount of air supplied into the furnace, oxygen concentration, air preheating as well as straw moisture on the combustion process and characteristics defining it, i.e. combustion velocity, temperature and formation of pollutants, is determined.

Boiler *Kalvis 5-16DG*, heated with wood pellets, was purchased together with the laboratory of Heat-equipment Research and Testing. Research methodology was developed and tests were performed at different loads under standard conditions, using different pellets, also using additional air draught regulation means.

Economical and environmental protection efficiency research of biogas and biofuel production and usage

Biogas. Anaerobic treatment technologies are one of the most effective organic waste utilization measures, which are directly related to the reduction of environment pollution. Without these technologies it is almost impossible to implement the environment protection requirements for the manure treatment, in accordance with order No. D1-367/3D-342 of the Ministry of Environment of the Republic of Lithuania, July 14, 2005. Therefore, the laboratory performs the applied research of this trend.

Alongside with the most important purpose of biogas power plants – to reduce environment pollution with liquid organic waste, it is also important that their usage contributes to the implementation of Directives recommendations of the EU Parliament and Council. One of them – **Directive 2001/77/EC – on the promotion of electricity from renewable energy**

sources in the internal electricity market, and other – Directive 2004/8/EC – on the promotion of cogeneration based on a useful heat demand in the internal energy market.

Analysis of the existing situation, overall assessment of biogas power plants technical-economical activity were performed, actual efficiency of energy production from organic waste was investigated, possibilities of the development of these technologies in the country were revealed as well. In the past two years biogas power plant was built in Sakiai region, JSC *Lekeciai*. Bioreactor volume of this biogas power plant is 2000 m³, power capacity – 0.6 MW, heat capacity – 0.9 MW. Thus, the use of biogas increases in the country, however, insignificantly.

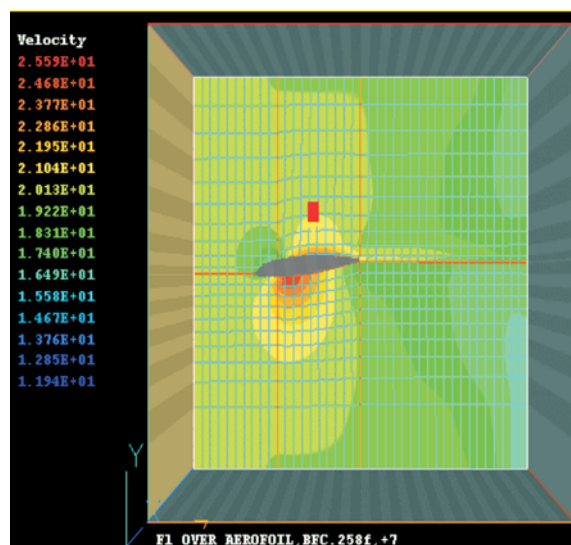
Methodical recommendations for the country's enterprises are prepared on the implementation of efficient energy production from organic waste technologies, corresponding to the most important environment protection requirements and thus

contribute at maximum to the responsibilities of the Republic of Lithuania while implementing the recommendations of the EU Directives.

Biofuel. The laboratory personnel for a number of years have been participating in implementing applied research works in the field of biogas production industry creation. For the moment biodiesel and bioethanol factories are operating in Lithuania. However, further development of biofuel industry is vague, therefore it is necessary to renew and continue research of issues essential for biofuel industry development. Lithuanian Government aiming to implement directives of the European Parliament and European Council regarding regulations of promotion of usage of biofuel and other RES in transport, and reduce the country's energy sector and economical dependence from the imported fuels, made of oil, which are constantly getting more expensive, pays a lot of attention to the development of this industry branch. At the Laboratory research of technical-economical and cost price reduction possibilities of motor biofuel with bioethanol additives were performed, the overview of ecological biofuel standards was carried out, research of their technical-economical characteristics as well as impact on cars' components was forecasted, research of possibilities of biofuel production and usage balancing were performed.

Research of wind energy parameters change and modelling of power plants operation, taking into account local conditions

Lithuanian metrological stations arrangement net annual observation data and other measuring information were em-



Wind velocity distribution on the surface of power plant blade profile

ployed for the analysis of wind energy parameters. Wind parameters measurements were performed in Klaipėda region, using contemporary wind parameters measurement equipment *Wicom-C* of Giruliai Radio Television Station. Numerical modelling of wind power plants crossflow was performed, employing PHOENICS 3.5 programme.

Generalizing the existing and measured wind integral parameters data, wind atlas of Lithuanian terrain was formed. It was determined that the prevailing wind directions were north-west and south-east. Reliability of wind power plants work and elements depended on the following basic wind parameters: maximum velocity, annual average velocity and turbulence as well as extreme wind-flaw parameters.

Numerical modelling of wind power plants at various crossflow conditions aerodynamic characteristics – wind vector fields, pressure and kinetic turbulence energy were performed in Cartesian and curvilinear coordinates. Peculiarities of the

finite size obstacles' crossflow was analysed, taking into account the impact of wind turbulence pulsations, wind-flaws and other parameters. It was determined that wind energy conversion into the mechanic one is determined by the extent of air mass turbulence, which largely depends on the roughness of the ground surface and relief. With the increase of these sizes conversion coefficient decreases as well. Construction parameters of wind power plants were analysed, their selection method was created, environment protection requirements for equipment of wind power plants were analysed. Criteria for the selection of wind power plants construction areas were determined. Calculation methodology of the arrangement of power plants and occupying earth area in wind power plants' park was prepared. Technical-economical analysis of wind power plants' equipment was performed. Investigation is important while making detailed plans of wind power plants construction, safe work standards as well forecasting perspectives of wind power development in the country.



A small wind power plant in Juragiai, Lithuania

International projects and programmes related to RES usage were carried out in the Laboratory in 2005:

- **Development of constructive solutions of new generation wind power plants.** Project implemented in accordance with the bilateral collaboration scientific research programme (2005–2006) between the Republic of Lithuania and Ukraine;
- **Investigation of possibilities of technical-economical and cost price reduction of motoring ecological fuels with bioethanol additives.** Project implemented in accordance with the bilateral collaboration scientific research programme (2005–2006) between the Republic of Lithuania and Ukraine;
- **Large-scale integration of RES-E and co-generation into energy supplies in new EU countries.** EU 6th Framework Programme (2005–2006);
- **Regional Bioenergy Initiatives around Europe.** EU ALTENER project (2003–2006);
- **Extend Accredited Renewables Training for Heating (EARTH).** EU programme *Intelligent Energy for Europe* project (2003–2006);
- **Service Buildings Keep Cool-Promotion of “sustainable cooling” in the service Building sector (Keep Cool).** EU programme *Intelligent Energy for Europe* project (2003–2006);
- **Baltic biomass network.** Project implemented in accordance with INTERREG III B programme (2005–2007).

Implementing general projects together with the institutions of other EU countries, research of biomass, biogas, wind, biofuels and other RES sources and new technologies implementation, were performed, including research of cogeneration power plants integration processes into the country's energy sector, covering analysis of possibilities of local and renewable energy sources usage in co-generative power plants' development as well as implementation of the requirements of the European Parliament and Council Directives 2001/77/EU and 2004/8/EC. Cooper-

ating with Germany, Denmark, Poland and other Baltic countries' science centres, research of bioenergy development perspectives in European regions is performed. Implementing project due to INTERREG III B programme main attention was paid to the evaluation of biomass sources, research of possibilities of their development, spreading growth of energy plants in unused Lithuanian earth, also planting new areas of woods.

In 2005 Laboratory researchers published four articles in science journals and

two science popularisation articles. They also participated in three international and six Lithuanian science conferences, one doctoral thesis was defended.

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ENERGY EFFICIENCY RESEARCH AND INFORMATION CENTER

Main activities of the Center:

- to compile, analyse and provide to experts and society the experience of efficient energy consumption in Lithuania and worldwide;
- projects for the realisation of National Energy Efficiency Programme;
- participation in international projects, organization of conferences and training courses.

Implementing its research programme, according to the determined basic science work directions, the center implements the following programme objectives:

- compiles and analyses information concerning energy sources, efficient generation of various kinds of energy, energy distribution and consumption, provides information and consults on these subjects;
- investigates utilisation possibilities of renewable and waste energy sources and propagates their significance in Lithuanian economy sector;
- executes energy audits in energy enterprises, industrial enterprises and buildings; assists in implementing means, which enhance energy consumption efficiency;
- participates in preparation and implementation of the National Energy Efficiency Programme, prepares energy saving legal acts and standard specifications;
- takes part in international projects related to the development of energy sector efficiency;
- arranges seminars, conferences and courses on efficient energy consumption, develops publishing activity related to efficient energy consumption and promotion of new energy technologies.

In 2005 the project ***Investigation and assessment of implementation and usage of advanced, energy efficient technique, means and technologies in industry and buildings***, financed from the state grant, was completed.

New data on the consumption of fuel and energy in Lithuania and its industry in the period of 2000-2004 was presented in the work, a thorough analysis of such data was performed. Energy audits were performed in the chosen water supply enterprise using state-of-the-art research methodologies. The possibilities of energy efficiency increase in this enterprise were determined on the basis of the performed experimental research. Up to 50% of consumed power in individual water supply and waste-water elimination pump-houses by performing their modernization can be saved. Payback time of the proposed energy saving measures does not exceed two years.

The possibility to use the waste heat, existing in the exhaust gases, cooling them

lower dew point temperature, in heat production industry, burning natural or liquid gas and biofuel in different energy boilers, was analysed. In the work the overview of literature of condensing economizers, used in foreign countries, and designed for the usage of waste heat, was performed. The possibilities of energy consumption efficiency increase by implementing condensing economizers in operating boilers were presented on the example of Anyksciai town Lower part boiler-house. Economical and technical efficiency of implemented and operating condensation economizers was analysed. Calculation methodology for the selection and design of such economizers was prepared and presented.

Assessment of the possibilities of energy consumption efficiency increase in buildings was carried out. By using contemporary methodologies, impact of heat stations modernization on the energy consumption in two types of the prevailing dwelling-houses (five floors and nine floors) was evaluated. The impact of heat

station and building renovation on the microclimate of premises in Lithuanian Energy Institute (research carried out in ten workrooms, library and experimental hall) was evaluated.

By implementing work for ***the Realization of National Energy Efficiency Programme***, series of legal documents for Heat Law was continued to be prepared.

Project on the regulations of heat equipment installation and safe operation and the project on the regulations of renewed heat energy accounting design, installation and safe operation were proposed.

Methodology for biofuel (wood, straw, municipal waste) accounting in energy production sources was made.

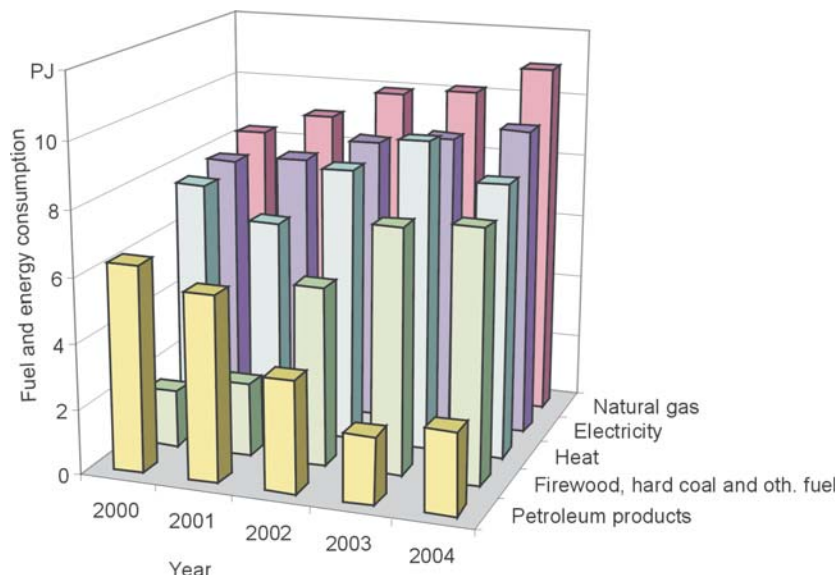
Expertise assessment of operating boilers (total 7) of Jurbarkas hospital, JSC *Jurbarko komunalininkas* and JSC *Baisiogalos bioenergiija* as well as price calculations of their supplied heat, in accordance

with the requirements of National Control Commission for Prices and Energy in Lithuania, were carried out.

Expertise assessment of possibilities of cogeneration power plant with micro-turbines in Birstonas town boiler-house was performed.

Partial expertise of wood waste – shaving, sawdust and lignine – assortment, desiccation, pressing line project and building by the order of JSC *Minties jėga* was carried out.

In the contract with Vilnius town second locality court, documental heat supply expertise in the civil case was carried out.

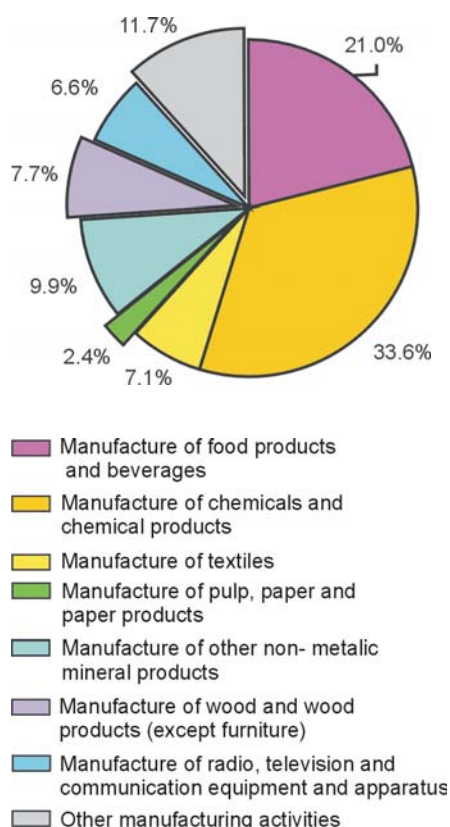


Changes of fuel and energy consumption in industry in 2000-2004

In 2005 the following international projects were carried out:

- **Data comparison and energy management schemes in small and middle size enterprises.** The project was implemented in accordance with the EU programme *Intelligent Energy for Europe* together with partners from 11 countries. Duration of the project – 28 months. The primary objective of the project – to develop and promote usage of energy management in SMEs, improving energy consumption efficiency and orienting towards the industry of food products and beverages. It is aimed to create a positive attitude towards innovative decisions, guaranteeing undisruptive connection of SMEs with energy management and efficient energy consumption. For the implementation of the objectives an international internet page was created <http://www.bess-project.info>. It is expected that the means will help to reduce production cost-price, energy consumption efficiency and implement the environmental protection responsibilities of the Kyoto Protocol.
- **Integration of electricity production from RES into the EU network with least expenses.** The project was implemented in accordance with the EU programme *Intelligent Energy for Europe* together with partners from 19 European countries. The perspective of electricity production from RES in Lithuania up to year 2020 was evaluated in the project.
- **Clearing House for Third Party Financing in Eastern Europe.** Project performed in accordance with the EU SAVE programme together with partners from eight Central and Eastern Europe countries. In the project financing possibilities of energy saving projects were evaluated, applying the so-called *third party financing schemes*. Projects of legal documents (energy activity agreement, energy supply agreement, etc.) necessary for the usage of these schemes in Lithuania were prepared.
- **Development and application of efficiency of electricity engines usage.** Project performed in accordance with the EU programme *Intelligent Energy for Europe* together with partners from 15 European countries. In the work efficiency of electricity engines utilization in water supply enterprises was analysed. Means were proposed for the reduction of electricity energy consumption in these enterprises.

Distribution of industrial final energy consumption according to activities in 2004



Research results of 2005 were published in five scientific articles. Four papers were presented at international and Lithuanian conferences. Seven seminars on efficient energy consumption, with the participation of representatives from Denmark, Sweden and other countries, were organized.

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LABORATORY OF HEAT-EQUIPMENT RESEARCH AND TESTING

Main directions of scientific research and applied work of the Laboratory:

- provision of metrological support to the Lithuanian energy sector in the field of fluid flow measurements, establishment and maintenance of state flow standards and ensuring measurement traceability to national and international standards;
- test of thermal equipment and gas appliances carried out with the aim to determine its conformity to the requirements of Lithuanian and European normative documents;
- application of theoretical and experimental methods, relating flow hydrodynamic parameters investigations, to metrological parameters of unique reference facilities and working standards and measuring instruments;
- investigation influence of liquid physical properties and flow disturbances on the metrological characteristics of reference and working volume and flow rate meters, operating under different principals. Proving the reliability of metrological characteristics of meters calibrated by fluids-substitutes for measuring real flow of technical and nutritional liquids;
- scientific research in order to develop methodologies of liquid and gas flow measurement, to determine the impact of influence factors on measuring accuracy and forecast non-balances of energy supply and consumption.

The Laboratory, performing the authorization of the Government of the Republic of Lithuania, investigates and develops four state standards, comprising of six different reference aerodynamic and hydrodynamic facilities, designed for the reproduction of air velocity from 0.2 up to 30(60) m/s and air volume and flow rate from 0.005 up to 9700 m³/h, water up to 50°C volume and flow rate from 0.01 up to 100 m³/h, liquid oil products (fuel) volume and flow rate from 1 to 120 m³/h unit values and transfer them for working standards.

State standard facilities created in the Laboratory and their basic technical characteristics



Air(gas) velocity units (0.2-60 m/s) state standard

Reference measurement instruments: static Pitot tubes, convergent nozzles and ultrasonic anemometer and laser-Doppler anemometer, purchased in 2005. The best measurement capabilities of velocity: $\pm (7.0-1.0)\%$, when $v = (0.2-60)$ m/s



Air(gas) volume and flow rate (Part 2: 5.7-308.8 m³/h) units state standard

Reference measurement instruments: 5 critical nozzles. The best measurement capability of volume: $\pm 0.17\%$



Air (gas) volume and flow rate (Part 3: 1-9750 m³/h) units state standard
Reference measurement instruments: rotary displacement and turbine gas meters. The best measurement capabilities of volume: $\pm 0.25\%$, when flow rate (1-1600) m³/h and $\pm 0.30\%$, when flow rate (1600-9750) m³/h



Air(gas) volume and flow rate (Part 1: 0.016-16 m³/h) units state standard
Reference measurement instrument: bell type prover.
Working volume – 0.340 m³.
The best measurement capability of volume: $\pm 0.13\%$



Water volume and flow rate (0.01-100 m³/h) units state standard
Reference measurement instruments: reference scales – 60, 600 and 1500 kg. The best measurement capabilities: volume $\pm 0.08\%$ and flow rate $\pm 0.12\%$



Oil products' volume and flow rate (1-120 m³/h) units state standard
Reference measurement instruments: reference volume standards 0.5, 2 and 5 m³ and liquid fuel meters. The best measurement capabilities: volume $\pm 0.12\%$ and flow rate $\pm 0.15\%$

All these standards created at the laboratory correspond to the international level, satisfy basic and most significant metrological needs of Lithuanian economy and science. Calibration and measurement capabilities of laboratory standards were evaluated positively at the international technical committee FLOW of EUROMET organization and were confirmed by authorities of BIPM.

The most significant projects in the field of scientific investigations are related to the development of state reference facilities, especially in reproducing values of small velocities and flow rates.

The Laboratory participated actively in implementing the directives of the European Parliament and of the European Council in Lithuania, related to the conformity assessment of gas, water and liquid fuel meters, as well as water boilers and gas appliances. New facilities were created for testing meters and subassemblies. The field of meters calibration was extended and accredited. Accreditation scope for testing water boiler and gas appliances was extended, following standards, which implement 92/42/EEC and 90/936/EEC directives.

Issues of efficient burning of renewable energy sources' fuel and pollution reduction remain relevant, therefore, the laboratory proceeds with the research of efficiency and pollution of equipment burning wood fuel in order to give advices and support for the enterprises that produce these equipments.

Works are not yet completed in the testing field since it is not prepared for the implementation of requirements for directive 2004/22/EC of the European Parliament and of the European Council on measuring instruments, 10 measuring instruments, including water, gas and liquid (non water) meters, before placing them on the market, which comes into force 31-10-2006. Laboratory actively participates in preparing technical regulation and technical basis for the testing of gas, water, heat and liquids (non water) meters and for the assessment of meters conformity with relevant requirements.

Test facilities developed in the Laboratory



Heat equipment up to 400 kW test facility



Cold and hot water meters (flow rate up to 10 m³/h) test facility



Turbine gas meters (flow rate up to 1000 m³/h) test facility



Domestic gas meters test facility with climatic chamber

It should be mentioned that laboratory personnel is included into the conformity assessment infrastructure development programme, the purpose of which is not only to create conditions for producers and suppliers of measuring instruments, but also to perform measuring instrument type examination and conformity to the type assessment.

The Laboratory performed the assignment of Economy Ministry of the Republic of Lithuania and in 2005 became the notified institution No 1621 for conformity assessment in accordance with modules of directives 92/42/EEC *New Hot-water Boilers Fired with Liquid or Gaseous Fuels* and 90/936/EEC *Appliances Burning Gaseous Fuels*.

Research development and personnel qualification

Generalizing the Laboratory activity in the field of liquid and air (gas) measurements, it should be noted that it is not limited to practical services supply, but covers a much wider field of science and applied works:

- research of flow hydroaerodynamic parameters and their relation with metrological characteristics of reference facilities, working measurement standards and measurement instruments;
- investigation of impact of fluid physical properties and influence factors on measurement accuracy of flowing fluid volume and flow rate;
- performance of interlaboratory comparisons of flow measurements with state laboratories of EUROMET organization members;
- publication of scientific and information data. In 2005 eight science and two science popularization articles were published.

The Laboratory personnel are comprised of 30 employees, including 10 research associates (among them 1 Dr. Habil. and 6 Dr.), 3 PhD Candidates and 12 highly qualified engineers.

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LABORATORY OF COMBUSTION PROCESSES

Main directions of scientific activities:

- efficiency increase of combustion processes;
- creation and development of burners;
- research of hydrogen dissociation from organic fuel;
- experimental research of solid waste utilization-gasification;
- numerical modelling of granular mediums;
- research of carbon nanostructures extraction optimization.

Development of tires gasification reactor and work optimization

In 2005 experimental research of tires gasification was continued in laboratory-scale gasifier (0.8 m diameter, 2.65 m height). Tires were gasified at temperature 360-800°C at air excess ratio 0.1-0.4 and tires combustion rate 60-200 kg/h.

In order to maintain stable structure and amount of gas produced by the reactor, the following improvements were carried out in 2005: air supply system was modified, temperature sensors were installed at several points near combustion zone for temperature profile measurement, ventilator was installed in front of the burner for the transportation of hot gas, remote measurement of reactor produced CO was implemented as well as constant observation of tires top level, new burner with improved impeller was installed, stationary igniter was installed. All performed actions created a possibility to control the reactor and gas combustion process in the boiler. Three parameters are the most significant: temperature profile in combustion zone, structure and amount of gas, level of loading with tires. All these parameters are closely connected, therefore, it is important during each process to have information on each of them. The measuring methodology was chosen, which allowed to have a whole understating on reactor's operation.

After reconstructing the reactor, during gasification at the determined optimal air excess ratio 0.24 and tires combustion rate 135 kg/h, the obtained gas and vapour total average calorific value increased from 4 MJ/m³ up to 7 MJ/m³. During the experiments at $\alpha = 0.1$ calorific value was approximately 7-12 MJ/m³. Approximately 60% of heat was transferred to water in the boiler. Gaseous products are comprised mainly of CO, H₂, CH₄, C₂H₆ and heavier

hydrocarbons, total calorificity of which was 2-12 MJ/m³. Carbon residue varied from 30% to 18%. Structure of inorganic gas and light hydrocarbons gas was investigated employing VARIAN gas chromatograph with thermal conductivity detector. More than 4% of hydrogen was found in the gas.



*Tires
gasification
reactor*

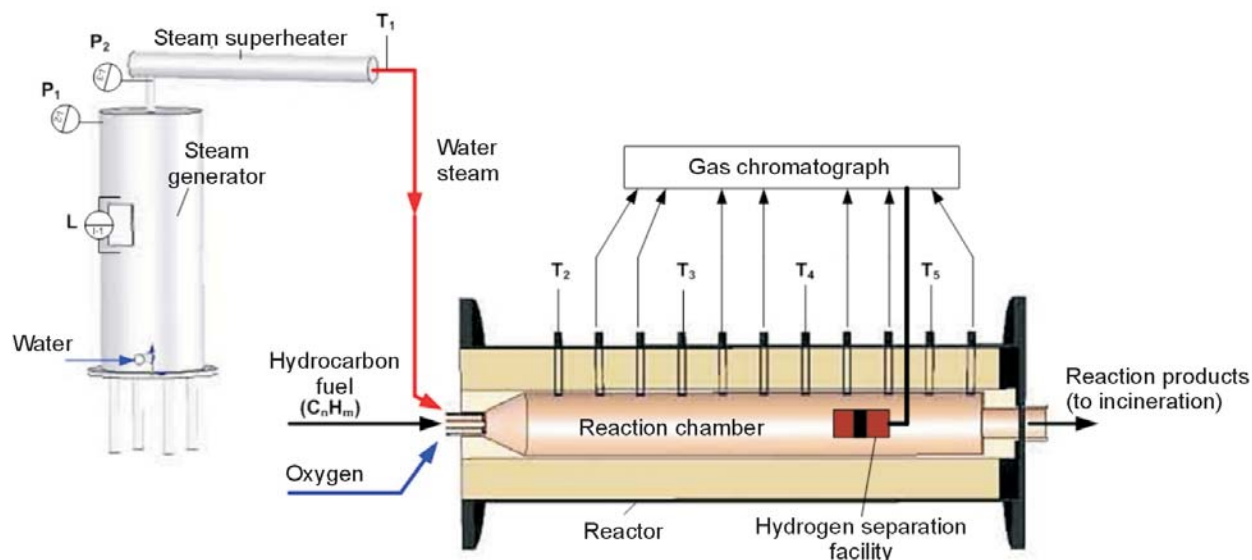
The obtained information may be employed in designing experimental tires gasification facility, which will be applied for the lime combustion furnace.

Organic fuel decomposition for hydrogen dissociation at high temperature

Forming hydrogen economics it is necessary to depart from the existing fossil fuel infrastructure. One of the most effective methods to solve this problem is

hydrogen extraction from organic fuel: hydrogen release from natural gas (Steam Methane Reforming), autothermal decomposition of hydrocarbons with partial oxidation. These methods of hydrogen production from fossil fuel are not new, but they are rather known and analysed.

Our objective is to create a process during which heat production would be combined with hydrogen generation and separation within one facility.



Organic fuel autothermal conversion research facility

The initial research of organic fuel decomposition for hydrogen production and modelling of reaction kinetics were performed, in order to investigate autothermal conversion process conditions and obtain the largest hydrogen concentration in resulting gas mixture. The results showed that H_2 concentration in gas mixture increases with the decrease of air excess ratio mainly at temperature range 1200-1400°C. The major part of hydrogen is generated during quick exothermic partial fuel oxidation, i.e. in the initial reactor part approximately 70-90% of all H_2 , and the other part – during slow endothermic CO conversion with water vapour.

Calculation results were checked experimentally, determining gas chemical composition with gas chromatograph. The obtained results were similar to the results of numerical modelling.

In further research the usage of heavier hydrocarbons usage for hydrogen partition and hydrogen release from gas mixture with selective membranes or molecular sieves (zeolites) are planned. Glycerol ($C_3H_8O_3$) is expected to be used as an

organic fuel, which is a secondary product in biodiesel production. Usage of glycerol fractions from biofuel production waste is part of EUREKA project **Utilisation of Glycerol Fractions from Biodiesel Plants**.

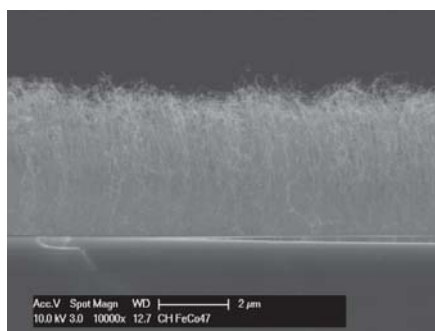
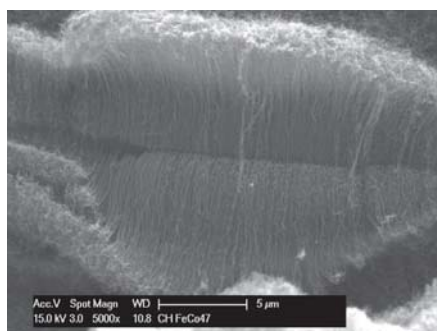
Research of carbon nanostructures growing

During the last decade carbon nanostructures, particularly carbon nanotubes, have been of great interest for many researchers due to their unique properties. Considerable amount of finances and manpower have been devoted to the research. Further research and employment of materials based on nanostructures are limited by high price of nanotubes, small amounts of production, heavily controlled structure, therefore, the first step in nanotubes application is a development of mass production. Basic synthesis methods are: laser, arc-discharge and chemical vapour deposition, which due to method simplicity and cheapness is the most relevant for mass production.

In the research of carbon nanostructures main attention is given to the growth of carbon nanotubes, research of their structure and properties, preparation methodology of catalysts and general definition of growing model.

In the initial stage the simplest method of carbon nanostructures growth was selected – chemical catalytic vapour deposition on the catalyst. Nichromium was chosen as a catalyst since it is a heat resistant material and it does not lose strength properties in the temperatures interval necessary for the experiment. The obtained carbon nanostructures were investigated with the scanning electronic microscope. Diameter of obtained structures from 50 to 100 nm, length up to 100 microns, optimum growing conditions were determined: gas structure, temperature, and reaction time. Due to the obtained results growing model was created, defining the effect of gas and temperature on the formation of carbon nanostructures. Growing of nanostructures occurs in the non-inert environment, oxygen significance for growing process was determined. Changing the environment conditions – temperature, time and combustion rate – diameter and length of the produced structures are controlled, also a sudden diameter jump in the same carbon structure is possible.

Research of these carbon structures will be continued, growth and structure control process will be improved as well as application of different gas for the growing of nanostructures. The following properties of nanostructures will be investigated as well: electric conductivity, resistance to temperature and various environ-



Coal nanotubes obtained employing chemical catalytic vapour deposition method

ments; research of internal structure will be performed with transmission electronic microscope; with the help of coatings and atomic force microscope tests will be performed to determine mechanical properties.

In order to obtain good quality and high density carbon nanotubes, training was carried out at Swiss Federal Institute of Technology. Research was performed employing chemical catalytic vapour deposition method, using chemically prepared catalyst. On the polished silicon *n*-type plate a thin layer of calcium carbonate catalyst was placed, the basis of which – iron and cobalt. The growth occurs under inert conditions, at 680°C temperature, carbon source – acetylene. Carbon nanotubes were produced, the diameter of which 10-15 nm, length 5-10 microns.

This method of nanotubes growing will be further developed at our laboratory, to implement for mass production, perform growing on various surfaces, to find the optimum process conditions, aim for structures of better quality – of smaller diameter and longer ones. Research of carbon tubes synthesis from organic fuel decomposition products will be carried out as well.

Numerical modelling of granular materials

Processes occurring in granular materials attract a great deal of attention. These phenomena are important not only from the practical point of view (e.g., in handling of bulk materials), but are interesting from the theoretical point of view as

well. Qualitatively new phenomena occur in granular media compared to motion of separate solid objects and the processes occurring in continuous media (liquids and gases). In cooperation with the Karlsruhe Research Center (Forschungszentrum Karlsruhe, Germany), the program was developed and is being improved for the simulation of motion of granular materials using the discrete element method (DEM). This method is based on tracking the motion of each separate particle in the granular material. The program was used for the analysis of the processes of mixing and segregation in the granular media and dependence of its intensity upon the mechanical properties of the material as well as for research of mixing of the solid waste particles on the moving grate.

The programme implements the combustion model enabling to simulate the process of particle combustion, taking into account the chemical structure and temperature variations of the particles, reduction of the particle sizes and heat exchange among the particles and the gaseous environment. Figure shows the temperatures and sizes of wood granules in the experimental pyrolysis facility at the initial time moment (a) and after 10,000 seconds (b) when the granules are heated at 490°C in the ambience on inertial gas.

Since modelling of particle motion is computationally expensive, the program is being modified in order to adapt it for parallel calculations, using computer clusters and supercomputers. Some calculations were performed using the supercomputer SGI Altix 3700 at the Netherlands supercomputer centre SARA in Amsterdam in

accordance to the EC funded program HPC-Europa.

The principles of modelling using the discrete element method are also applicable for the molecular dynamic simulations. It is expected to apply the software for solving the problems of molecular dynamic, in particular, modelling the growth of nanostructures from hydrocarbons.

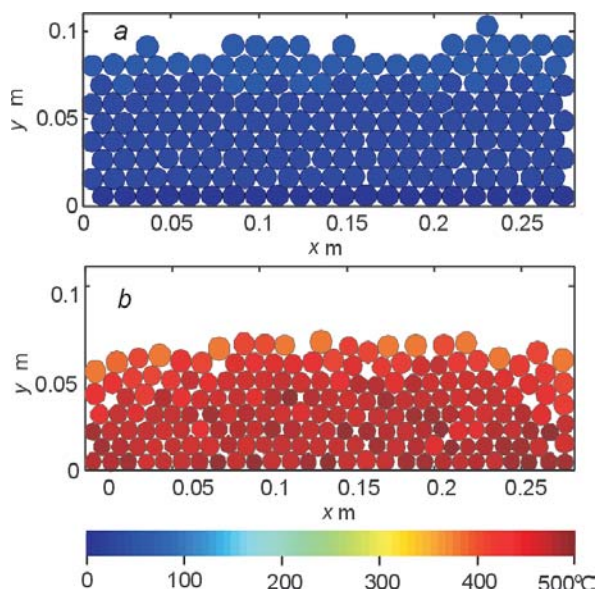
Applied science projects for industry and economy subjects

Burners were produced for Alytus DH steam boiler, which is reconstructed with the aim to produce a qualitative steam designed for electricity production. Burners were reconstructed in Telčiai DH, which are designed for burning furnace fuel in case of gas fuel supply instability.

Works were continued from the point of view of environmental protection safely burning volatile organic compounds – the whole combustion facility complex with burners and heat-carriers was produced.

A special heavy fuel oil combustion furnace was designed and assembled for the production of hot dry air, designed for desiccation of calcium powder. Calcium powder is used in aviculture industry and for quality bitumen production. Furnace proved to be useful and it can operate without repair for several years. The second furnace is to be constructed in 2006.

In 2005 Laboratory researchers published eight articles in science journals and other science publications, three articles in popular science literature, participated in five international and three Lithuanian science conferences.



Numerical modelling of pyrolysis of wood granules (the temperature of the granules is shown in colours) and their sizes at the initial time moment (a) and after 10,000 seconds (b)

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Main research areas of the Laboratory:

- experimental investigation of turbulent convection heat transfer regularities in single-phase flows: forced and mixed convection, influence of channel geometry, variable physical properties, roughness, centrifugal forces and transients effect;
- numerical modelling of heat transfer and turbulent transport in single-phase flows in various channels and geological structures;
- management of spent nuclear fuel: modelling of fuel characteristics, safety and environmental impact assessment of storage and disposal facilities, normative and legislative base;
- management of radioactive waste: strategy, safety and environmental impact assessments of treatment technologies and storage and disposal facilities, normative and legislative base;
- evaluation of different factors related to decommissioning of nuclear power plants: planning of decommissioning and dismantling, cost of decommissioning, radiological assessment of buildings, systems and facilities, safety and environmental impact assessment, normative and legislative base;
- fire hazard analysis of nuclear power plants and other large facilities.

Experimental and numerical heat transfer and turbulent transport investigation in channels and geological structures

The Laboratory has a comprehensive experience of 30 years in investigations of heat transfer and flow hydrodynamics. Investigations on turbulent mixed convection heat transfer and flow structure in inclined flat channels with one-side and two-sides heating for aiding and opposing flows, as well as stable and unstable air density stratification have been performed also. In 2005 experimental and numerical investigations in laminar-vortex (transition) flow zone of vertical channel were continued. Numerical modelling under different cases of mixed convection was performed applying FLUENT (USA) code.

It was determined that in case of unstable air density stratification, there are heat transfer regimes when nature of heat transfer along the channel length changes very suddenly. Such change of heat transfer is caused by the separation of flow near the channel wall. It was also determined that heat transfer in case of unstable density air stratification does not depend on the channel inclination angle, when it changes from 90° to 0° (contrary than in stable stratification case).

Results of numerical modelling in laminar-vortex (transition) flow zone for opposing flows showed that with the increase of thermogravitational forces influence,

non-stationary circulation flows are formed at the channel walls, arranged in a chess order along the channel length, evoking asymmetry of velocity profiles and wall temperature pulsations. Numerical modelling in laminar-vortex (transition) flow zone in the aiding flows showed that three characteristic flow zones along the channel length could be distinguished. In the first stable flow zone due to thermogravitational forces influence, parabola velocity flow profile is deformed into profile of form "M". The second is recirculation flow zone, however, heat transfer there does not differ much from heat transfer in the stable laminar flow zone. In the third unstable vortex flow zone wall temperature and Nusselt number obtain a pulsating character.

Management of spent nuclear fuel (SNF)

The dry interim storage facility for SNF at Ignalina NPP with CASTOR RBMK-1500 and CONSTOR RBMK-1500 type casks was commissioned in 1999. The Laboratory has been performing studies related to the safety assessment of SNF storage and disposal. The Laboratory carried out criticality assessments for the casks of normal and extended capacity with fresh and burned-up nuclear fuel under normal operational and accident conditions, variation of radioactive nuclides activity during the interim storage period, ra-

diation doses on the cask surface and at the specific distance from it, and temperatures of the cask.

In 2005 the Laboratory together with GNS-RWE NUKEM GmbH (Germany) consortium started to implement project – **The Interim Storage Facility for RBMK Spent Nuclear Fuel Assemblies from Ignalina NPP Units 1 and 2 Supply and Installation (B1)** (2005-2009). The Laboratory prepares environment impact assessment and safety analysis reports of this SNF storage facility (operational time no less than 50 years) and offers support in licensing the storage facility. In 2005 the Laboratory experts prepared **Environmental Impact Assessment Programme** that was approved by the Ministry of Environment of the Republic of Lithuania. **Environmental Impact Assessment Report and Safety Analysis Report** are under preparation.

Implementing **The Assessment Programme of the Possibility of Spent Nuclear Fuel and Long-lived Radioactive Waste Disposal in Lithuania** (2003-2007), the Laboratory experts with the assistance of Swedish experts, proposed the generic concepts of deep geological repository in clay and in crystal rocks in Lithuania, performed assessment of geological repository costs and initiated the generic repository safety assessment. Two repository evolution scenarios were analysed and the numerical



General view of spent nuclear fuel storage facility. 202 CONSTOR RBMK1500M/2 containers will be placed inside (height of container approximately 4.5 m, diameter – approximately 2.7 m). Operational time – not less than 50 years

modelling of radionuclides migration in the near field and far field for defective disposal container was carried out. COMPULINK, CHAN3D, PREBAT-BATEMAN (Sweden), SCALE (USA), FLUENT, AMBER (UK) codes were applied in order to cope with these tasks.

In 2005 the Laboratory specialists on the basis of the existing information on probable climate changes during the forecasted geological repository operational period performed assessments of radionuclides emission under changed climate conditions (icing).

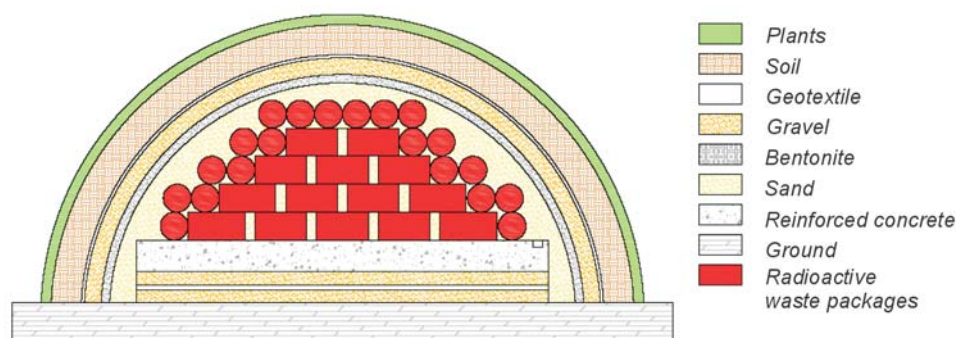
Radioactive waste management

Since 1994 the Laboratory has been actively involved in the analysis of the radioactive waste management problems at Ignalina NPP. Laboratory experts together with experts from *SKB International* (Sweden) carried out a number of projects, including safety evaluation of existing waste storage facilities. Long-term safety assessment of existing radioactive waste storage facilities at Ignalina NPP and Maišigala

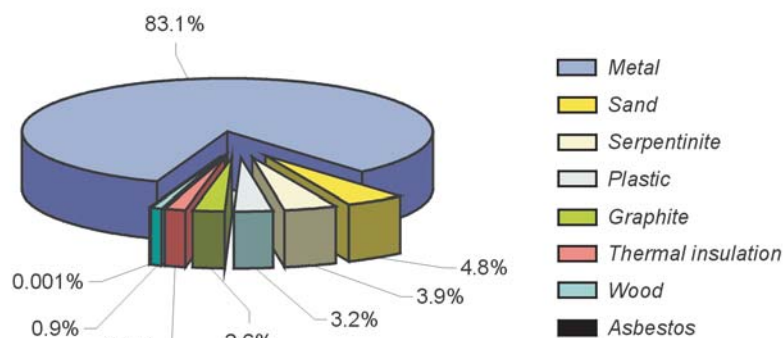
was performed, and the possibilities to transform these storage facilities into repositories were analysed. In 2001-2004 the Laboratory together with *Framatome ANP GmbH* (Germany) prepared **Environmental Impact Assessment** and **Safety Analysis Reports** for Ignalina NPP cement solidification facility and a temporary solidified radioactive waste storage facility. The Laboratory constantly participates in IAEA coordinated research programmes, among them **Application of Safety Assessment Methodologies for Near Surface Waste Disposal Facilities (ASAM)** (2002-2005). The Laboratory specialists with the assistance of Swedish experts prepared the set of criteria for choosing a near surface repository site, improved the concept of a near surface repository project, and prepared implementation programme. In 2004 together with the Institute of Geology and Geography prepared *Environmental Impact Assessment Report for Implementation of a Near Surface Repository for Low and Intermediate Radioactive Waste*. DUST, GENII, GWSCREEN (USA), AMBER codes were used for the safety assessment.

In 2004-2006 new PHARE project will be implemented together with French companies *Thales Engineering and Consulting* and *ANDRA* as well as Institute of Physics – **Safety Assessment and Upgrading of Maisiagala Repository in Lithuania**. The Laboratory specialists have already developed the database containing all information on the radioactive waste inventory, which is being stored in the Maišigala storage facility, and performed a comprehensive nuclide composition analysis. **Safety Analysis Report** is under development.

In 2005 the Laboratory specialists started also a new project **Preparation of Preliminary Waste Acceptability Criteria for a Landfill-Type Repository**, where information on very low activity radioactive Ignalina NPP operational and decommissioning waste will be analysed. This waste is planned to be disposed of in a landfill-type repository (operational time about 50 years). After analysis a site will be selected, and preliminary acceptance criteria will be defined for radioactive waste intended to be disposed of in repository.



Cross-section of a landfill-type repository for depositing low-activity radioactive waste. Operational time – about 50 years



Percentage distribution of waste mass, which will be generated during Ignalina NPP decommissioning

Evaluation of different factors related to decommissioning of nuclear power plants

In 1998 the Laboratory specialists started a new activity related to the planning of decommissioning of Ignalina NPP. Our experts participated in PHARE project preparing *Preliminary Ignalina NPP Decommissioning Plan*. An extensive database describing the characteristics of the elements of different systems and DECOM software was developed. This software enables to estimate the amount of radioactive waste, which will be accumulated at Ignalina NPP, and also financial expenses for carrying out the presumable operations. In the course of preparing *Final Ignalina NPP Decommissioning Plan*, this code was further developed at the Laboratory and information on radiological and technical data on Ignalina NPP systems was updated. In order to evaluate radioactive contamination level of the most contaminated systems, LLWAA-DECOM software of Belgium Company TRACTEBEL adjusted to RBMK reactors was used. In 2004 the Laboratory specialists prepared the drafts on *The Ignalina NPP Decommissioning Programme and the Plan of Means of its Implementation for the period 2005-2009*.

Since 2002 the Laboratory has been participating in IAEA coordinated research project *Disposal Aspects of Low and Intermediate Level Decommissioning Waste* (2002-2006). The Laboratory performed radioactive deposits formation analysis, also analysed the expected amounts of the radioactive waste at final INPP shutdown. In 2005 the preliminary waste acceptance criteria for activated reactor metallic components to be disposed of in near surface repository have been defined.

In 2005 together with Institute of Physics the Laboratory started the project *Development of radiological characterization programme for equipment and installations at INPP (2005-2006)*, where after analysing the international experience *General Programme of Radiological Survey* was drafted, and after accumulating and analysing data about Ignalina NPP site *Historical Assessment Report of Radiological Situation at INPP* was prepared.

Fire hazard analysis of nuclear power plants. Fire hazard prevention in nuclear facilities is one of the primary aspects in order to avoid nuclear accidents. In 2001-2004 the fire hazard analysis for Ignalina NPP Unit 1 and Unit 2 was carried out together with Swedish experts. In 2005 fire hazard assessment of some renewed Ignalina NPP rooms was carried out. Fire hazard assessment of newly designed Ignalina NPP SNF storage facility was carried out as well.

In 2005 the Laboratory continued two state funded research projects and performed 13 contract works and earned over a half million Lit. Researchers of the Laboratory actively participated in different training programmes, co-ordinating meetings, presented 14 papers at international conferences (Japan, Great Britain, Netherlands, Austria, Scotland, Egypt, Ukraine and Lithuania), and published more than 20 scientific articles in international and Lithuanian journals, including three with ISI impact factor. One PhD thesis was defended.

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LABORATORY OF MATERIALS RESEARCH AND TESTING

Main research areas of the Laboratory:

- testing of materials, assessment and analysis of their quantitative indicators;
- investigations in the field of hydrogen energy;
- hydrogen and hydride induced degradation of the mechanical and physical properties of zirconium-based alloys;
- investigation of degradation of heat carrier pipes;
- research and development of arc-plasma reactors, diagnostics of plasma jets and flows;
- neutralization of hazardous waste;
- synthesis and characterization of catalytic, tribological coatings and plasma polymers.

Research in the field of hydrogen energy. Hydrogen storage

Successfully continued activity *IEA Hydrogen Implementing Agreement Task 17: Solid and Liquid State Hydrogen Storage Materials*. Results of the analysis of Mg-alanate synthesis and properties were presented at the seminar in Japan. The project *Hydrogen behaviour in Mg₂Ni thin-film structures* funded by the Lithuanian State Science and Studies Foundation was completed. The originality of this work is related with the employment of non-equilibrium plasma technologies for the hydriding of nanocrystallite materials. During interaction with plasma, the surface becomes unstable, surface potential increases, absorption-desorption kinetics changes and hydriding efficiency increases. During this work thin, nanocrystallite films of Mg₂Ni were obtained employing physical vapour deposition methods. During hydriding of nanocrystallite materials the hydrogen may be stored not only in chemical compounds, but in grain boundaries, which significantly increases the amount of stored hydrogen. In this work the impact of grain boundaries on the hydriding of materials is analyzed in detail. Results of the work were presented at seminars *Nordic Energy Research Programme Network 'New Metal Hydrides for Hydrogen Storage'* in Norway and Lithuania.

In 2005 the laboratory personnel continued EU Sixth Framework Programme projects NENNET and HYTRAIN. A PhD student from France – Emmanuel Wirth was invited to implement the forecasted works of HYTRAIN project. PhD studies were per-

formed together with Vytautas Magnus University (Lithuania) and Joint Research Center Energy Institute (Holland).

By the Order No. 312 of the Minister of Education and Science of the Republic of Lithuania, Lithuanian Energy Institute was granted a support of 365000 Lt for the purchase of vacuum thin film synthesis system. PVD-75 system (Kurt J. Lesker company, USA) was purchased, which will be used performing synthesis works of nanocrystallite thin films.

In 2005, March 2, the Ministry of Education and Science, the European Social Fund and Lithuanian Energy Institute signed a trilateral Support agreement for the project **Organization of hydrogen energy technologies training**. Project duration – 36 months, it will be implemented by Lithuanian Energy Institute and Vytautas Magnus University – partners have been working in the field of hydrogen energy since 2000.

The main aim of the project: to raise the qualification of scientists and researchers as well as prepare new specialists in the field of hydrogen energy technologies so that the quality of performed scientific research in Lithuania would satisfy the needs of the concerned society groups (business, education, etc.), and performed research would be competitive at the EU level. During project implementation participants actively participate in lectures and seminars, perform laboratory works in Lithuanian Energy Institute and in the laboratories of project partners. In 2005 five project participants were on training in France, Universite de Poitiers, Laboratoire

de Metallurgie Physique. Methods of different nanomaterials chemical structure and surface morphology analysis were acquired theoretically and practically during this training. Project activities and obtained results in more detail are given on the web site: www.hydrogen.lt.

Research of hydrogen and hydrides degradation impact on mechanical and physical properties of zirconium-based alloys

The laboratory since 1999 has continued research of hydrogen and hydrides degradation impact on mechanical and physical properties of zirconium-based alloys. The laboratory works together with Ignalina NPP in investigating the condition of fuel channels condition of INPP Unit 2. In 2005 together with scientists from eight countries IAEA coordinated project **Slow hydrogen-induced cracking of fuel elements zirconium-based alloy** was initiated. In the same year the laboratory joined science research project **Research of RBMK fuel channels ageing process and determination of safe operation criteria**, which is implemented in accordance with the Priority directions of Lithuanian research and experimental development. The aim of all this science research is to ensure the resistance of constructional elements of zirconium-based alloys to the impact of operational factors, control and forecast their ageing process.

Considerable attention in the laboratory is given to the development of experimental activities. Mechanical experiments and corrosion research are performed, taking into account materials resistance and ageing impact on the operational reliabil-



Students at new thin film synthesis facility

ity of constructional elements. In project **Additional combustion of Ignalina NPP Unit1 fuel in Unit 2**, using state-of-the-art equipment, materials shock experimental facility was created. Dynamic samples of new construction shock absorber were performed. During testing the determined characteristics were employed for the confirmation of numerical simulation data of experimental results and for the optimization of shock absorber construction.

Research of nanocrystalline zirconium electroceramics used for the hydrogen fuel cells systems

Yttrium stabilized zirconium oxide (YSZ) powder synthesized in chemical method. After evaluating merits and demerits of different powder production methods as well as basis for powder synthesis, chemical analytically pure powder retraction method was chosen for the synthesis – general precipitation of components out of saline deliquescent in water. It was determined that powder was comprised of aggregated powder with size 10-20 μm. After burning powder at temperature 800-1000°C, crystalline YSZ powder was retrieved, which comprised of monoclinic, tetragonal and cubic crystalline mixture. The impact of combustion temperature on the retrieved raw material and its ceramic properties were investigated. The possibility to form coatings, prepared by plasma spray technologies out of synthetic YSZ powder was analyzed. Comparing coatings' structure with the coatings of mechanically granulated YSZ powder, coatings retrieved from synthetic raw material were less porous.

Research of operational properties of high-temperature ceramics

With the support of Lithuanian State Science and Studies Foundation, cooperating with the Institute of Materials Science Problems of Ukraine, the laboratory acquired new thermal conduction methodology in accordance with LST EN 993-15 standard, thus increasing high-temperature materials thermal conduction measurements up to 15–20 W/mK. Earlier such measurements were performed neither in Lithuania nor in Ukraine. Cooperating with Lithuanian and Ukraine laboratories, the material of stable properties at high temperature (up to 1000°C), thermal conduction of which 1.25 W/mK, was created. Works were initiated investigating materials, thermal conduction of which 0.3–1 W/mK. Material of such properties could be a high-temperature thermo isolation material standard for

the verification of thermal conduction equipment.

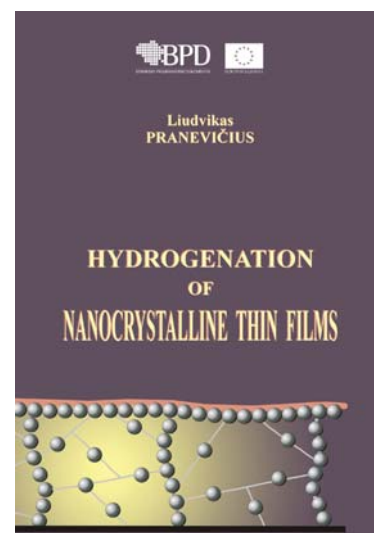
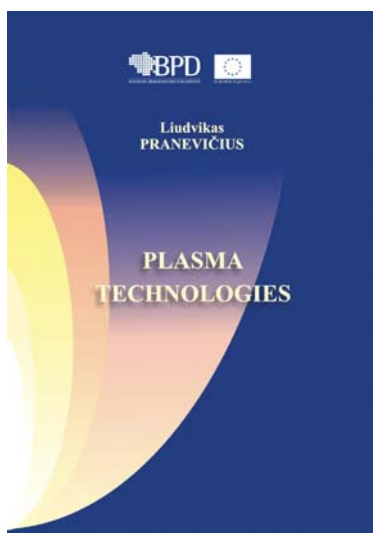
Plasma research under atmospheric pressure conditions

Formation of high-temperature gas flow, its dynamic, heat transfer in different form of channels and heat-carrier element models were analysed. Regimes of linear electric arc heaters and reactors and their operating characteristics were analyzed, work duration expansion conditions and methods of arc turbulisation were determined. Thermal equilibrium conditions of atmospheric pressure plasma jet were investigated applying contact method. Regularities of rate, temperature and their pulsation distribution in high-temperature plasma jet were determined.

Electric arc and plasma jet interaction with dispersed materials was investigated in order to neutralize harmful materials, form various coatings, synthesize new materials; physical, chemical and mechanical properties of obtained coatings and materials were determined.

Reactor was created to burn hazardous materials, which complies with the environment protection requirements and conditions (neutralized materials are kept longer than 2 s at temperature higher than 1200°C), its technical characteristics were determined.

New plasma technology equipment created for the synthesis of solid coatings. Active aluminum oxide, carbon compounds, diamond-like carbon and various catalytic coatings, the specific surface of which reaches 100 m²/g, were retrieved.



The mechanism which generated combustion products jet of permanent characteristics as well as a new methodology for the investigation of catalytic properties of coatings and mass transfer processes near the active wall surface were created.

Regularities of heat and mass transfer processes in oxide catalytic reactor channels were analyzed in order to improve catalytic properties of coatings, determine gas velocities, temperature distribution in catalytic reactor, jet and wall heat-mass transfer coefficients. Results of the research may be employed in creating, designing and calculating catalytic reactor oxidizing CO, to enlarge modelling programme data basis since there is a lack of experimental data on the processes occurring in catalytic reactor.



Materials testing and assessment of their qualitative indicators

In 2005 the laboratory successfully approved its accreditation in carrying out tests of plastic and insulated pipes, building mortars, polymer bitumen sheeting, thermal insulating products, refractory materials and products. Constant renewable of technical investigations basis enables to carry out building products testing in accordance with the requirements of international standards and European Norms.

In 2005 doctoral thesis by Vilma Snapkauskienė **Research on properties of catalytic coatings by plasma spray technology for the acceleration of CO oxidation** was defended.

In 2005 Laboratory personnel participated in the following international programmes:

- **The COST Action 525 Advanced Electronic Ceramics: Grain Boundary Engineering**, with the participation 16 European countries. The main objective of the COST Action is to understand the role played by grain boundaries in controlling the manufacture, microstructure and properties of electronic ceramics. For this purpose LEI formed yttrium stabilized zirconium oxide coatings, and investigated their structure and properties. Dependence of obtained coatings' structure, phase structure and crystallites size from plasma process parameters and thermal treatment conditions was determined. The activity coordinated by Manchester University, Great Britain.
- **The COST Action 527 Plasma Polymers and Related Materials**, with the participation of researchers from 18 countries. The objective of the Action is to improve the knowledge of the plasma polymerisation process in relation to the desired physical and chemical properties of resulting plasma polymers with special regard to the understanding and following suppression of ageing processes of plasma polymers at ambient and extreme conditions. Facility and plasma polymers deposition method in atmospheric and reduced pressure plasma jet was created in Plasma Technologies sector.
- **The COST Action 530 Life Cycle Inventories for Environmentally Conscious Manufacturing Processes**, with the participation of 17 European countries, coordinator PE Product Engineering GmbH, Germany. In Plasma Technologies sector implementing the activity programme, the investigation of thermal neutralization process life cycle of hazardous materials was initiated.
- **The COST Action 532 Triboscience and Tribotechnology: Superior Friction and Wear Control in Engines and Transmissions**, with the participation of 17 countries, coordinator – Technical Research Center, Finland. Participating in the programme, personnel of Plasma Technologies sector performs project "Research of surface processes during the stainless steel nitriding in atmospheric and reduced pressure plasma jet".
- **The COST Action 533 Materials for Improved Wear Resistance of Total Artificial Joints 2003-2009**. Research related to one of the approved institute research activity fields – to implement research of materials durability and new multifunctional materials technologies. With the support of Lithuanian State Science and Studies Foundation the laboratory acquired the technology of bio-compatible titanium oxide coating formation on the titanium steel trays.
- Cooperation programme between Lithuania and Ukraine 2002–2008 **Development of technologies of catalytic neutralizers formed in plasma method designed for automobile exhaust gas complex treatment**. Issues of synthesis and employment of catalytic reactors, designed for the reduction of pollution, were discussed.
- **The COST Action 538 High Temperature Plant Lifetime Extension 2005-2008**. The main objective of the Action is to develop an innovative integrated toolbox of predictive methods/models and targeted invasive and non-invasive measurement techniques, improving the means for European industries to reliably quantify the condition and remaining life of plant components in all types of conventional fossil, biomass and waste-fired power plant.
- Cooperation programme between Lithuania and Ukraine 2002-2008 **Development of plasma-technological methods, designed for the formation of coatings of desirable properties from nanodispersive materials**. Performing this programme, physical model of formation of nanodispersive particles at low temperature plasma, was created; plasma processes are analyzed and new facilities are developed. LEI personnel develops the technology of plasma coatings formation, employing ultradispersive particles.

In 2005 the researchers of the Laboratory presented six articles in journals with ISI impact factor, 4 articles in other international journals, 9 articles in Lithuanian journals, 10 papers at international conferences, 3 papers at Lithuanian conferences and 6 science popularisation articles.

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LABORATORY OF NUCLEAR INSTALLATION SAFETY

Main research areas of the the Laboratory:

- thermal-hydraulic analysis of accidents and operational transients;
- thermal-hydraulic assessment of Ignalina NPP Accident Localization System and other compartments;
- simulation of radionuclides and aerosols transport in the compartments;
- assessment of RBMK-1500 reactor core modifications and analysis of postulated reactivity accidents;
- nuclear safety justification calculations;
- safety analysis of thermonuclear synthesis reactors;
- Level 1 and Level 2 Probabilistic Safety Assessment of Ignalina NPP;
- assessment and prognosis of the graphite stack-fuel channel gap closure dynamics;
- structural analysis of plant components, piping and other parts of Main Circulation Circuit;
- fundamental investigations in thermo-physics;
- two-phase flow fundamental investigations;
- single failure analysis and engineering assessment for complex technical systems;
- risk and hazard analysis of industrial sites.

In 2005 researchers of the Laboratory together with Lithuanian and international partners worked on fundamental and applied research projects. These projects were devoted not only to the assessment and development of Ignalina NPP safety, but also to the operational reliability assessment of other national industry objects.

PROJECTS FUNDED BY THE GOVERNMENT

Fundamental investigations

In the field of thermal physics the study – ***Investigation of Condensation Implosion Event Initiated by Hydrodynamic Instability*** was continued. The objective of this study was related to the use of the pressure difference, which is generated during the condensation implosion in the different parts of thermal-hydraulic circuit to create an energy and mass transport cycle, opposite to a natural circulation. In 2005 constructional criteria, which determine the condition for condensation implosion event, was chosen and confirmed. A possibility to employ an alternative accident cooling system in RBMK-1500 reactors, driven by condensation implosions, was analyzed. Numerical models were created, and experimental facility, designed for the investigations of interphase surface instability, was constructed. Methodology to investigate the condensation impact on the occurrence of interphase surface in-

stability was created and verified experimentally.

In the field of energy objects' safety, reliability and uncertainty in 2005 two projects were implemented: ***Uncertainty Analysis of Technical, Natural and Social System Modelling Results and Reliability and Risk Assessment and Control for Energy Objects***. The aim of the first project, which was performed together with LEI Laboratory of Energy Systems Research and Laboratory of Hydrology, was the expansion of applicability of uncertainty analysis methodology for 2D and 3D equation systems, while solving tasks of technological science, also carrying out numerical investigations in the field of physical (hydrology) and social (energy economy) sciences. In 2005 methodology of sensitivity and uncertainty analysis of individual parameters and SUSANA software were employed for the analysis of results of reactor kinetics processes modeling with neutronic dynamics 3D models, for the analysis of initial parameters of Kaunas HPP hydrodynamic model as well as for the analysis of results of Lithuanian power needs' forecast in economy sectors.

The aim of the work ***Reliability and Risk Assessment and Control for Energy Objects*** (2003-2005) - assessment of complex energy systems risk and reliability methods and development of risk management methods, risk analysis methodology and hazardous processes control optimization methods. This scientific research

work is also related to the development of complex system modelling and control methods. Scientific value of this work is comprised in conjugation of several risk research methods into one integrated methodology. The risk and hazards assessment and analysis methodology, reliability assessment of system components and strategies of their renewal, control efficiency assessment model, and principles of control criteria and requirements were developed. The developed methodology was applied for the assessment of Ignalina NPP, high voltage electricity network in Lithuania, Kaunas HPP and other energy systems.

Priority Lithuanian R&D projects funded by Lithuanian State Science and Studies Foundation

In 2005 three priority R&D projects funded by Lithuanian State Science and Studies Foundation were performed.

In project ***Development of beyond design basis accidents methodology for Ignalina NPP Unit 1 and 2*** Ignalina NPP safety justification studies and their results were overviewed, legal basis overview was performed, processes occurring during beyond design basis accidents in Ignalina NPP operating and shutdown units were discussed and analysed, the most dangerous initiating events, that could develop to severe accidents, were determined. Information basis necessary for the

Heat Transfer and Hydrodynamics in Gas-Cooled Fuel Rod Assemblies

Benediktas Čėsna



preparation of beyond design basis accidents analysis methodology in the operating and shutdown reactors as well as in spent fuel storages was accumulated.

During the project **Impact of external events on the safety of new nuclear reactors** criteria were formulated, according to which important external events significant for safety are selected, for which overview analysis must be performed and methodology of their assessment must be created. A list of all external events, which may have impact on the safety of nuclear facilities in Lithuania, was created. Mathematical models were developed for the forecast and assessment of selected most significant events frequency. Methodology of buildings and facility resistance to airplane crash, seismic events and to hit of breakaway turbine parts, was created. Indicators influencing safety were selected, their calculation formulas and methods as well as respective software were presented.

In project **Investigation of RBMK fuel channels ageing process and determination of safe operation criteria** participated two Lithuanian organizations (LEI – Laboratory of Nuclear Installation Safety and Laboratory of Materials Research and Testing, KTU – Faculty of Mechanical Engineering and Mechatronics and Prof. K. Barauskas Ultrasound Research Institute). In 2005 in the Laboratory of Nuclear Installation Safety the preliminary modelling of fracture parameters was performed using finite elements methodology (ABAQUS software). The obtained results were compared to experimental research results. The hydrogen concentration was evaluated in the modelling of the fracture parameters.

Analysis of the variation of thermohydraulic parameters in fuel channels at normal operation conditions was performed using Ignalina NPP model by RELAP5 code.

Cooperation with State Nuclear Power Safety Inspectorate (VATESI)

Laboratory of Nuclear Installation Safety is one of the technical support organizations, which for a number of years has been closely cooperating with VATESI. In 2005 the review activities, related to the documents that are proposed for VATESI, were performed, new regulation documents were prepared.

Performing agreement **Expertise of INPP documents, related to reactor core zone configuration, physical characteristics and control changes and other issues of reactor physics and nuclear fuel storage and control**, Ignalina NPP documents were analyzed in order to justify changes of different RBMK-1500 reactors core modifications, control of compliance of reactor passport characteristics for the determined limits, and safety of hermetic and non-hermetic fuel assemblies during their transportation for testing. Independent calculations were carried out as well, on the basis of which conclusion were drawn on the reliability and expedience of presented safety justifications.

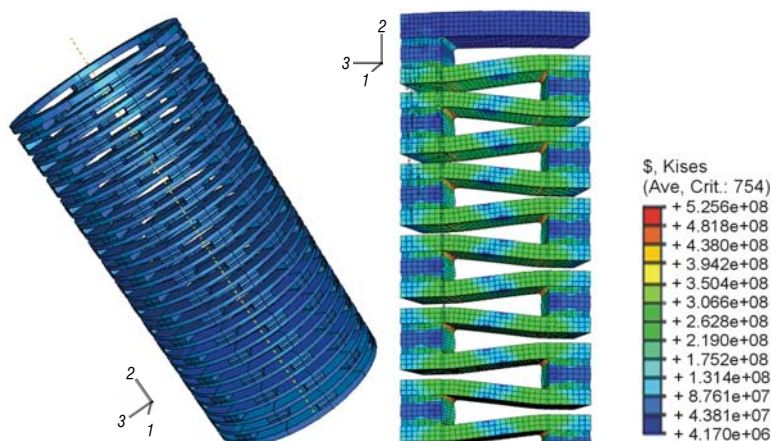
The work **Expertise of documents on the systems significant for Ignalina NPP safety and their components common cause failure** was focused on expertise of NPP probabilistic safety analysis model on common cause failures. The expertise was targeted to review model changes due to IAEA IPSART mission recommendations. Performed CLM model expertise and

additional calculations show high uncertainty of this model results, which should be taken into account and further evaluated.

PROJECTS WITH LITHUANIAN PARTNERS

Cooperation was continued with Ignalina NPP, SC *Lietuvos energija*, and JSC IKSADA.

Reuse of Unit 1 fuel in Unit 2 Reactor of Ignalina NPP. In the report of the World Bank experts **Lithuania: Aiming for a Knowledge Economy** (March, 2003) it is stated that Lithuania has a well-established culture of valuing knowledge, but it is using its knowledge assets – human resources, education systems, researchers and entrepreneurs, and so on – below capacity, and so forgoing opportunities to compete internationally as well as potential growth and income. In the report of the World Bank it is emphasized that in the future Lithuanian research institutions should be more oriented towards the development of new technologies. The example of such activity is development of technology of nuclear fuel transportation for the reuse from Ignalina NPP Unit 1 to the reactor of Unit 2, performed while implementing the contract with Ignalina NPP. This technology is the first to be created in nuclear reactors operation history. In 2005 technical safety justification report of set of equipment intended for reuse of Ignalina NPP fuel was prepared and submitted for VATESI expertise. In this report all issues relevant to NPP safety analyses were considered: description of set of equipment, engineering assessment, development of accidents list, analysis of failures and accidents, etc. In the safety justification report it is proved that set of



Model of shock-absorber devoted to saveguard fuel assembly in case of dropping

equipment, which is developed, will perform its functions and ensure the required safety level. Together with technical safety justification report, technical designs of newly developed equipment and buildings and auxiliary systems renovation were submitted for VATESI expertise. One of the newly developed equipment components is a shock absorber, which protects the fuel assemblies from failures in case of their drop. Calculation model of this shock absorber is presented in Fig.

In 2005 in enterprises-manufactures (Czech company *Skoda JS*, Estonian company *Dzidra*, Russian company *Petrozavodskmash*) manufacturing works of set of equipment intended for fuel transport were implemented successfully. In 2005 the guide protective shafts were manufactured, delivered and installed at Ignalina NPP. Container and its transport vehicle manufacturing works were completed as well. Up to February 2006 all basic equipment is to be delivered to Ignalina NPP.

In accordance with contract conditions, while implementing this project not only set of equipment is manufactured, but also a lot of attention is given to the training of Ignalina NPP personnel, who will operate this equipment. In October of 2005 in LEI theoretical training of Ignalina NPP personnel, who will be involved in operational and technical service of set of equipment intended for fuel transport, took place.

Preparation of methodology and software of RBMK-1500 reactor core hydro profiling. In this work methodology of RBMK-1500 reactor core hydro profiling was developed. Software GIDRA, based on the new methodology, was developed to computerise the process of reactor hydro profiling. Results of this work were implemented at Ignalina NPP after reactor planned preventive maintenance in September 2005.

Calculation of environment conditions in case of design basis accidents in the compartments with important for safety system elements that require qualification. In 2005 data basis was prepared on the compartments with important for safety system elements that require qualification. Equipment operation time, necessary for safety function implementation, was determined. Models were developed for calculating environment conditions in the compartments, calculations according developed models were carried out and results analysed. The obtained results will be used performing the qualification of important for safety system elements.



Training of Ignalina NPP personnel

Replacement of flowmeters due to the diagnostic results in Unit 1 and Unit 2 in 2005. In each technological channel of RBMK-1500 reactor coolant flowmeters are installed. When the flowmeter fails, the operation of appropriate technological channel is interrupted until the next shutdown of the reactor, when the broken flowmeter is replaced with a new one. Flowmeter diagnostics is being carried out before annual maintenance in order to avoid failures. In 2005 in the continued work analysis of diagnostic measures results was carried out and it was determined that 415 flowmeters had to be replaced in Ignalina NPP Unit 2 in order to guarantee a reliable operation of Unit 2 until the next planned maintenance.

Analysis of radiological consequences of design basis accidents in the Ignalina NPP Unit 2 reactor, filled with uranium-erbium fuel with 2.8% enrichment. In 2005 an agreement was signed regarding 2.6% and 2.8% enrichment fuel with uranium-erbium properties for all fuel combustion range and thermal hydraulic analysis was carried out. The obtained results will be used in 2006 performing analysis of parameters change and radionuclides transport in Ignalina NPP compartments and determining radiological consequences for these initial events.

The residual graphite-fuel channel gas gap probabilistic analysis and forecast at Ignalina NPP Unit 2. The residual graphite-fuel channel gas gap probabilistic analysis and forecast at Ignalina NPP

Unit 2 was performed in 2005. Statistical analysis was performed based on reactor measurements, completed in 2005. The residual graphite-fuel channel gas gap closure probability until the next planned preventive maintenance period in 2006 was estimated and compliance to VATESI requirements was demonstrated.

Improvement of RBMK-1500 reactor fuel channel linear protection coefficient computational algorithm. This work is aimed at improvement of RBMK-1500 reactor fuel channel linear protection coefficient computational algorithm in order to avoid frequent value fluctuations due to purely computational reasons. The work will be completed in 2006.

Investigation of the parameters of delayed hydride cracking and preparation of the realization of the analysis of conception 'leak-before break' for the pipings of fuel channel TMO-2. Two laboratories of LEI, i.e. Laboratory of Nuclear Installation Safety and Laboratory of Materials Research and Testing are participating in the project started at 2005. The object of this project is to define the parameters of hydride cracking and to carry out evaluation of the fulfilment of conception 'leak-before break' for the pipings of fuel channel TMO-2. The part of pipe RBMK fuel channel TMO-2 was received from Ignalina NPP to perform preliminary experimental research. In this work the controlled hydriding of the pipe segments Zr-2.5% Nb alloy, microstructure investigation for this alloy containing hydrogen and the experiments of delayed hydride cracking were performed.

The material fracture toughness magnitudes and mechanical properties parameters of Zr-2.5%Nb alloy without and with hydride were determined by experimental investigation at different temperatures. This project will be completed in 2006.

Development of set of equipment designed for picking spent fuel fallings in the hot cells of Ignalina NPP. The set of equipment designed for picking spent fuel fallings in the hot cells of Ignalina NPP will be developed and installed at Ignalina NPP in the frame of the project, which started in 2005. The technical design and preliminary safety justification report was developed in 2005. The completion of project implementation is scheduled for 2006.

Safety Justification of Ignalina NPP diverse shutdown system servodrives. During 2005 the work was continued on safety justification of Ignalina NPP diverse shutdown system servodrives. Final safety justification report is planned to be prepared in the first half of 2006.

Reliability evaluation of power transmission network. In 2005 the project with JSC Lietuvos energija was finished. Under this project a methodology for power transmission network reliability assessment was developed, typical 110 kV switchyards which are used in the transmission network were described, weaknesses and advantages of probable failure schemes were identified. Software tool NETPRAS for power transmission network reliability assessment, upgrades planning, and estimation of energy not supplied, was developed. Network segment assessment models using analytical expressions and computer simulations, assessment of component technical state and algorithms of lifetime calculation were presented.

INTERNATIONAL COOPERATION

In 2005 researchers of the Laboratory continued projects with international partners, signed new projects and participated actively in European science research development programmes.

EU Sixth Framework Programme (FP6)

SARNET Network of Excellent. Contract on Network of Excellent for severe accident research and management (SARNET) was signed between the European Community and Institut de Radioprotection et de Surete Nucleaire (France) on



Researchers of Laboratory discussing SARNET project issues

18 March, 2004. 49 European R&D organizations, including LEI, have participated in this project. In 2005 the laboratory personnel participated in work groups meetings, where codes ASTEC, CONTAINMENT, COCOSYS and PSA-2 were introduced. With the help of ASTEC and COCOSYS codes RBMK-1500 hermetic compartments models were created and processes in those compartments were simulated. Report was prepared on ASTEC employment for the simulation in Ignalina NPP; another report on the requirements for the codes in order to simulate accident processes (including severe accidents) in RBMK type reactors, and on the possibility of ASTEC employment and arising problems, material was prepared for the publication on severe accidents phenomena in NPPs.

FUSION programme. A very perspective and innovative activity field – research in thermonuclear energy programme FUSION, to which the EU pays a lot of attention. According to experts, in the second part of this millennium thermonuclear energy could serve in the production of ecologically pure energy. It was decided to construct an experimental thermonuclear reactor ITER in Cadarache (France). Researchers of the Laboratory have accumulated experience in justifying nuclear power plants safety. The analogous safety justification works are relevant in developing thermonuclear synthesis equipment. Active interest in safety justification research in thermonuclear synthesis programme and in possibilities to employ the experience, accumulated analyzing power plants operating according nuclear fission

principle (i.e. NPP), gave the results – in 2005 the agreement was signed with EURATOM for the implementation of a project called **Cost-Sharing action: Hydrogen deflagration/detonation analyses in ITER HNB- and DNB-boxes and cryopumps following a loss of vacuum accident.** This is the first project in Lithuania in the frames of thermonuclear synthesis programme. In 2005 information was begun to be accumulated on ITER compartments, where hydrogen distribution will be analyzed. The project to be completed in 2006.

PHARE projects

Support to VATESI in solving significant Ignalina NPP licencing tasks. In 2005 PHARE project LI 0118-03-01-0001 was completed. Implementing this agreement, the Laboratory personnel prepared and submitted to VATESI projects of four regulating documents in English and Lithuanian:

- *Requirements for the Ignalina NPP transient and accident analysis;*
- *Regulatory guide on implementation of requirements for the Ignalina NPP transient and accident analysis;*
- *Requirements for the assessment of BDB accidents in RBMK-1500 reactor;*
- *Requirements for the management of BDB accidents in RBMK-1500 reactor.*

Training material on RBMK BDB phenomena and severe accidents control was prepared and presented as well.

Support to VATESI and its TSOs in Assessment of Beyond Design Basis Accidents for RBMK-1500 Reactors. In 2005 in the initiated PHARE project, which is coordinated by RISKAUDIT, and where GRS, IRSN, Institute of Physics and LEI will participate, it is forecasted to give support to VATESI and its TSOs in evaluating BDB accidents in RBMK-1500 reactor. Fuel matrix, fuel rods, main circulation circuit, reactor accidents localization system and spent nuclear fuel pools behaviour in cases of Ignalina NPP severe accidents are to be investigated. The result of this work will be as follows: severe accidents scenarios, analysis of radionuclides transport and discharge into the environment, including realistic analysis of radioactive materials discharge into the environment, and assessment of such discharge radiation consequences.

Assistance Programme to VATESI and its TSOs in the Field of Structural Dynamics. This work was performed in the framework of PHARE project LI01.18.02, where four Lithuanian organizations (Geology and Geography Institute (GGI), Vilnius Gediminas Technical University (VGTU), Kaunas University of Technology (KTU), and LEI) participated. In 2004 the review of requirements in the field of used buildings structural dynamics analysis in case of external events loads was performed. Seismic, aircraft crash and explosion events were selected for the analysis. Experience of Sweden and United Kingdom, evaluating strength of nuclear power plants building at the above mentioned external events loads, was reviewed. Ignalina NPP reactor seismic analysis was carried out by GGI and VGTU, aircraft crash analysis was performed by LEI, and explosion analysis was carried out by KTU experts. On the basis of the performed requirements analysis, in 2005 the finite requirements documents were prepared in English and Lithuanian.

The International Atomic Energy Agency (IAEA) funded Project

In 2005 the work was carried out in accordance with the contract with IAEA *Review of economical benefit of evacuation zone and safety measures around nuclear power plants with innovative small and medium capacity reactors in the regions, where reactors are used for electricity and heat generation.* According to this contract, economical effect of evacuation zone reduction or elimination is determined if reactor was used for the production of electricity and heat. In such a

case, NPP could be constructed nearby cities and used for electricity production as well as for district heating. The obtained results revealed that in such case efficiency of NPP increases significantly.

Projects supported by the UK Department of Trade and Industry

Technical assistance in preparation of regulatory documents for licensing Ignalina NPP operations. In cooperation with Jacobsen Engineering Ltd (UK) and SCIENTECH (USA) under contract NSP/03-L9 signed with Department of Trade and Industry (UK) the following draft regulatory documents were prepared:

- *Requirements for risk assessment and risk control;*
- *Requirements for probabilistic safety assessment Level 1 of NPP;*
- *Requirements for probabilistic safety assessment Level 2 of NPP;*
- *Requirements for probabilistic safety analysis employments at NPPs;*
- *Requirements for the assessment of PP operational experience system;*
- *Requirements for human factors evaluation in NPPs.*

Preparation of manual on the management of Ignalina NPP beyond design basis accidents. In cooperation with Jacobsen Engineering Ltd (UK) and SCIENTECH (USA) (contract NSP/03-L10) in 2005 analysis of selected BDB accidents was completed, which is necessary for preparing strategies designed for the management of BDB accidents in Ignalina NPP. This analysis enabled to better understand processes occurring in RBMK reactors and after evaluating the specificity of this type reactor, in comparison to case reactors, to prepare BDB accidents manual. The project is to be completed in 2006.

Projects with German GRS mbH Research Centre

A 10-year cooperation with GRS company was continued in 2005. Agreement was signed regarding Ignalina NPP accidents localization system analysis. The first project stage was completed in November, where hydrogen distribution in ALS compartments during BDB accident in Ignalina NPP. Before performing analysis of hydrogen distribution in ALS compartments, calculations of coolant release and hydrogen generation in the reactor were carried out. This analysis allowed

evaluating hydrogen distribution in Ignalina NPP ALS compartments during BDB accident. Other stage of this project is foreseen for the assessment of radionuclides transport in ALS compartments. The project is to be completed in 2006.

Participation in other science networks

PHEBUS FP programme. Phébus-FP programme comprises five integral experiments on reactor severe accidents dealing with fuel degradation, hydrogen generation, fission product release, transport and behaviour in the containment. In 1988 the programme was initiated and coordinated by IRSN. In its activity participate representatives from the EU countries, USA, Japan, and South Korea. An invitation to participate in this programme is obtained on the basis of agreement among IRSN, European Commission and Joint Research Center of the EU Commission. In 2005 Lithuanian Energy Institute signed the agreement and joined PHEBUS FP programme activity in the following two fields:

- fuel assemblies analysis;
- analysis of aerosols behaviour in the cooling circuit and containment.

IRIS project. IRIS (International Reactor Innovative and Secure) is a new international innovative and safe nuclear reactor project, the objective of which is to produce a Generation IV advanced reactor design. The IRIS team is an international consortium led by Westinghouse Electric company (USA) and consisting of 21 vendors, energy companies, and universities from 10 countries. Lithuania was represented in this consortium in 2004, when Lithuanian Energy Institute signed an agreement to participate in the consortium and contribute to the development of new reactor. One of the most significant events in 2005 was IRIS seminar in Kaunas, which was organized with the help of the laboratory personnel. 26 representatives from different foreign organizations participated in the seminar. Reports were made by representatives from Oak Ridge National Laboratory (USA) and Westinghouse Electric Co (USA). Representatives from several Brazilian companies, nuclear fuel production company BNFL (UK), Pisa University (Italy), ENSA (Spain), Design Institute OKBM (Russia), Fluent companies (German), etc. participated in the seminar as well. On behalf of Lithuania researchers from different universities, institutes and institutions (Ministry of Economy of the Repub-



IRIS conference, 20-22 April, Vilnius, Lithuania

lic of Lithuania, VATESI and representatives from USA and Italy embassies) participated in the seminar. This seminar was a good opportunity for Lithuanian researchers to get acquainted with the most innovative science accomplishments in the fields of nuclear power and complex systems reliability and safety.

In 2005 the Laboratory scientists continued the participation in the activities of **BEQUAR** (Benchmark Exercise in Quantitative Area Risk Assessment) project. The BEQUAR is coordinated by the European Commission Joint Research Center Institute for Protection and Security of Citizens. The main objective of BEQUAR is to introduce ten new EU member states with the requirements of Seveso II Directive 96/82/EC to ensure safety of hazardous industry enterprises. During the project participants perform the selected hazardous industry enterprise (factory in Hungary) risk study technical expertise. BEQUAR participants are trained to use APIRAR software, which is designed to evaluate risk of large territory (one of Seveso II requirements). In 2005 APIRAR 4.0 version was given to the laboratory for noncommercial use. Project duration prolonged and it is to be completed in 2006.

In 2005 the Laboratory researchers participated in **ENIQ** (European Network on

Inspection Qualification) network **TGR** (Task Group Risk) activities, which is established to develop European approach towards risk informed in service inspections by integrating best European practices. TGR activity is designed for creating methodological basis for risk based inspection programme in European nuclear power plants. In 2005 document **European Framework document for risk-informed in-service inspection**, ENIQ report No.23, was prepared and published by this group.

In 2005 project ARIADON proposal was prepared and submitted to the EC for funding by Sixth Framework Programme (project coordinator: ES-Konsult). LEI is a partner organization in this project.

Active participation in the International Standard Problem ISP-47 continued. This project investigates the problem of the gas mixing in the containments of NPP. This problem is especially important for the analysis of hydrogen distribution and possible hydrogen deflagration in case of severe accident at NPP. In 2005 experiments forecasted in the project were performed in Germany, THAI facility. For the moment the project is to be completed, the final project report to be written, the final conclusions and recommendations are formulated.

In the field of structural analysis the laboratory personnel has been participating in EU Fifth Framework Programme NESC III (Network for Evaluating Structural Components - focuses on the testing of a full-scale dissimilar weld assembly representative of a critical primary circuit component) working group activity. The laboratory personnel determined acceptable cracks sizes in the pipe weld, calculated the velocities of cracks propagation and fracture mechanics characteristics using finite element methodology. The obtained results are presented in NESC III project final report (NESC-III Project: Dissimilar Weld Integrity, Final Report).

Research results obtained in 2005 can be traced in scientific reports, 63 scientific articles, 50 conference papers. It should be noted that laboratory researchers participated and presented papers in all basic international conferences, where safe operation of nuclear power plants and physical phenomena in them were analyzed. They also participated in different training programmes, many IAEA technical committees meetings, and coordination meetings. The fact that Laboratory researchers are invited to participate in various meetings as independent experts and consultants, speaks of their high competence.

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LABORATORY OF REGIONAL ENERGY DEVELOPMENT

Main research areas of the Laboratory :

- analysis and modelling of municipal energy sector development, allowing forecast in short and medium periods;
- analysis of activity indicators development of district heating companies, taking into account economical and social factors and impact of regulation measures;
- integration of local and renewable energy sources into regional energy development programmes;
- development of data basis for municipal energy sector development and macroeconomic analysis of regional energy issues.

Government-funded research

In 2005 state funded research work ***Assessment of social and economical factors integrating renewable energy projects into regional development programmes*** was completed. The results of the analysis revealed barriers and causes, which slow down reorganization of energy sector in accordance with sustainable development principles.

Though ecological merits of renewable energy are obvious, relative cheapness of energy generated using fossil fuel does not allow removing them from dominant positions. The problems arise when there is a need to measure a positive effect, which comprises behind direct process limits. For example, combustion of both renewable energy sources – wood biomass and municipal waste – simultaneously solves the problems of urban environment management, employment, and reduction of import fuel input.

Economical theory explains the situation: this means market distortions, when marginal social benefit is larger than private marginal expenses. Therefore, corresponding organizational form – municipal and regional energy development programmes and approved methodology for assessment these merits, based on economical theory, is needed for the assessment and exploitation of renewable energy merits.

Research carried out in the work and generalizations formed **methodology on assessment of economical, social, environmental factors' for RES integration into regional/municipal development programmes**, which is recom-

mended for integrating sustainable energy projects into municipal/regional development programmes.

Work was considered as integration into development of scientific ideas in the field of energy economics at international level. Five articles were published or accepted in ISI sited journals. Articles summarize research in energy economics, which have international dimension and suggest innovative theoretical solutions, based on specific research, designed for priority issues of energy development.

In 2005 research work ***Investigation and mathematical modelling of factors, having impact to municipal heat sector and regulation measures*** was initiated. It continues previous research in this area and is designed to create theoretical and applied basics for establishment of monitoring and regular development forecasting system in municipal heat sector. This work is aimed to create a tool for the assessment the impacts and revising of heat sector liberalization policy. The tool should be based on the model of national municipal energy sector, evaluating social and economical restrictions and enabling to forecast activity indicators of heat supply, fuel, distributed electricity generation, etc., activities in the short-term and medium-term periods.

Elaborated models will be tested for tackling the following problems:

- justification of financial viability restoring in heat sector and economical expedience of its renovation;
- jefficiency assessment of mas-

tering and use of domestic and renewable energy sources;

- justification of introduction small-scale distributed CHP plants into the market, taking into account the need to improve the reliability of energy supply;
- revising the development of local energy sector with regard to the need to address social problems;
- preparing of generalized modelling results for the incorporation into macroeconomic models (MEM) or applied general equilibrium Lithuanian models (AGELM).

The first stage the research on district heating (DH) market was completed in 2005. A detailed investigation of heat market in residential sector covered the period of 3-4 years in several Lithuanian towns. This enabled for the first time to give qualitative evaluation of residents' reaction towards the growth of heat tariff. It was concluded that reduction of heat consumption was reached on the account of worsening comfort level in buildings.

Little-Mirles methodology for the activity planning of DH companies was mastered successfully for mathematical modelling of heat consumption, generation and the activity of district heating companies. New computer-based model of financial flows was created for the implementation of such methodology, using differential description of companies' financial flows. The created software package has been used for several years in research activities of the laboratory. Currently elaborated software tool is being tested in two district heating companies.

Relevance of competitive ability of heat supply networks increased due to the tendencies of consumers' disconnection from district heating systems. Research of alternative options for efficiency improvement of the uneconomical district heating systems requires much work and may be performed only due to the contracts with DH companies.

Correlation of heat transmission costs and linear pipes loading in two marginal cases – the case of large number of small consumers and one large consumer – was determined for preliminary assessments of existing DH networks viability.

Forecasted low long-term marginal electricity purchasing prices (~130 Lt/MWh) prevent from a possibility to use CHP technologies for the reduction of heat generation costs in district heating systems smaller than 5 MW_{th}, and they are justified for satisfying own electricity needs only. CHP plants larger than 5 MW_{th} with gas engines could be used for the reduction of heat costs, with annual duration of installed capacity exceeding 6000 hours.

Uncertainties, related to determination of perspective economical fuel costs, particularly wood, and electricity, appeared in the course of the work. Current pricing policy, when there is no significant difference of natural gas prices for residential and industrial (business) consumers create unfavourable competitive conditions for heat supply from small-scale district heating systems and decentralized heat supply. In the first case business and environmental taxes increase heat supply costs.

It is expected that the research results will contribute to the implementation of regular forecasting and monitoring system of the municipal energy sector development.

Applied research

Feasibility study for construction of combustible waste utilization CHP plant in Klaipeda city, was performed as the contract of JC *Klaipėdos energija*, revealed that using combustible municipal waste energy in district heating systems would be more expensive than heat generation in traditional facilities (operating on imported fuel). Current electricity and heat prices cannot ensure decent dividend of investment into the construction of waste thermal utilization facilities, and compensating these expenses from waste treatment taxes would require increasing these taxes several times.

Feasibility study for the use of local and renewable energy sources in CHP plant to be constructed in Siauliai, considering the expected prices growth for imported fuel and RES promotion in EU and Lithuania showed that at current prices of local fuel (peat) and natural gas this project

would be financially unattractive. Difference of natural gas and local fuel prices should be no less than 20 Lt/MWh. Meanwhile biofuel cogeneration plants, the electricity of which is purchased at favourable tariff, enable to reduce heat production costs.



RUSE project participants at LEI, 2005

The aim of international **RUSE project – Redirecting Urban Areas Development towards Sustainable Energy (under INTERREG-IIIC programme)** is to support new EU countries in directing energy policy towards sustainable development, using the Structural Funds. This support is provided at the level of urban development, transferring the experience of 15 old EU members in various aspects of energy sector. The task, assigned to Lithuanian Energy Institute in the project, is to coordinate the formation of joint projects implementation strategy.

Objectives of the project are to be reached through implementing the following activities:

- disseminating information to municipalities of new EU member states and third countries on the experience using the Structural Funds, accumulated by European countries and demonstrating it through the best practice examples;
- developing a capability to elaborate energy projects in municipalities and associate structures (municipal associations, networks, agencies, etc.);
- assistance in training municipal experts, elaborating high quality tenders related to sustainable development in their competence field, financing energy projects in accordance with ERPF programmes (including INTERREG IIIA, URBAN, etc.), i.e. practical help in integrating sustainable energy concept into urban development plans;
- incorporating of energy saving measures and promotion of renewable energy sources into the national strategies, which would have a positive impact on the urban development.

Consortium of 20 partners institutions participate in the project implementation. The most significant activities:

- development of expertise network for municipal and agencies' experts, having a big experience;



International **BBN project – Baltic Biomass Network (under INTERREG IIIB programme)** is implemented in the Baltic Sea Region (BSR) and is partially financed by the EC funds. The aim of the project is to contribute to implementing the EU objectives for biomass heat, power, and fuel production and use. Integrating new biomass processing schemes for bio-energy applications into areas with competing biomass processing and land-use structures raises complex spatial planning issues in regions where bio-energy and industrial biomass production capacities compete for a limited amount of resources, or in countries where woody biomass is blocked for profitable export markets, leaving few resources for local bio-energy applications. Consortium consists of partners from Germany, Finland, Poland, Lithuania, Latvia and Estonia.

In 2005 SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis was prepared for the assessment of issues of bioenergy planning in the Kaunas County, possibilities of regional data accumulation were overviewed, motives of the participants in this activity and barriers for bioenergy development were evaluated. Data basis of the Laboratory was renewed.



Mrs. J. Grigoniene defends PhD thesis

- transfer of experience, knowledge and skills through seminars, studies or practical activities in the recipient organizations;
- summarizing of best practice examples, preparing and promotion of guidelines procedures;
- dissemination of information and consulting for municipalities and adequate institutions in each new member state.



BBN project participants in Finland

6th Framework Programme EIFN (Energy Innovation Financing Network) was initiated in 2005. A wide network of energy enterprises and institutions, as well as financial agencies, which will help to implement the EU innovations and energy policy, offering financial services in energy sector, making practical and effective decisions, which would enable the access of innovation agencies to financing sources in energy sector, is to be created.

The project scope includes:

- stable collaboration of the EU innovation financial network for energy projects;
- co-ordination with other relevant EU initiatives: *Gate2growth* and *PAXIS*;
- identification and analysis of energy sector characteristics in relation to innovation financing and establish European map linking needs of sectors and funding sources;
- develop methodologies, tools, guidance materials and procedures to improve the access of energy research players to innovation financing;
- IT infrastructure development to support the designed technologies, tools and procedures;
- elaborate policy and operative recommendations to the EU innovation community.

Enterprises, research institutes, universities, energy agencies, private and public institutions participate in the project.

The Laboratory actively participated in preparing tenders for EU 6th Framework Programme and *Intelligent Energy Europe*. In 2005, 16 publications were published, including four articles in international journals and 12 papers at Lithuanian and international conferences. PhD Candidate J. Grigoniene successfully defended doctoral thesis ***Investigation of District Heating for Residential Sector***.

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LABORATORY OF SYSTEMS CONTROL AND AUTOMATION

Main research areas of the Laboratory:

- mathematical modelling of power systems and network, investigation of control issues;
- modelling information-control systems of power systems and optimization research;
- modelling of power systems and power network development.

Power systems and networks are complex objects, which require application of sophisticated mathematical models for the analysis of their operation, control and development issues. Formulation of models, realization with computer programs and application require a considerable inputs of high-qualification work and time resources. In the Figure the tasks of the transmission system operator, who controls power systems, are presented as well as structure of Laboratory's performed research related to these tasks.

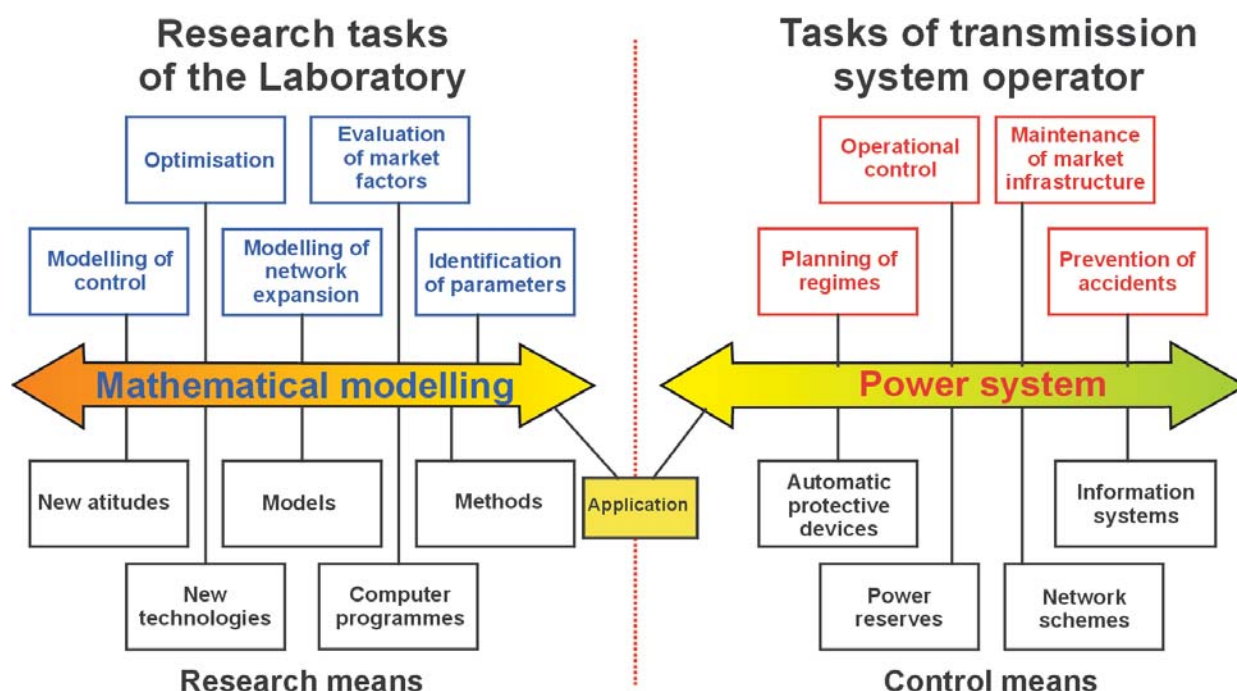
In November SC *Lietuvos Energija* became the true member of ETSO (the European Transmission System Operators As-

sociation). Since then Lithuanian power system control is becoming more observable at international level. Therefore, in Laboratory research there is a tendency to contribute to the aim of ETSO activities – harmonize the activity of electricity transmission systems, facilitating the liberalisation of electricity market.

In 2005 the Laboratory completed two research contracts for Lithuanian companies. The Laboratory prepared the study ***Research of incidents in power system and development of recommendations for the prevention of incidents*** for SC *Lietuvos Energija*. Statistics of failures in transmission network in 1999–

2004 is summarized in the study, regularities and consequences of failures are determined, recommendations prepared to reduce the frequency of failures.

In the study the impact incident sequence (cascade events) on the operation of transmission system was modelled and the transmission system's resistance to a degree of disturbance in various network regimes was determined. Calculation results and research conclusions will assist Lithuanian transmission system operator to improve the emergency prevention measures and work emergency prevention plans.





PhD Candidate V. Radziukynas paper "Evaluation of power system static parameters" in the LEI PhD Candidates and young researchers conference "Youth Energy 2005" received "Best paper" award

As a result of contract with Kaunas Regional Energy Agency *The feasibility study of meeting the electricity demand of Kaunas city Centre – Newtown* was prepared. In the study the scheme of electricity network of Kaunas city Centre – Newtown as well as the existing and perspective electricity loads were analyzed. The analogous issues were analyzed for the rest thirty administrative districts of the city. Perspective loads were determined on base of Kaunas city general development plan. In the study it is suggested how to redistribute perspective loads among 110 kV substations and which substations should be reconstructed. Performing this investigation, the Laboratory co-operated with JSC *Vakaru skirstomieji tinklai* Kaunas division and municipality enterprise *Kauno planas*. The study will assist Kaunas municipality to retain status of energy town, which was conferred to Kaunas in 2005 together with the European Energy Award.

The Laboratory finished the State funded project *Research of optimisation and functioning of power systems control algorithms and information systems, taking into account market operation*. Specificities of Lithuanian power system were analyzed and discussed. Regulation was simulated using mathematical models of power systems, which were supplemented with original mathematical models of wind power plants and their parks. Although there are no operating wind power parks in Lithuania, however, the State's plans up

to year 2010 to have approximately 200 MW of wind power plants give rise to investigate the interaction of wind energy system and power system. Employing measurement data of wind velocities in Lithuania the probable fluctuation of total wind generation and its impact on system frequency were modelled.

New evaluation method of power system parameters based on combination of known identification methods was drawn up, it allows to obtain values of system dynamic characteristics parameters more exactly and operatively. The obtained values were used to improve system control, including control of reserves and balance maintenance. Control possibilities were investigated taking into account the changed environment of power system performance e.g. competitive electricity market, national regulation of certain activities in electricity sector and public service, obligations. Under market conditions, data of electricity trading transactions and commercial metering is used in the control of power generation and transmission.

In electricity market environment the information systems turn out to be a rather significant subsystem of control system. In the above mentioned project the criteria of choosing the wind park information systems are analysed. Original statistical probabilistic multicriteria method, which allows under uncertainty conditions to evaluate the efficiency of each decision in

terms of normal distribution categories and to compare the alternative decisions, is suggested for the selection of information systems of wind power parks.

The Laboratory personnel presented four papers at international conferences in St Petersburg (Russia), Orland (USA), and five papers at national conferences, published seven scientific publications, four of them – in the international editions and three – in the journal *Energetika*.

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LABORATORY OF ENERGY SYSTEMS RESEARCH

Main research areas of the Laboratory:

- scenarios analysis of macroeconomic development, modelling and forecasting of energy demand;
- analysis of medium- and long-term energy supply scenarios using widely approved optimisation models;
- environmental impacts of the energy sector, analysis of pollution reduction technologies and implementation of environment protection policies;
- generalization of energy restructuring and liberalization experience in the European Union Central and Eastern European countries and application of the analysis findings for reforms in the Lithuanian energy sector;
- development of energy information system, collection of statistical data on the energy sector development in Lithuania and worldwide.

In 2005 the Laboratory performed research significant for the Lithuanian energy sector, the analysis of specific energy systems development, forecasting of energy demands, formation of optimization methodology and software of the energy sector development, and renewal of necessary statistical data basis.

State funded science research work ***Modelling of sustainable energy development*** analyzes a wide spectrum of issues related to energy sector and energy system development. In the work analysis of the following issues is presented:

- model of sustainable development of energy sector, which is implemented applying MESSAGE model software, a brief description of model and detailed description of heat supply system;
- specific aspects of energy sector modelling and formation of methods necessary for data basis,
- a comparative analysis of changes in energy consumption and tendencies of energy intensity in the Baltic countries and other Central and Eastern European countries;
- analysis of factors having impact on macroeconomic indicators and energy demands and their territorial distribution;
- a thorough analysis of the requirements of the EU directives (limiting emissions into the atmosphere of enterprises producing energy, promoting efficiency of energy consumption and usage of renewable energy sources) and assessment of possibilities to implement these directives in Lithuania;
- Balmorel model modification (module *Network*), designed for the modelling of complex electricity, district heat supply and natural gas network, and complex analysis;
- analysis of electricity network activity efficiency and transmission pricing improvement problems, assessment of systemic and additional services in the market and barriers for the distributed energy production development;
- energy infrastructure control model under market conditions based on Lagrange conception;
- prospective fossil fuel balance and natural gas consumption scenarios and assessment of territorial distribution of gas consumption;
- assessment of natural gas consumption regimes and pressure in critical points of the Lithuanian gas supply system, obtained applying STANET programme package in case of basic and maximal demands scenario.

Egidijus Norvaisa defends his PhD thesis. Besides him scientific supervisor dr. A. Galinis and Chair of Power and thermal engineering science direction council prof. J. Vilemas



In 2005 the cooperation with the Ministry of Economy of the Republic of Lithuania was successfully continued. The Laboratory won the tender for the preparation of four science research projects.

In the project ***Analysis of technical and economical indicators of the Lithuanian energy sector, their comparison with the indicators of the EU countries*** the following results are presented:

- analysis of technical economical indicators of the Lithuanian energy sector;
- general and detailed country's fuel and energy balances for 2000-2004 as well as balances of production and consumption of individual fuel and energy types;
- a comparative analysis of energy consumption indicators in European countries for year 2002;
- on the basis of performed analysis of data presented in publications of Lithuanian Department of Statistics, SC *Lietuvos energija* and international statistics, the publication *Lietuvos energetika 2004* was prepared.

In the project ***Reliability assessment of energy and fuel supply and justification of respective recommendations on legal regulation, in respect to the EU countries experience and EU law acts, and preparation of measures plans*** the following is presented:

- reliability assessment of natural gas supply in Lithuania, considering conditions of country's gas supply system;
- assessment of modernization and development of gas-mains;
- analysis of possibilities for underground natural gas storage construction in the country's territory and rent of Latvia storage;
- principles of legal basis formation of natural gas supply and project of the Lithuanian Government decision *Order of natural gas supply reliability ensurance*.

In the project ***Investigation of energy sector activity and other factors, influencing economical safety, and preparation of recommendations*** the following is presented:

- analysis of energy sector activity indicators and other factors, which have impact on the economical safety;
- assessment of probable hazards for the energy sector;
- recommendations for strengthening energy safety for the period up to 2025.

In the project ***Assessment of possibilities of the Lithuanian energy sector preparation for greenhouse gas emission allowance trading for the period 2008-2012 and trading of them with the neighbouring countries*** the following is presented:

- recommendations regarding distribution of emission allowances trading for Lithuanian power facilities;
- analysis of Lithuanian enterprises' trading of emission allowances and possibilities to implement projects with neighbouring countries;
- analysis of basic administrative and technical obstacles, related to the implementation of emission allowances;
- correction principles regarding legal acts related to emission allowances trading.

In the frame of contract with Kaunas University of Technology the laboratory performed science research work **Possibilities and competition of electricity energy export**, the following is presented in the work:

- forecast of final electricity energy demand and net electricity production and balance of capacities;
- tendencies of oil, natural gas and other types of fuel prices' change;
- method, enabling to evaluate increase of fuel prices and impact of power plants structure changes on the price of power production;
- assessment of power prices increase on the markets of Poland and Scandinavian countries;
- analysis of factors determining new nuclear power plant competitiveness in Lithuanian and neighbouring countries' electricity markets;
- scenarios of Estonian, Latvian, and Lithuanian power systems' sustainable development.

Based on the above mentioned analysis the study **Analysis of nuclear power plant competitiveness in electricity markets of Baltic, Scandinavian, Western Europe countries and Russia** was prepared together with Electric Power Systems Department at Kaunas University of Technology.

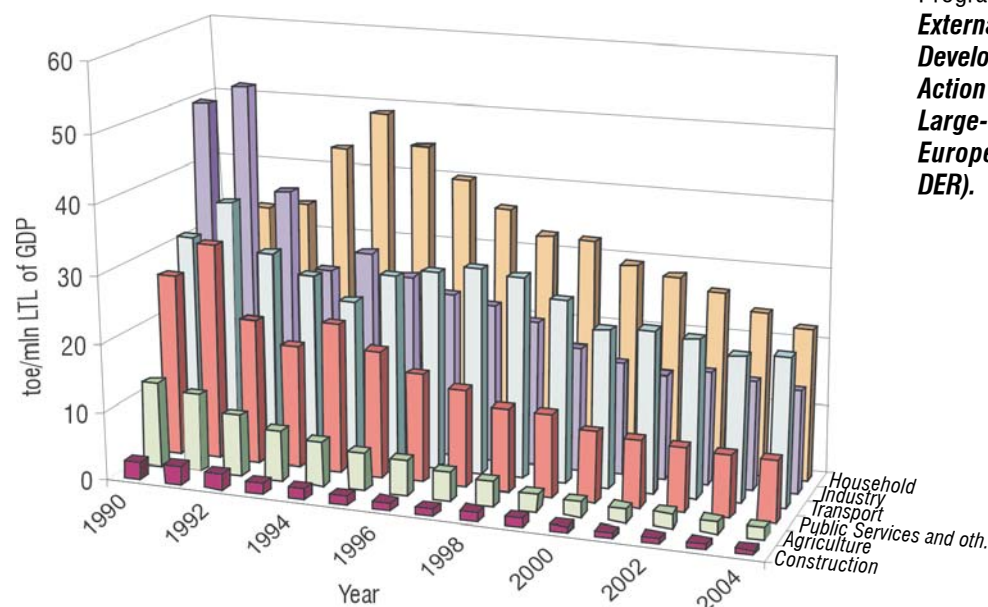
Within the framework of the Intelligent Energy for Europe programme in the projects **European tracking system for electricity (E-TRACK) and Assessment and optimisation of renewable support schemes in the European electricity market (OPTRES)** the following is presented:

- assessment of best experience, promoting consumption of RES and key obstacles for the development of these sources usage;
- information gathered on the implemented RES support schemes in the EU countries;
- data basis of *green power* production and installed capacities in the EU countries during the period of 1990-2003;
- analysis and assessment of requirements of power origin identification, which are defined by European and national legal acts.

Cooperation with SC *Lietuvos energija* was successfully continued. In the frame of contract with Central Project Management Agency, together with JSC *Paspara* project **Realization and implementation of Lithuanian power network planning system** was prepared and it will assist to company's specialists in solving power system prospective planning tasks. The Laboratory personnel contributed to the preparation of publication **Overview of Lithuanian power system and development perspectives**.

The Laboratory participates in the EU Fifth Framework Programme project **Analysis of Policy Instruments and Identification of Tools for the Implementation of Rational Energy Use and Increased Use of Renewable Energy Sources in the EU Candidate Countries**, Sixth Framework Programme **The Development of New External Cost Research for Sustainable Development (NEEDS)**, and **Coordination Action to Consolidate RTD Activities for Large-scale Integration of DER into the European Electricity Market (SOLID-DER)**.

Variation of final energy intensity





Dr. I. Konstantinaviciute congratulates Ramunas Gatautis with successful defence of PhD thesis

Laboratory researchers participated in the project **Power system development in the common Baltic countries market** financed by the Denmark power company *Elkraft System*. Besides, Laboratory personnel contributed to the implementation of **INTERREG-IIIC project Redirecting Urban Areas Development towards Sustainable Energy**, also joined the project International Reactor Innovative and Secure (**IRIS**).

Accumulated experience of the laboratory was used at international level in preparing:

- power sector models of Mongolia, Serbia and Montenegro, and Poland and performing analysis of their development scenarios (A. Galinis);
- Intergovernmental climate organization report **Climate change reduction means** (I. Konstantinaviciute);
- UNECE (United Nations Economic Commission for Europe) second environment protection assessment for the Republic of Moldova (D. Streimikiene);
- UNECE (United Nations Economic Commission for Europe) second environment protection assessment for Ukraine (D. Streimikiene);
- Report of Nordic Council of Ministers **Kyoto Protocol challenges for the Baltic countries power sectors** (D. Streimikiene).



Dr. D. Streimikiene and PhD Candidate A. Mikalauskienė

Year 2005 was significant for increasing competence and qualification of laboratory researchers. Senior research associate Dalia Streimikiene prepared the overview of works *Solution of environmental and social problems by overcoming energy market failures*. Dalia Streimikiene was the first woman from Lithuanian Energy Institute to successfully complete habilitation procedure at Vilnius Gediminas Technical University. Junior research associates Egidijus Norvaiša and Ramunas Gatautis defended doctoral dissertations: E. Norvaiša *Modelling and analysis of sustainable development of Lithuanian power and heat supply sectors*; R. Gatautis *Mathematical modelling of cogeneration power plants and energy transmission networks in electricity and district heating markets*. Senior research associate D. Streimikiene was for three months on traineeship in the

head quarters of BASREC Group of Senior Energy Officials, Iceland, Reykjavik. Senior research associate Arvydas Galinis and PhD student Dalius Tarvydas participated in IAEA training courses in Argonne National Laboratory (USA).

Besides, D. Tarvydas raised his qualification in Germany in 2-week courses organized by IAEA, designed for mastering the experience of MESSAGE model employment for energy research analysis.

Student S. Gorlitz from Germany (Hanover University) was on traineeship at Laboratory of Energy Systems Research (Lithuanian Energy Institute) for six weeks.

Researchers participated in international conferences in Austria, Belgium, Denmark, Croatia, Latvia, Poland, Taiwan,

Germany and other countries, where more than 20 papers were presented. In 2005 Laboratory researchers published 18 articles in Lithuanian and international journals and proceedings of international conferences.

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Main directions of research activities:

- investigations on safety and reliability of power plants and transport objects and their impact on water environment;
- analysis of climate change and rivers runoff variation;
- accumulation of data on Lithuania water bodies (rivers, ponds, the Curonian Lagoon and the Baltic Sea).

Scientific research object and methods

The investigation of Lithuanian water bodies has been performed using a numerous of hydrographic, hydrologic, morphologic, meteorological and other data accumulated in the Laboratory of Hydrology since 1961. The modern modelling system MIKE 21 from Danish Hydraulic Institute is used to solve the main task of environment protection – to evaluate the impact of human activities on environment. MIKE 21 models of hydrodynamic, wave, advection and dispersion, sediment (sand and mud) transport are used to model water levels, flow rates, surge, dynamic of sediments (erosion of bottom and coast, sediment ac-

cumulation, turbidity), dispersion of pollution.

International cooperation

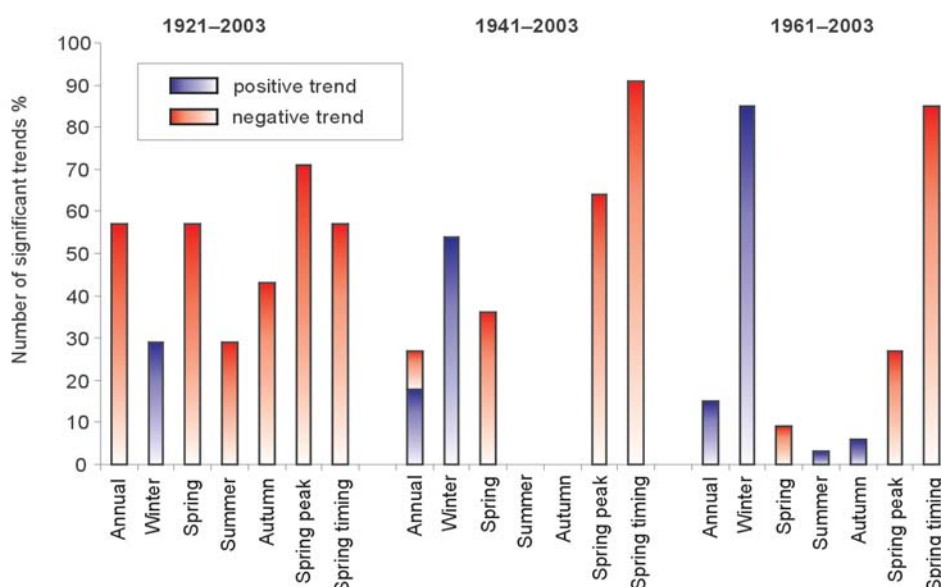
In 2005 the joint project with Northern countries ***Climate and Energy*** was launched. The project is funded by Nordic Energy Research. Researchers from Norway, Sweden, Finland, Denmark, Iceland, Lithuania, Latvia and Estonia take part in this project. The main objective – to assess the impact of climate changes on energy sector. Research groups of climate change scenarios, statistical analysis and hydrological modelling were created for this aim. Scientists of Laboratory of Hydrology participate in the activity of statis-

tical analysis group. In 2005 the following activities were performed: hydrological and meteorological data basis of Lithuanian territory was created, analysis annual, seasonal and flood discharge trends of Lithuanian rivers for 1920-2003, 1941-2003 and 1960-2003 was performed. The obtained results were compared with the analogous research carried out by Northern countries. Common tendencies were determined (rivers winter runoff increases, spring floods occur earlier, maximum discharges of flood reduce).

The Laboratory researchers were invited as experts into two NATO/CCMS seminars ***Integrated water resources management***, which took place in Portugal and Turkey.



Research object of project "Climate and Energy" – territory of the Nordic and Baltic countries



Changes of many year parameters of Lithuanian rivers' runoff (positive trend – tendency of increase, negative trend – tendency of decrease) in three different periods (1921–2003, 1941–2003, 1961–2003)

Research objects

Most significant scientific research objects of the laboratory are as follows: the Kaunas Reservoir, the Nemunas river, the Curonian Lagoon, and the Baltic Sea. These water bodies are under the extreme nature expressions (storms, excess rainfalls, and draughts) and are affected by human activities.

Using an accumulated database the following tasks are solved:

- the assessment of environmental impact of human activities in water bodies and justification of environment protection means;
- protection and management of coasts of the Baltic Sea.
- determination of the extreme hydrological and hydraulic conditions under the exploitation of the hydrotechnical constructions.
- determination of operation regime of power plants taking into account the environment protection objectives;
- numerical assessment of mixing and dispersion of contamination under critical operation conditions in water bodies.
- exploitation of Seaport and water ways maintaining secure depth for navigation.

Cooperation with other institutions

The Laboratory of Hydrology closely cooperates with a number of Lithuanian institutions. The main areas of cooperation are as follows:

- works in accordance with the agreements between the Ministry of Environment of the Republic of Lithuania and Lithuanian Energy Institute in the field of water bodies protection, hydrography and hydrology, assessment of human activities impact on water bodies;
- joint doctoral studies between Lithuanian Energy Institute and Institute of Environmental Engineering of Kaunas University of Technology in the field of environmental engineering and land management;
- publishing of scientific journal *Environment research, Engineering and Management* in cooperation with others scientific institutions of Lithuania (Kaunas University of Technology, Vilnius University, Vilnius Gediminas Technical University, etc.);
- complex environmental research together with Institute of Geology and Geography, Institute of Ecology of Vilnius University, Vilnius Gediminas Technical University, Lithuanian University of Agriculture, and Klaipeda University;
- cooperation with geological research enterprise *Geoprojektas*.

Applied research works

In the frame of contract with *Klaipeda State Seaport Authority* and additional funding from Lithuanian State Science and Studies Foundation, *Atlas of waves of the Klaipeda Strait and the Baltic Sea near shore* was prepared. Distribution of waves' parameters (height, period, direction) in water area was modelled employing 2D system MIKE 21. Work results – maps of waves' parameters distribution may be employed:

- for the characteristics of navigation and loading works conditions operating Klaipeda seaport water area under extreme conditions;
- for training of navigators;
- for determining hydrotechnical construction waves loads;
- for investigating consequences of extreme storms on the environment (constructions, coast, and beach) and navigation (ship crashes).

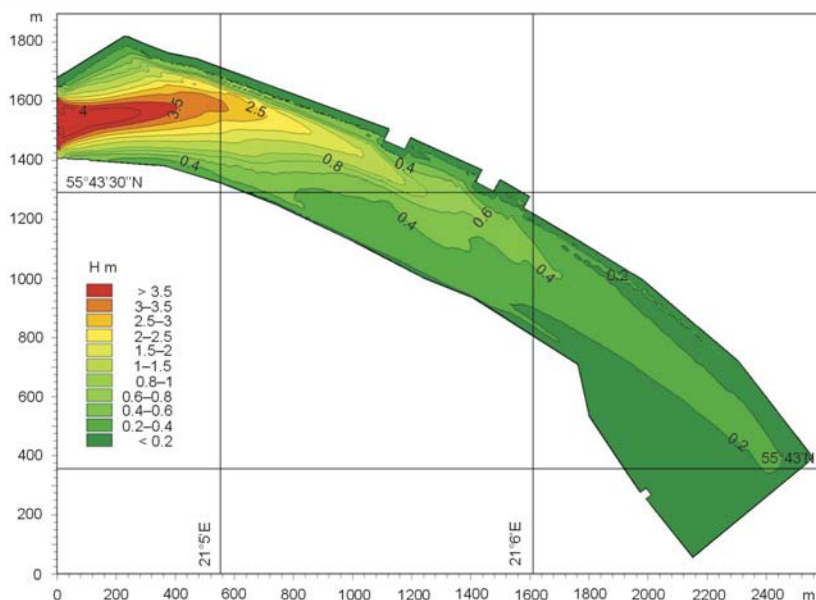
In the frame of the project with *Klaipeda State Seaport Authority* three projects for dredging harbour cover work technology, the sequence and implementation of works as well as assessment reports on harbour dredging impact on the environment were prepared.

In the frame of the project with J SC *Lithuanian Energy* adjustment of rules for Kaunas HPP pond usage and maintenance was carried out. The aim of this work was to match pond water resources usage conditions for electricity production with the objectives of environment protection.

Laboratory personnel participated in two international conferences and published five science articles in scientific journals.

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*Distribution of the wave height in the Klaipeda Strait
 (wind direction – West, wind – speed 20 m/s)*



FINANCIAL HIGHLIGHTS

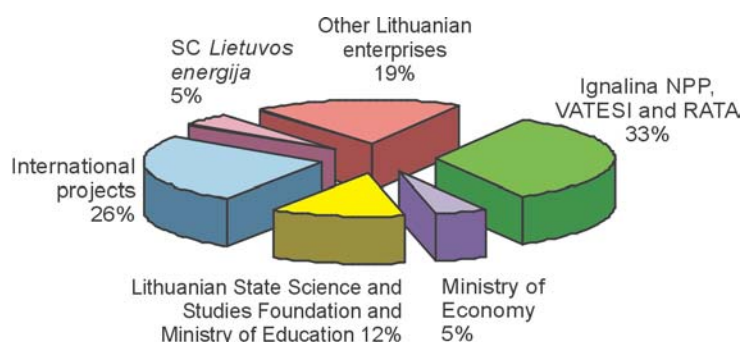
The financial sources of the Institute consist of:

- State budget subsidies;
- financing for research programmes and education of specialists;
- financing received from Lithuanian and foreign enterprises and organizations for contract works, realization of products and services;
- funds received from various international research programmes and funding organizations;
- subsidies, received from enterprises and associations for participation in joint activities and training of specialists.

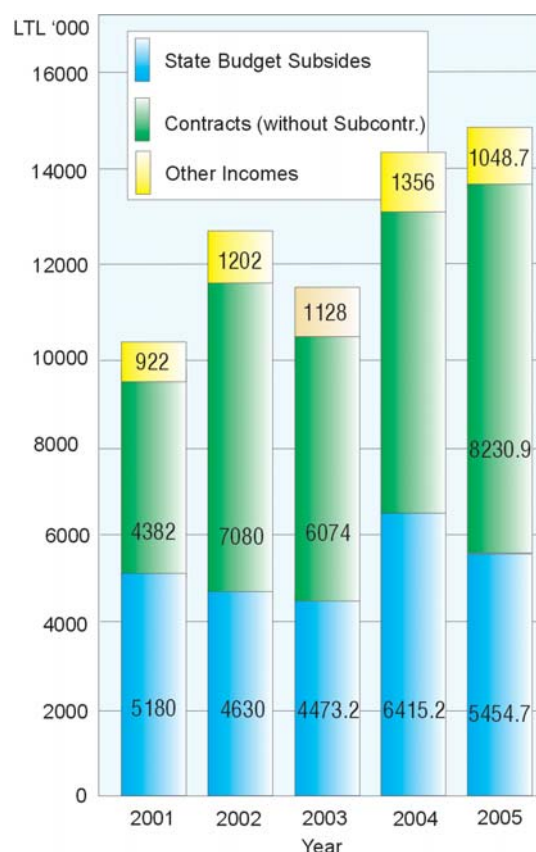
Structure of Income and Total Expenses (LTL'000)

	2001	2002	2003	2004	2005
Income:					
State Budget Subsidies	5180	4630	4473.2	6415.2	5454.7
Contracts	4382	7080	6074.0	6833.0	8230.9
Other Income	922	1202	1128.0	1356.0	1048.7
Total:	10484	12912	11675.2	14604.2	14734.3
Expenses:					
Salaries (soc. ins. incl.)	6362	7181	7783.0	8667.0	9345.5
Operating Expenses	2544	2842	3572.2	3699.7	3559.0
Capital Funds	659	1887	571.0	1564.3	1548.4
Total:	9876	11910	11926.2	13931.0	14452.9
Long-term Projects Assets	954	1956	1705.0	2378.2	2878.0

Financial Sources of Economical Activity in 2005



Variation of Financial Structure



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11 January. Participants of seminar "The European Energy Award"



8 March. Women researchers of LEI



28 March. General meeting of LEI scientists



8 April. Employees of the Institute visit Lithuanian Power Plant



20-22 April. IRIS conference



3 May. Prof. J. Augutis at seminar "Face to face to the Nemunas River"



12 May. Expo „Kaunas city days - 2005“



2 June. Steering committee of young LEI scientists and PhD candidates' conference "Youth Energy 2005"

10 June. Conference of the Lithuanian Academy of Sciences "Application of information and control technologies in electricity sector"



12 July. Establishment of the summer garden



11 November. Seminar "Hydrogen energy technical training"



25 November. Students and teachers of Ariogala and Josvainiai schools visit LEI



28 December. Employees of LEI bid farewell to year 2005



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