LITHUANIAN ENERGY INSTITUTE



ANNUAL REPORT

SCIENTIFIC RESEARCH DIRECTIONS TODAY

The year 2010 marks the beginning of new scientific directions at the Institute. Presently more than a half of scientific work is applied research, however the Institute is continuing fundamental research in the fields of thermal physics, combustion processes, thermohydraulics of nuclear reactors, material science, metrology and hydrology. The research in the field of hydrogen energy technologies is also rapidly developed.

Lithuanian Energy Institute carries out the development of methods for energy sector planning and research on safety, reliability and environmental impact of energy objects, energy efficiency and renewable energy sources. Researchers of the Institute also perform research in the fields of thermal physics, fluid and gas mechanics, and metrology, models elaborate systems and develops operational methodologies and technical means for system control. Moreover, the Institute performs research on the lifetime of energy systems constructional elements and innovative multifunctional material technologies, combustion and plasma processes in the fields of fuel saving, reduction of environmental pollution and thermal decontamination of materials, as well as fundamental and applied research of nuclear, fusion and hydrogen energy.

ACCNOWLEDGEMENT

Many activities deserve mentioning, however the acknowledgement of one of the priority projects in the Institute, *The Center for Hydrogen Energy Technologies*



Lithuanian Confederation of Industrialists' nomination Successfully Operating Company 2010 granted to the Institute is especially pleasing. The project was evaluated by the experts and competed in the nomination *For Science and Innovations,* where it received the support of the Lithuanian experts.

Active operation of our Institute and its influence on the development of science did not pass unnoticed. Important agreement on the financing of *Integrated Science, Studies and Business Valley SANTAKA* was signed.

EDUCATION

LEI take part in relevant social activities, educate the society and present as many solutions to the energy issues as possible. The possibilities of renewable energy sources use in both Lithuanian enterprises and households are important not only for the society, but also the like-minded colleagues. For this purpose, in 2010 the Institute organized a number of seminars providing information on the perspectives of this field.

In order to contribute to the attempts made by the State to promote the interest



Signing project funding contract of Integrated Science, Studies and Business Valley SANTAKA

in science and its innovations, provide information about scientists and their work methods, the Institute organized **Researchers' Night 2010.** During this event, visitors (mainly teenagers) were welcomed to various laboratories not only to see different equipment, but also to observe demonstrative tests. A 5-minute TV reportage was broadcosted from the Institute by the national TV channel. Additionally, lectures-discussions related to the current research and emphasizing its application in everyday life as well as its influence on society development took place during *Researchers' Night*. The topics discussed during the lectures were very wide, including tracking, risk of extreme events, medicine development, nuclear energy and science philosophy.



Researchers' Night 2010 at the LEI Laboratory of Materials Research and Testing

FUTURE

The most important future plans of the Institute are the development of Lithuanian energy security assessment methodology and the work on security of energy supply and reliability assessment. This work, financed by State grant, is expected to contribute to the reduction of the energy dependence on foreign suppliers.

I strongly believe that such steps reinforce the competitiveness of our country in the global level and signify the ability of our nation to act and develop independently.

Our goal is to work on the research and implementation of state-of-the-art energy technologies in Lithuania, including innovative hydrogen technologies, improvement of fuel elements and their application to the present needs.

Prof. Dr. Habil. Eugenijus Ušpuras Full member of the Lithuanian Academy of Sciences Director of the Lithuanian Energy Institute

LITHUANIAN ENERGY INSTITUTE IN 2010

MISSION OF THE INSTITUTE

To carry out research and develop innovative technologies by applying the research results and new discoveries in business, industry and education; to consult public and private institutions on the issues of sustainable energy development.

OBJECTIVES OF THE INSTITUTE

To perform fundamental and applied research necessary for the sustainable development of the Lithuanian energy and integration into the European energy networks; in cooperation with governmental and business subjects, to spread scientific knowledge in the society and promote the development of the Lithuanian economy on the basis of innovations and knowledge.

SHORT-TERM STRATEGIC OBJECTIVES

- To build and develop a highly-qualified Centre for Scientific Research and Experimental Development;
- To develop education and study system;
- 3. To prepare first-class specialists for solving energy issues;
- 4. To maintain and develop the experimental basis.



MEMBERSHIP AND COOPERATION WITH NATIONAL AND INTERNATIONAL ORGANIZATIONS

LEI belongs to the following associations:

Nuclear Energy Association (**BEA**), Lithuanian Electricity Association (**LEEA**), Lithuanian Energy Consultants Association (**LEKA**), Engineering Industries Association of Lithuania (**LINPRA**), Lithuanian Research Library Consortium (**LRLC**), Confederation of Lithuanian Industrialists (**CLI**), Lithuanian Thermotechnical Engineers Association (**LTTEA**), National Space Association of Lithuania (**NSA**), Lithuanian Gas Association (**LGA**), Association for Energy Economics (**EEA**), Building Product Testing Laboratory Association (**BPTLA**), Hydrogen Energy Association (**HEA**), European Technical Support Organisations Network (**ETSON**), European Network of Freshwater Research Organisations (**EurAqua**), European Network of Freshwater Research Organisations, The European Association of National Metrology Institutes (**EURA-MET**), Euro-Asian Cooperation of National Metrological Institutions (**COOMET**), European Nuclear Safety Training and Tutoring Institute (**ENSTTI**), International Energy Agency Hydrogen Implementation Agreement (**IEA HIA**), New European Research Grouping on Fuel Cells and Hydrogen (**N.ERGHY**), European Sustainable Energy Innovation Alliance (**ESEIA**).

ORGANIZATIONAL STRUCTURE OF THE INSTITUTE

According to the LEI Statute, approved by the decision No. 1812 of the Government of the Republic of Lithuania made on 23 December 2009, the administrative bodies of the Institute are the following:

 Scientific Council of the Institute (Scientific Council); Director of the Institute.

A public supervision institution, the Supervisory Council of the Institute is established in LEI.

Following the determinate order of the Statute, the Scientific Council is elected for 5 years from the researchers and administration of the Institute, and the representatives of other institutions, companies and organizations concerned about reaching the objectives of the Institute.

In 2010 a new Scientific Council of the Institute was elected.



Scientific Council of the Institute (standing on the left): Daivis VIRBICKAS, Technical Director of JSC LITGRID; Dr. Vitas VALINČIUS, Head of the Laboratory of Plasma Processing; Prof. Dr. Habil. Juozas AUGUTIS, Chief Research Associate of the Laboratory of Nuclear Installation Safety; Dr. Rimantas BAKAS, Director General of SC Kauno energija; Prof. Dr. Habil. Eugenijus UŠPURAS, Director of the Institute; Dr. Nerijus PEDIŠIUS, Senior Research Associate of the Laboratory of Heat Equipment Research and Testing; Dr. Rolandas URBONAS, Scientific Secretary, Head of the Information Department; Saulius BILYS, Head of Strategic Department of SC Lietuvos dujos; Dr. Dalius ŠULGA, Energy Expert of the Lithuanian Electricity Association; (sitting on the left) Prof. Dr. Habil. VacIovas MIŠKINIS, Head of the Laboratory of Nuclear Installation Safety; Dr. Rimantas LEVINSKAS, Deputy Director of the Institute; Dr. Arvydas GALINIS, Chief Research Associate of the Laboratory of Nuclear Installation Safety and Dr. Rimantas VAITKUS, Director General of SC VST (presently Director of External Affairs of Visaginas Nuclear Power Plant)

The Supervisory Council of the Institute is elected from the social partners interested in the scientific research and experimental (social) development pursued by the Institute. The Council consists of 7 members: 3 social partners are proposed by the Institute Scientific Council, 2 – by the Research Council of Lithuania and 2 – by the Ministry of Education and Science.

The Supervisory Council of the Lithuanian Energy Institute

- 1. Assoc. Prof. Dr. Jolanta Zabarskaitė, Director of the Institute of the Lithuanian Language;
- 2. Dr. Stanislovas Karčiauskas, Executive Director of SC Kauno energija;
- Dr. Gintautas Klevinskas, Head of the Safety and Licensing Competence Centre of JSC Visaginas Nuclear Power Plant;
- 4. Prof. Dr. Habil. **Marijonas Bogdevičius**, Professor at the Department of Transport Technological Equipment of Vilnius Gediminas Technical University;
- 5. Prof. Dr. Habil. **Algirdas Žemaitaitis**, Professor at the Department of Organic Technology at Kaunas University of Technology;
- Mr. Gintautas Danaitis, Chief Specialist of the Division for Energy Resources, Electricity and Heat of the Ministry of Energy of the Republic of Lithuania, Chairman of the Council;
- 7. Dr. **Stanislovas Žurauskas**, Head of the Division of Science and Technology, the Ministry of Education and Science of the Republic of Lithuania.

SCIENTIFIC RESEARCH ACTIVITY OF THE INSTITUTE

- I. Research in the fields of thermal physics, fluid and gas dynamics, and metrology;
- II. Materials, processes and technologies research for the management of renewable energy sources, hydrogen energy, effective use of energy resources and reduction of environmental pollution;
- III. Safety and reliability of nuclear, thermonuclear energy and other industrial objects;
- IV. Radioactive waste management and decommissioning of the Nuclear Power Plant;
- V. Modelling and control of energy systems; energy economy.



Distribution of researchers according to the research directions

16 state-funded projects were implemented in the Institute and 5 of them were completed and defended in 2010.

Development of Multicriteria Decision Making Methods and their Application in Energy and Environmental Policy (Project leader – Dr. D. Štreimikienė). In the report of the completed project:

- a conceptual model and consistent methodology for multicriteria decision making in the energy sector were proposed. The methodology describes the research stages, tasks and results as well as their interrelationship; it also enables a thorough assessment of the decisions related to the energy sector taking into consideration the developmental priorities of the sector;
- the proposed methodology was applied for the monitoring of energy strategy, the assessment of electricity generating technologies, developmental scenarios of energy sector and measures for climate change mitigation, and their ranking according to the level of ensuring the priority objectives of the energy sector;
- the assessment of electricity generating technologies by applying different ranking scenarios and altering the index weight in the integrated sustain-



Distribution of laboratories according to the research directions



Variation of staff number

able index showed that the best technologies use renewable energy sources, whereas the worst ones employ coal and lignite. These results were not substantially influenced by the sensitivity analysis.

Experimental and Numerical Modelling Research of Biofuel and Calorific Waste Aiming at Improving Energy Production Technologies (Project leader – Dr. A. Džiugys).

During the implementation of the project:

- the dependence of gaseous products exhaustion, resulting from autothermal conversion of glycerol, on the ratio of water vapour to carbon in the glycerol was examined. It was estimated that the H₂ exhaustion increases up to 20%.
- the covered layer of the oxide catalytic coatings, produced by plasma spray, was identified to have good thermal properties and adhesion with the covered substrate as well as being dense and porous;
- having carried out the research of glycerol gasification, it was noticed that the nickel (Ni) catalyst was the most effective, whereas the conversion of hydrogen comprised about 65%. The efficiency was also improved by the Cu and CuO mixture catalysts (conversion 47%);
- the activation of carbon, obtained during the gasification of pulverized used tires, using water vapour and carbon dioxide gas was performed. It was determined that the water-vapour-based activation reduces the carbon mass of the tires by 13.8%, while carbondioxide-based by 16.35%. On the grounds of the received results a conclusion can be made that when carbon dioxide is applied, the active surface of the carbon is greater than the one obtained using water vapour;
- a methodology for qualitative and quantitative evaluation of mixing and segregation was developed, an equa-



Dynamic of age of scientists (researchers with PhDs)

tion describing the process of segregation was deduced and the coefficients of the equation were assessed in relation to the investigated system;

- a methodology for distinguishing particle groups according to selective parameters was created;
- an integral combustion model of combustible particles was adjusted to the numerical modelling of combustion processes together with the dynamics of granular material.

Heat Transfer and Flow Hydrodynamics Research in Transitional Flow Zone at Mixed Convection and Interaction of Stable and Unstable Air Density Stratification (Project leader – Dr. R. Poškas).

The experimental research demonstrated that heat release in both turbulent flow zone and vertical flat channel is much more intensive at the interaction of mixed convection and stable and non-stable air density stratification in the flat channel than at turbulent flow. The experimental and numerical research carried out in a leaning flat channel when $\varphi = 60^{\circ}$ showed that the impact of stratification is insignificant and the data obtained from the top and bottom wall do not differ much. In contrast, a greater heat release from the bottom wall is observed then $\varphi = 30^{\circ}$; in this case, the difference between the data of both walls is about 40%. Having carried out numerical research in the leaning channel, it was determined that in the case of two-sided heating, local flows are formed at the full length of the channel walls when the impact of the thermo-gravitational forces is sufficient, similarly as in the case of the vertical channel. For determining the place of flow stability loss, generalised dependencies were proposed.

Planning Principles and Implementation Possibilities of Sustainable Energy Development (Project leader – Dr. V. Kveselis).

During the implementation of the project:

- information on the formation principles, criteria of sustainability and foreign experience in the sustainable regional energy development programmes was collected and summarised;
- a model of systemic analysis was prepared; it assesses the estimation and forecasting of quantitative and qualitative indexes of energy supply in a region (administrative unit), and encompasses economic, environmental (including pollution and greenhouse gas emission) and social aspects;

- on the basis of the selected region (municipality), a methodology for the analysis and forecast of regional energy sector development was developed together with a numerical modelling programme for its realization. The methodology encompasses economic, reliability, environmental and social criteria of sustainability;
- energy development of the selected region (Kaunas district) was assessed using the MESSAGE model.

Experimental Modelling and Research on Patterns of Zirconium-Based Alloys Decay and Temperature-Affected Phase Changes in Heat-Resistant Carbon Steel Structure (Project leader – Dr. A. Grybėnas).

The following results were achieved in this project:

- the conditions for hydride crack formation in the thermal element claddings were assessed, the crack growth rate was determined and experimental measurement methodologies were developed;
- the rate of hydride cracking and threshold stress concentration coefficient under cyclic loading were estimated;
- the sequence of melting and forma-



Variation of publication number (author's contribution evaluated)

tion of heat-resistant steel carbides and the variation in the quantity of the carbide phases under the effect of temperature and time were determined;

- the parameters of hydride cracking were identified in the tubes of different structures and production technologies;
- the variation of carbide-phase crystal lattice parameters under the effect of temperature and time was determined and the patterns of physical condition and structure change of heat-resistant steels were assessed.

26 international projects, including 9 projects of FP7 were under implementation in 2010

- 7BP European Fusion Development Agreement EFDA) FU37-CT-2007-00044. The representative of Lithuania – *E. Ušpuras*.
- Security of Energy Considering Its Uncertainty, Risk and Economic Implications (SECURE). The representative of the Institute – *J. Augutis*.
- Energy technological foresight and scenario development (PLANETS).
 The representative of the Institute – *D. Štreimikienė*.
- Integrated European Network for bio-

mass and waste reutilisation for Bioproducts (AQUATERRE). The representative of the Institute – *V. Katinas*.

- Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste (CARBOWASTE). The representative of the Institute – *P. Poškas*.
 Eate of Papacitany Cases (EOPCE)
- Fate of Repository Gases (FORGE).
 Instituto atstovas *P. Poškas*.
- Network of Excellence for a Sustainable Integration of European Research on Severe Accident Phenomenology (SARNET2). The representative of the Institute – *A. Kaliatka*.
- Product and Process Design for Aml Supported Energy Efficient Manufacturing Installations (DEMI). The representative of the Institute – *R. Škėma.*
- Researchers' night 2010: You could be a researcher too (LT-2010). The representative of the Institute – *D. Mei-Iutytė-Barauskienė.*

European scientific research

LEI researchers have successfully joined the common field of European scientific research (2004–2010):

- the 6th Framework Programme 14 projects;
- the 7th Framework Programme 9 projects;
- Intelligent Energy Europe 25 projects;

- International Atomic Energy Agency 7 projects;
- Leonardo Da Vinci 1 project;
- INTERREG 3 projects;
- COST 10 projects;
- EUREKA 3 projects;
- Nordic Energy Research Programme – 2 projects;
- Baltic Sea Region Programme 2007– 2013 – 3 projects;
- South Baltic Cross-border Cooperation
 Programme 1 project.

The successful participation in the FP7 projects can be shown from **30** submitted applications **19** have already passed the assessment (**9** projects are under implementation).

In 2010 the Institute became a member of Confederation of Lithuanian Industrialists and Lithuanian Energy Consultants Association, and on 15 September joined the Sustainable Nuclear Energy Technology Platform (SNETP) under the decision of its Governing Board.

In 2010, the Institute organized 2 international conferences, more than 10 international seminars and meetings as well as various discussions on international projects and their presentation to the society.

DOCTORAL STUDIES

Lithuanian Energy Institute has a right for joint doctoral studies with Kaunas University of Technology in the following fields:

- Power and Thermal Engineering (Technological Sciences, 06T);
- Environmental Engineering and Land Management (Technological Sciences, 04T);
- Economics (Social Sciences, 04S).

In 1992–2010, 69 students completed doctoral studies and 49 (71%) defended doctoral theses. Every year doctoral studies are joined by 23–28 students and 3–5 theses are defended.

In 2010, Kaunas University of Technology together with Lithuanian Energy Institute granted PhD Degrees of Power and Thermal Engineering (Technological Sciences, 06T) to the PhD Candidates of the Institute, namely:

- 9 February. Aušra MARAO for her work Simulation of Processes in Fuel Rods Of RBMK Type Reactors;
- 23 February. Raimondas KILDA for Analysis of Radionuclide Migration from Near-Surface Repositories for Radioactive Waste;
- 24 May. Jonas KUGELEVIČIUS for his work *Research of Lithuanian* Gas *Transmission Network Functioning* and Development;
- 21 December. Mindaugas VALINČIUS for his work *A Study of Condensation*



Arrangement of PhD Candidates according to science directions in 2006–2010



Structure of PhD Candidates' number in 2006–2010



Having successfully defended the doctoral thesis, Žydrūnas Kavaliauskas is congratulated by the colleagues from the Plasma Processing Laboratory

Implosion Employment in Passive Cooling Systems.

In 2010, Vytautas Magnus University granted PhD Degrees to two researchers of the Institute, namely:

 – 21 June. Inga ŽUTAUTAITĖ-ŠEPUTIENĖ (Engineer at the Laboratory of Nuclear Installation Safety) for Physical Sci-

ences, Information Technologies (09P) work : *Parameters Estimation of Non-Stationary Processes Models Using Bayesian Approach*;

9 December. Žydrūnas KAVALIAUS-KAS (Junior Research Associate at the Laboratory of Plasma Processing) for Physical Sciences, Physics (02P) work: *Investigation of Supercapaci-*

tors with Carbon Electrodes Obtained from Argon-Acetylene Arc Plasma.

Admission to doctoral studies takes place at the end of June, and in August-September if any vacancies remain.

Doctoral studies provide an opportunity of employment, participation in international projects, training courses in foreign science centres and international conferences. Future doctoral students are offered to meet possible supervisors in advance.

More information on doctoral studies in the Institute on **http://www.lei.lt** (in Information: Doctoral Studies).

> Contact person: Jolanta Kazakevičienė Studies Administrator Tel.: +370 37 401 809 E-mail: jolanta@mail.lei.lt



Number of papers in scientific conferences

LABORATORY OF HEAT-EQUIPMENT RESEARCH AND TESTING

Main directions of scientific research of the Laboratory:

- research of liquid and air (gas) flow structure at variable flow regimes and under the effect of flow pulsations and turbulence, caused by hydrodynamic disturbances, velocity distribution and changes of pressure gradients;
- research of accuracy and reliability of means and methods for reproduction and transfer of reference values and measuring of liquid and air (gas) flow velocity, volume and flow rate;
- research and development of universal liquid and gas amount measurement method, based on Coriolis principle, aiming at justification of reliable operation of travelling standards at realistic conditions and variable flow physical properties, composition, pressure and temperature;
- research of biofuel, its mixtures and recovered fuel physical properties, calorific value and the composition of their combustion products;
- research of efficiency of small and medium capacity heat-equipment burning the solid biofuel and the implementation of innovative technologies.

Main directions of applied work of the Laboratory:

- provision of metrological support to the Lithuanian economy and science sectors in the field of fluid flow parameter measurements and ensuring measurement traceability to National Measuring Institutes in Europe and Lithuanian laboratories based on the authorisation of the Government of the Republic of Lithuania to preserve the basis of standards in the field of these measurements;
- research, testing and conformity assessment of measuring devices of liquid fuel, water, heat and gas, as well as gas appliances and hot water boilers burning gaseous, liquid and solid fuel (including biofuel);
- other services related to the solutions for accurate energy and other resources accounting, supply-consumption disbalance and effective use of resources.

The principal fields of applied work and services, required by the Lithuanian economy subjects, are accredited by Lithuanian National Accreditation Bureau against LST EN ISO/IEC 17025 and 17020 standards or notified by the LR Ministry of Economy and State Metrology Service (identification No 1621). The Laboratory completely satisfies the LST EN 305-1:2000 requirements for testing and conformity assessment of hot water boilers.

Calibration and measurement capabilities approved and declared by International Bureau of Weights and Measures (BIPM) and accredited by Lithuanian National Accreditation Bureau are presented in the corresponding websites http:// www.bipm.org/en/db/ and http://www.lei.lt/.



Laser Doppler Anemometer for measuring velocity distribution (researcher A. Bertašienė and dr. V. Janušas)

RESEARCH OF LIQUID AND GAS FLOWS

The laboratory investigates the regularities of air (gas) velocity distribution and flow structure under the turbulent and transitional flow regime in the entrance region of the channel and streams, flowing into a limited space. Such tasks are solved not only by analysing the intensity and effectiveness of momentum, mass and heat transfer processes in various systems, but also by evaluating different means and methods used for measuring the amounts, flow rates and velocity of liquid and gas. The accuracy of these measurements is especially relevant for the reproduction of their values in standard equipment and ensuring measurement traceability in Lithuania and on the international level.

The measurement results were verified by comparing the measured velocity values with the values obtained by differential pressure devices and ultrasound anemometer. The experiments demonstrated that the limiting velocity value 0.05 m/s (Re_p = 1.3×10^3) occurs at the area of the transitional flow from the laminar regime to the turbulent. For this reason, the greatest instabilities appear at the beginning of the flow when the velocity varies in the range of 0.05-0.2 m/s, but when the velocity increases, the instabilities diminish. The instabilities of the transitional flow in particular determine the rapid increase of the uncertainties of velocity reproduction values at small velocity.

These results signify the principal novelty and practical importance of the prepared doctoral dissertation (PhD Candidate A. Bertašienė) which was discussed in an expanded seminar and recommended for submission to the Doctoral Committee.

By solving the mentioned tasks and employing the Doppler Anemometer (LDA), one more research stage was completed. It provides reasonable possibilities for regularization and publication of the following expanded uncertainties of reproducible air velocity values:

Velocity, m/s	0.05 l	0.15	0.5	1	3	5	10	15	30	60
Expanded										
uncertainty, \pm %	8.0	4.9	2.3	1.9	1.1	0.81	0.55	0.45	0.45 0).45

Noticeably improved possibilities of measuring other values were also submitted for examination:

- in the range of water volume and rate of (0.01–100) m³/h, the uncertainties constitute ± (0.054–0.082)%;
- in the range of liquid (other than water) volume and rate of (1-150) m³/h, the uncertainties constitute $\pm (0.060-0.065)$ % applying a volume measuring method, and $\pm (0.040-0.045)$ % in the range of (1-50) m³/h rate applying a weighing method.

The other research direction, which enables solving many practically important tasks, is related to the impact of various hydrodynamic disturbances causing essential changes in velocity distribution, flow turbulence and even complicated variable flow pulsations. A method for evaluation of the dynamic response of meters to flow pulsations, which change according to different consistency patterns, and of their influence on the errors of measurement was created. The method was applied for the evaluation of dynamic errors of velocity, flow rate and amount of different tachometric liquid and gas flow meters as well as the reasons for the disbalance of gas and liquid supply/consumption. The experiments carried out in the water flows also showed that the standardized means presently applied for modelling flow dis-



Equipment with improved possibilities of examining and researching hot water boilers and heat equipment, fired with various solid fuel (PhD Candidate T. Vonžodas and M.Sc student A. Grigula)

turbances do not create the flow structure changes corresponding to realistic conditions when the liquids flow in pipes.

In practice the requirements for the accuracy in measurements of various liquids and gas (compressed or liquefied), whose viscosity and density depend on their type, temperature and pressure, are growing. For this purpose, the experimental research is performed seeking to apply mass (Coriolis) meters as travelling standards for the calibration of working meters at operational conditions. Thus, in order to perform research using liquids of different viscosity and compressed gas, experimental equipment was developed, and the analysis of the primary experimental results obtained at operational conditions was performed.

RESEARCH OF EQUIPMENT FIRED WITH BIOFUEL

The most important scientific field of applied research, which is constantly developed, is the investigation of small and medium capacity hot water boilers and other heat equipment, fired with biofuel and its mixtures. The research is carried out taking into account the construction of the equipment, the type of fuel used, means and technologies applied for its improvement, air flow distribution in the combustion chamber, temperature in the combustion zone, draught and other factors.

The need for such research is determined by the fact that the mentioned equipment is widely used in households and elsewhere, and its production is rather rapidly developed. However, the effective fuel combustion and reduction of pollution was not given enough attention until recently. As the prices of fossil fuel and the use of renewable energy sources increase, the mentioned problems inevitably require solution. The European Directives have already introduced stricter requirements for the evaluation of the heating equipment of residential buildings and their mandatory conformity, carried out in participation of the notified bodies.

Having evaluated these changes, the Laboratory is now expanding the capacity



Equipment for examining the calorific value of solid fuel and a device with two piston cells for developing and measuring small gas flows (0.3–300 dm³/h)

of the experimental equipment for hot water boilers research and testing in order to apply it for examining the heat equipment effectiveness in residential buildings. Its capacity is going to be noticeably improved after the purchase of innovative measuring instruments as planned by the Valley SANTAKA. The instruments will be used for carrying out detailed analysis of fuel and combustion products as well as examining the gas flow structure by applying a particle visualization method.

As a part of the open access scientific Renewable and Alternative Energy Centre, the Laboratory now has a possibility to determine the calorific value of various solid fuels and examine the accuracy of small gas flow measurement and evaluation of their parameters. Aiming at the varied range of services for the Lithuanian manufacturers, the Laboratory is planning to become the notified body in the field of conformity assessment of heat equipment, fired with solid fuel, in 2011.

PERSPECTIVES OF SCIENTIFIC RESEARCH IN THE FIELD OF FLOW MEASUREMENTS

In 2010–2011 the Laboratory is going to complete a stage in research and practical work: it is going to be established as a national laboratory measuring liquid and gas flows, ensuring the traceability of measurements carried out in Lithuania and on the international level, and assessing the conformity of measurement equipment produced and supplied to Lithuanian market. In all fields of measurements, the Laboratory has approached the level of the leading national European institutes and for this reason, the activities are going to be developed in this field, regarding the following:

- the perspective of the needs of Lithuanian consumers;
- the tasks to be solved in the European Metrology Research Programme;
- the need for the developing innovative technologies in the systems
- the need of innovative technologies more scientific knowledge about flow structure and the processes of momentum, mass and energy transfer in the microscale systems;

The importance of the tasks performed in the Laboratory for the Lithuanian economy is also evidenced by the fact that the number of employees has recently increased. Presently 31 researchers work in the Laboratory: 1 of them has a Doctor Habilitus degree, 5 – Doctoral degree, 1 has completed the doctoral dissertation, whereas 4 are preparing them and 3 are studying for the Master's degree.



The researchers of the Laboratory (standing – Dr. J. Tonkonogij, Dr. V. Janušas, Dr. A. Stankevičius and Dr. Habil. A. Pedišius, sitting – Dr. G. Zygmantas ir Dr. N. Pedišius)

 problems emerging in the other fields related to the flow measurements (not only energy or thermal engineering).

INTERNATIONAL CO-OPERATION

Baltic Sea Region INTERREG III B Neighbourhood Programme



Activity in EURAMET and COOMET

technical committees



In 2010, the Laboratory was continuing the implementation of the international *Baltic Sea Region Bioenergy Promotion* project which is partially funded by the EU and is a part of Baltic Sea Region INTERREG III B Neighbourhood Programme. The aim of the project is to strengthen a stable, competitive and territorially integrated development of Baltic Sea region in the field of stable bioenergy usage.

An international conference *Promotion* of Sustainable Bioenergy Production and Consumption: Policy, Demonstration and Business Solutions in the Baltic Sea Region was held on 25–26 November 2010 in Kaunas.

Implementing national standard laboratory functions, the Laboratory participated in the activity of technical committees Flows of international organizations EURAMET and COOMET in 2010. In the annual EURAMET meeting in Glasgow (8-12 March 2010), the comparison results, carried out on the international level, and the problems in liquid (other than water) flow measuring were discussed and a work group was set up for solving these issues. In the meeting, the Laboratory presented the up-to-date results of expedience and methods of conformity of reproduction conditions for air velocity units in national European laboratories.

Quality management system, employed by the Laboratory and other laboratories of the virtual Lithuanian Institute of National Standards, was resubmitted for evaluation and approval of EURAMET technical committee Quality in the meeting held on 23–25 February 2010 in Brussels. The activity of the Laboratory carried out during 2004–2009 was positively evaluated.

International comparisons

In 2010 the Laboratory participated in carrying out 3 international measurement comparisons following the EURAMET and COOMET projects (description given in the Table below). Moreover, in NMi Laboratory (the Netherlands), a travelling standard of oil products: positive displacement meter calibration/intermediary comparison was carried out in three flows having different viscosity and density.

The principal measurement results approved that the Laboratory has maintained appropriate measurement traceability to national European laboratories. At the same time, the fields of measurements requiring additional research have been identified. The perspective fields of metrological research, work developed by PTB and possible spheres of cooperation were



Conference Promotion of Sustainable Bioenergy Production and Consumption: Policy, Demonstration and Business Solutions in the Baltic Sea Region

International measurements						
Project No. status	Reference laboratory	Fluid, value	Measuring range	Number of countries/labs.		
 COOMET, 412/UA/07	SE "Ivano-Frankijvsk SM" Ukraine	Air, volume	4–160 m³/h	 4/4		
EURAMET, 1050	INRIM Italy	Air, velocity	2–50 m/s	9/11		
COOMET, 412/UA/07	PTB Germany	Water, volume	0.01–100 m³,	/h 7/7		

discussed in a scientific seminar, organized together with PTB (Germany) representatives.

Other important activity results of 2010

Other important results may be summarised as follows:

- 5 articles were published in foreign publications and the proceedings of international conferences;
- 7 papers were presented in Lithuanian conferences and published in their proceedings; over 250 calibrations and 3000 measurement equipment and system verifications, tests, conformity assessments and technical expertises were carried out in main areas of activity, including foreign con-

tractors;

- activities were carried out in accordance with the following most important and extensive agreements: with State Metrology Service – to maintain, improve and investigate the level of national standards; with SC *Lietuvos dujos*, *Axis Industries*, *Astra*, *Kalvis* and *Panevėžio energija* – to investigate manufactured products, estimate their conformity to the requirements, prepare normative documents and solve technical problems. Income from various applied works comprised 1.25 mln. LTL;
- 2 type examination and 121 conformity assessment certificates were issued for the meters produced by SC *Axis Industries*.

- 3 scientific seminars for the application of innovative measurement means and methods were organized together with the representatives of PTB Institute (Germany), TSI Incorporated and Vidix-Visible Dynamics SC;
- 2 new employees M.Sc students joined the Laboratory personnel;
- Lithuanian National Accreditation Bureau carried out reaccreditation and review of experimental activity of the Laboratory as a inspection body;
- a new Quality Guide, procedures and documents, necessary for reaccreditation of the Laboratory in the fields of calibration and testing, were prepared and submitted to the Lithuanian National Accreditation Bureau;
- 10 researchers participated in various courses and trainings;
- 3 Lithuanian interlaboratory comparisons in the fields of water and gas amounts and speed measurement were prepared and initiated.

Dr. Habil. Antanas PEDIŠIUS

Head of the Laboratory of Heat-Equipment Research and Testing Tel.: +370 37 401863 E-mail: **testlab@mail.lei.lt**

LABORATORY OF COMBUSTION PROCESSES

Main research areas of the Laboratory:

- improvement of efficiency of combustion processes;
- gasification of renewable fuel;
- reduction of atmospheric emissions;
- development and improvements of burners and fuel injection devices;
- research of hydrogen separation from organic fuel;
- research of thermal breakdown and gasification of solid high-calorie waste;
- numerical simulation of granular media and multiparticle systems;
- environmental impact assessment.

Research of combustion processes in the fields of fuel saving, reduction of environmental pollution and thermal decontamination. The works are performed in accordance with the newest trends of international progress.

EXPERIMENTAL RESEARCH OF HIGH-CALORIE SOLID WASTE GASIFICATION

Gasification of fuel derived from highcalorie waste was researched theoretically and experimentally, including scrap tires, wood, peat and textile waste. It was determined that large amounts of gas can be produced in case of more calorific fuel and when the parcels of fuel are better adjusted for more rapid heating in the specific volume of the reactor. The research of highcalorie gasification was performed at the experimental research facility for gasifi-





Pyrolysis of cotton (above); pyrolysis of wool (below)

cation processes of the Lithuanian Energy Institute (LEI), specifically allocated for these tests during the period of the presented research. The facility included the tire gasification reactor and the ovens designed for the experimental tests.

REDUCTION OF NITROGEN OXIDE EMISSIONS

The legislation on the limit values of nitrogen oxide emissions is becoming ever more stringent because this substance is one of the most damaging for vegetation. The current objective is to limit the emissions from large-scale boilers to 100-150 mg/Nm³ by the year 2016. For this purpose, additional means will have to be applied; first of all, the flue gas recirculation, the secondary combustion or even the chemical catalytic treatment of the flue gas will have to be invoked. The most accessible means for this purpose are categorized in the Laboratory based on the experience of the earlier work in upgrading the combustion processes in the boilers throughout the country.

Currently, the emphasis is on the future capabilities and the problems are



Distribution of molecular oxygen and oxygen ions in the beginning of the flame at the injection of the secondary air

solved by the means of numerical simulations. The essential assumption is the even distribution of the combustion process throughout the entire firebox. It is sought to achieve the hypothetical combustion in which the heat is uniformly distributed in the firebox. Various cases are simulated using the Fluent package. It was determined that the results of the simulated cases differ from the experimental data by a factor of up to two, although the general trend follows the simulation results. It was concluded that the methods for estimating the relations between the amounts of oxygen O₂ in the flame and the OH ions for calculating the contents of the nitrogen oxides should be improved in the software.

DEVELOPMENT OF A SMART BURNER USING OPTICAL FLAME SENSORS

In the framework of the National Research Programme *Mechatronika*, the research aimed at developing a smart burner equipped with optical flame sensors is performed. Using the information of the flame structure at the burner, i.e. changes in the colour, light spectrum and frequency of the turbulent flashes, the fuel combustor can be properly controlled resulting in a faster reaction to changes in the instantaneous power or fuel quality. The newest technologies of ICCD sensors make it possible to develop optical micromechanical flame diagnostic sensors used as the basis for the smart burner. The main experimental equipment comprises an ICCD camera, a spectrometer, a computer and a system for the image acquisition and analysis. The image recorded by the digital camera is filtered to the required wavelength by means of optical filters and the resulting image is sent to the computer that determines the physical parameters of the flame using the appropriate software: the radiating area of the flame, the "centre of mass" of the flame, the flash point, the spread angle, the luminosity, the homogeneity and intensity of the colour. The com-



Eng. A. Saliamonas, researcher G. Stravinskas and dr. N. Striūgas next to the combustion process test facility



Temperature distribution along the firebox

prehensive analysis of these images will enable identifying the dependencies that influence physical parameters of the flame the most.

Combustion of natural gas in a prolonged firebox with a closed end wall and lateral flue gas exhaust at the end was simulated. The burner implemented air supply in two stages and comprised a ceramic ring for the gas to provide for a hotter recirculation. An internal air swirling was used, and the major gas jets were directed at small angles in the direction of the air swirl. The temperature of the boiler screens was the same as that of the steam. In order to collect more data about the internals of the calculations, the results of simulation of heavy fuel oil combustion and solid fuel pyrolysis were used. In this case, the equations of the chemical conversions include production of OH and O ions.

An improvement to use additional fuel parcel consisting of separated waste for coal gasification and to enhance the process by using water steam jets was proposed. The results of direct measurements of NO_x content in the boilers were summarised and determined to be characterised by continuous dependencies of their values upon the input parameters.

METHODS OF ADJUSTING AIR AND FUEL JETS IN THE FIREBOX AND FLAME SHAPING FOR THE BEST COMBUSTION AND LOW POLLUTION

High-quality fuel combustion is obtained by achieving complete chemical combustion, when the residual CO content in the flue gas is low (approximately 100 mg/nm³) and the content of solid soot particles remains only 100 mg/nm³. Nitrogen and sulphur oxides are undesirable because they are the source of acid rains. Combustion process can be adjusted for low NO emissions.



An injector of combined jets for new types of fuel

200 mg/Nm ³ Two stage air burner					
	-70	Flue gas rcirculation			
	-30	Two stage gas CH ₄			
	± 20	Air temperature			
	± 10	Oxygen level			
	±30	Radiation, screen temperature			
	± 20	Furnace neat load			

Component analysis in the NOx reduction means



Principal scheme of biomass gasification setup: 1 – rotameter; 2 – heater; 3 – water vaporizer; 4 – vaporizer of the tested material; 5 – peristaltic pump; 6 – glass condensators; 7 – heating vessel; 8 – cooling vessel; 9 – gas meter; 10 – catalyst; 11 – reactor

After the adjustment of peripheral and central air supply in the burner, the fuel supply is the second most important parameter to be adjusted: during the injection of liquid fuel, the droplets of certain size must be produced and distributed in a manner properly tuned to the air flows; the same requirements apply to the diameters and directions of gas jets. The ignition of methane gas is slower than that of other fuel types, therefore, small jets are preheated directly at the burner. The burner spreads the fuel: preferably it should be spread as widely as possible throughout the firebox and supplied to the areas containing oxygen. There are more possibilities to spread liquid fuel in droplets throughout the firebox than to inject gas jets far to the depth of the firebox. For liquid fuel, the injectors comprising sets of multiple openings that spray fuel in far-reaching jets are fabricated.

In 2010, the Laboratory carried out The Research of Combustion Processes in the Areas of Fuel Saving, Environmental Pollution Reduction and Thermal Decontamination of Hazardous Waste financed by the state subsidies. The scope of these activities include applied works, scientific and technical consultations for the Lithuanian enterprises, cooperation with other scientific institutions in Lithuania and abroad.



RESEARCH ON COMPATIBILITY OF SIMULTANEOUS THERMAL DECOMPOSITION OF BIOMASS AND CATALYTIC TAR REMOVAL

In 2010, the research program financed by the Research Council of Lithuania (MIP-112/2010) **Research on** *Compatibility of Simultaneous Thermal Decomposition of Biomass and Catalytic Tar Removal* was commenced in the Laboratory. As the resources of fossil fuel get depleted and their costs increase, gasification of biomass or various types of biological waste is considered one of the most promising ways of production of heat and electricity. Compared to the direct combustion of biofuel, the gasification process is more economical, environment friendly, it also produces less emissions of greenhouse gas CO₂ and hazardous gas (NO₂, SO, volatile organic compounds). The produced syngas is further utilised as a fuel in internal combustion engines, gas turbines, hydrogen production industry and for the production of synthetic diesel fuel. The greatest obstacle to expanding the gasification processes is the presence of tars and solid particles in syngas. Tar is a compound mixture of polyaromatic hydrocarbons with higher molecular mass produced in the gasification process and condensing in gasification or treatment facilities. Polluted gas condenses, sticks and deposits to turbine blades, moving parts of the internal combustion engines or hydrogen separation membranes. In order to optimise the gasification processes, new ways to remove tars from gas are sought. The Laboratory analyses catalytic thermal breakdown of tars, whereby the constituent hydrocarbons of tars are additionally gasified to the final reaction products CO and H_a and in such way the total gas yield is increased. For this purpose, the compatibility of simultaneous thermal breakdown of



Initial particle positions and their temperature distribution on a moving grate with periodic boundary conditions (model)



Distribution of particle temperatures on a moving grate with periodic boundary conditions after 250 s from the start of the simulated combustion process

biomass and catalytic tar elimination is analysed in order to design and test an experimental device and to determine the optimal operating conditions ensuring elimination of residual tar droplets in syngas. Dolomite and charcoal catalysts that are suitable for catalytic breakdown of tars were tested. For the production of the dolomite catalyst, the dolomite fraction 1-2.2 mm found in Lithuania was used, it was calcinated for at least 2 h by annealing in a thermally regulated oven maintaining the temperature of 850 °C. To speed up the process, water steam or carbon dioxide gas was used. The tar concentration was determined using the standard method based on tar condensation in a solvent. The samples were analysed using a Varian GC-

3800 gas chromatograph, the substances were detected using a flame ionisation detector. The main tar producing substances include benzene, toluene and naphtalene. The further research is going to analyse the processes of thermal destruction of benzene and naphtalene hydrocarbons in various temperatures ranging from 700 to 1000 °C, in the presence of different catalysts and oxydizers.

NUMERICAL SIMULATION OF SOLID FUEL COMBUSTION

Solid fuel combustion is a complex process. In order to understand it better and adjust it for the economical and envi-

ronment friendly operation of solid fuel equipment, sufficiently precise models of the process are necessary. Due to the overall complexity of the involved processes, the system under consideration is divided into subsystems, for each of which an appropriate model is devised, and the operation of the entire system is described by the interaction of separate constituent processes. A sufficiently precise model for solid (granular) fuel combustion should include mechanical processes of motion of granular matter, combustion processes (drying, evaporation, pyrolysis, chemical conversions) in fuel pellets, heat and mass exchange between solid and gaseous phases. Earlier, a model of granular media motion was created and motion of fuel par-







Fir wood mass fraction in the particles on a moving grate after 250 s from the start of the simulated combustion process



Char mass fraction in the particles on a moving grate after 250 s from the start of the simulated combustion process

ticles on a moving grate in various conditions was simulated. Currently, a program for simulating combustion is being developed and coupled to the particle motion program. To test the model of heat transfer among the particles, 300 spherical 3D particles were simulated in a periodic system of a grate. As the heat source, radiation with power density of 20 kW/m² emanating from the top wall was used. The particle model includes direct heat transfer among the particles and heat transfer by radiation. The initial particle temperature is ~373 K. Simulation was performed for the particles made of fir wood, including drying, pyrolysis and gasification on a moving grate. In order to save computation time, only a part of the grate was simu-



Community structure of force clusters in a biaxially squeezed granular bed after relaxation. The particles belonging to different clusters are shown in different colours. The forces between the particles are given in lines with thicknesses proportional to the force module

lated and periodic boundary conditions were used at the input and output of the grate, i.e., the particles that reach the output end of the grate are transferred back to the input. The bed of particles was exposed to constant radiation flux from above. Every second step of the grate was moving back and forth periodically, and the steps situated between the moving ones were immobile. This motion of the grate makes particles move along the grate in the combustion chamber. The simulation yields temperature distributions, humidity, mass fractions of fir wood and char residue in the particles. The initial test simulations of granular combustion on a moving grate have shown that the particle combustion model works properly. The combustion process also includes heat and mass transfer between the solid fuel and the gas ambience; therefore, a precise combustion model should include the motion of gaseous environment as well. The motions in the gaseous environment are simulated using the OpenFOAM toolkit. For the general modelling of combustion process, including heat and mass transfer between solid and gaseous phases, data exchange is performed between the solid combustion program and an OpenFOAM solver simulating the gaseous medium motion. This work is performed in collaboration with the Luxembourg University.

The further activities will be aimed at improving the model, adjusting it to the experiments, and analysing the combustion processes in detail.

Simulations of mechanical properties of granular media are not only important for practical applications, but also interesting as a distinct problem of statistical mechanics. Simulation yields dynamic characteristics of separate particles in granular matter (positions, linear and angular velocities, interparticle forces) at certain time moments, which correspond to the microstates in classical statistical mechanics. However, an important task is to determine the macrostate of the medium from the microstates obtained by the simulations, e.g., calculating the strains from the interparticle forces. Usually this involves the analysis of force chains, and a great deal of effort is spent to these types of problems in granular mechanics. The Laboratory researchers are currently testing a different approach for this purpose: the community detection algorithms that are widely used in graph analysis. The picture shows force chains resulting from the biaxial compression of granular medium (the lines indicate the interparticle forces, with line thicknesses proportional to the force module), and corresponding "force clusters"; the particles belonging to different clusters are shown in different colours.

SPECIAL EMPHASIS ON IMPROVING INDUSTRIAL TECHNOLOGIES

Combustion processes are complex phenomena, and there is a shortage of experts in these areas in commercial sector. The Laboratory continuously provides consultations, adjustment of combustion processes and measurements of flows of pollutants. Special emphasis is given to the application of innovations. The Laboratory is experienced in improving combustion of liquid fuel (heavy fuel oil or its substitutes) and is continuously improving the fuel injection systems in SC "Orlen Lietuva" company, in order to reduce the emissions of NO_x and soot. An interesting task is to improve the combustion of gasoline vapour exhausted from the ship loading systems. In a device produced by J. Zink company, local enclosures and specifically tailored air distribution are improved in the burners that are used to save natural gas and to reduce emissions. SC Klaipédos Mediena was recommended to carry out a reconstruction: to save fuel by using recirculation of hot flue gas emitted to the atmosphere. The work in these areas always results in considerable fuel savings.

During 2010, 1 paper was published in an ISI journal, 1 paper was published in a journal referenced in the international databases of scientific information, 2 papers were presented in the international conferences and 2 in the Lithuanian.

Prof. Dr. Habil. Anupras ŠLANČIAUSKAS

Head of the Laboratory of Combustion Processes Tel.: +370 37 401 876 E-mail: **slanc@mail.lei.lt**

LABORATORY OF MATERIALS RESEARCH AND TESTING

Main research areas of the Laboratory:

- research of metal ageing processes and properties degradation under the impact of operational factors;
- research of the hydrogen and hydride influence on the mechanical and physical properties of zirconium alloys;
- assessment of reliability of power plant facilities and evaluation of remnant service life-time;
- development and research of multifunctional materials and composites;
- testing of materials, assessment and analysis of their qualitative indicators.

In 2010, a state subsidy financed project *Experimental Modelling and Investigation of Zirconium Alloys Degradation and Temperature Induced Structural and Phase Changes of Heat-resistant Carbon Steels* was completed. In this project consistent patterns of ageing and degradation of alloys used in power plant facilities were investigated.

Conditions for initiation of delayed hydride cracking process in zirconium alloy fuel channel and cladding tubes have



Hydride reorientation, crack increase and degradation of hydride crack initiated by surface defect on the Zry-4 CW fuel cladding tube

been analysed. The analysis of data on the condition of spent nuclear fuel cladding tubes was carried out and the influence of various possible factors on the cladding structural integrity during the long-term dry storage period was examined. On the basis of the complex research results, obtained during different zirconium alloy fuel cladding testing, the criteria of hydride cracking were determined. The research also involved an experimental investigation of hydride crack formation under static and cyclic loads, and theoretical justification of lower hydride crack growth rate under variable loading.

During the implementation of the work, the research equipment was upgraded and new, further work-oriented methods of research were developed to continue the projects coordinated by International Atomic Energy Agency (IAEA) that were initiated in 1998.

These issues are important in dealing with problems of ensuring safe operation of nuclear power plants and are relevant for storing spent nuclear fuel assemblies.

The other part of the mentioned work is devoted to the research of the ageing processes of heat-resistant pearlitic steels used in thermal power plants. In order to carry out the analysis of these processes on the structural level, the influence of temperature and time on steel phase structure was examined by experimental and numerical methods. Similarly, the consistent patterns of carbide phase transformation sequence and crystallographic parameter variation and their relation to the operational condition of steel were also determined.

ASSESSMENT OF RELIABILITY AND OPERATIONAL LIFE-TIME OF POWER PLANT FACILITIES

In 2010, together with JSC *GEOTERMA* the work was continued under the agreement *Preparation and Application of Complex Measures for Work Optimisation and Life-Time Expansion of Absorption Heat Pumps*. The aim of this project is to optimise operating conditions of absorption heat pump (AHP) systems, increase their reliability, prepare and implement methods that would enable reducing material consumption costs, and assess and reduce the intensity of corrosion process on the basis of laboratory and field test results.

The work includes the analysis of AHP monitoring data, control and maintaining of lithium bromide solution parameters. The research aims at discovering alternative, practically and economically-efficient materials for maintaining stable alkalinity and chromate concentration of AHP and also at preparing and implementing means for optimization the amounts of materials necessary for replenishment of LiBr solution. In addition, preventive means for reducing the probability of LiBr solution contamination with thermal and/ or geothermal water are foreseen. Using the results of corrosion research and mechanical tests, the assessment of condition and further service possibility of cooper-nickel tubes, used in MAA-12 AHP generator, was carried out.

Constructional elements of power plants (steam-pipes, valves, boilers) are manufactured from heat-resistant low alloy and low carbon steels. Their operation at high temperature and the influence of permanent stress changes steel structure, its phase composition and the crystal lattice parameters of carbides. This is why the properties of steel worsen and the reliability of constructional elements decreases.

In 2010, research was carried out to investigate the processes of ageing of steels that are used as the constructional elements of power plants, and to solve issues of their durability and aging control. Applying the X-ray Diffraction (XRD) analysis as well as optic and scanning electronic microscopy, structural changes of used and laboratory-aged steel were examined. Using GSAS software* and Le Bail and Rietveld methods for crystal structure refinement of compounds, changes and consistent patterns of carbide M22C6 crystal lattice parameters were determined. The obtained mathematical dependencies of these changes provide an opportunity to evaluate the condition of used steel and predict its remnant service life. Implementation of this work focuses attention on the investigation of fundamental physical phenomena in steel structures.



Research of effect of corrosion on cooper-nickel tubes after service in MAA-12 AHP generator

^{*} A.C. Larson and R.B. Von Dreele, "General Structure Analysis System (GSAS)", Los Alamos National Laboratory Report LAUR 86-748.





Change of steel $12X1M\Phi$ microstructure and carbide $M_{23}C_6$ crystal lattice parameters during the process of thermal ageing and remnant life prediction of steel according to structural changes at 550 °C temperature

DEVELOPMENT AND RESEARCH OF MULTIFUNCTIONAL MATERIALS AND COMPOSITES

CCOSE

impact of different factors (filler dispersion method, its chemical modification, selection of polymer composition and compatibility with filler) on intercalation/exfoliation of mineral filler in polymer matrix. Pure synthetic nanosized filler gyrolite and also sodium substituted gyrolite was used in this research. Surface characteristics of the filler were changed by organic compounds and ultrasound mixing to achieve

Researchers of the Laboratory are taking part in activity COST MP0701 *Composites with Novel Functional and Structural Properties by Nanoscale Materials* of the first working group *WG1 Nanoparticles/Interfaces* (selection of matrix and nanoparticles, production of nanoparticles, surface modification/chemical treatments of nanoparticles). The objective of participating in the COST MP0701 activity is to develop the preparation methodology of polymer nanocomposite with epoxy matrix and nanosized filler, to investigate the



effective compatibility with polymer matrix. A nanocomposite was prepared from the modified nanosize filler and polymer composition and its mechanical properties were determined.

Participating in COST MP0701 activity, Laboratory researchers cooperate with researchers from Department of Silicate Technology, Faculty of Chemical Technology of Kaunas University of Technology, who synthesize the nanosize gyrolite filler.

In 2010 researchers of the laboratory continued the project *Peculiarities of Nano-Structures Formation in the Cementitious Building Materials: Research and Technological Development* (Nano-CSM). It is relevant from both ecological and economical point of view since it helps to solve the problems of industrial catalyst waste utilization. The project under High Technologies Development Program is carried out together with Thermal Isolation Institute of Vilnius Gediminas Technical University, Kaunas University of Technology, and industrial companies. The objective of the project is the development of novel cementitious building materials, the properties of which are conditioned by nano-structures, developed in their structure. Research is carried out analysing principles of nano-structure formation of cementitious composite materials with nanomodifiers and the impact of these structures on the product properties. The main task of this research is to develop a thin refractory coating for thermal aggregate dumps made of refractory concrete for additional protection from combustion products. Waste catalyst of oil refinery industry was recycled by atmospheric plasma spray method and zeolite microfiber, produced in Laboratory of Plasma Processing, was used as reinforcing material. This microfiber may be also used as filler initiating hydration processes. The Laboratory investigated the interaction of cementitious complex binder with nanomodifiers and nanofillers, and their structural changes at elevated temperatures. Composite resis-

tance to corrosion was studied in the alkaline environment, suited for combustion of biomass products, at 800 °C temperature and by modelling this process in the environment of salts and solutions.

TESTING OF MATERIALS AND ASSESSMENT OF THEIR QUALITY

Researchers of the Laboratory provide accredited services, perform material testing and assessment of their quality (the Laboratory is accredited for LST EN ISO/ IEC 17025 standard). As a result of successful collaboration with commercial enterprises, the Laboratory carries out research and gives advises on guarantee for quality of products.

In 2010 researchers of the Laboratory published 12 scientific articles: 5 of them in the publications on the ISI list and 7 in reviewed conference materials, and participated in 8 international conferences.

Dr. Albertas GRYBĖNAS

Head of the Laboratory of Materials Research and Testing Tel. +370 37 401 908 E-mail: **grybenas@mail.lei.lt**

MEASURING THERMAL CONDUCTIVITY OF INSULATED HEAT-SUPPLY PIPES UNDER LST EN ISO 8497: EXPANDING LABORATORY FIELD OF ACCREDITATION: NEW SERVICE FOR PRODUCERS



Laboratory is accredited to carry out tests of:

- plastic pipes,
- pre-insulated pipes,
- * building mortars,
- * adhesives for tiles,
- * building putties,
- * refractory materials and products.



LABORATORY OF PLASMA PROCESSING

Main research areas of the Laboratory:

- development and research of DC plasma sources for wide range of applications;
- research of processes and phenomena taking place in discharge channels, exhaust plasma jets and flows;
- plasma and high-temperature gas flows diagnostics and development of diagnostics measures;
- interaction of plasma jets and substances in various plasma-technological processes;
- research and implementation of plasma neutralization process of extra hazardous substances;
- synthesis and characterization of catalytic and tribological coatings in plasma ambient;
- research on thermal and heterogeneous processes nearcatalytic surface immersed in the reacting flow of combustion products;
- formation and modification of constructional material surfaces in plasma;
- synthesis and characterization of micro and nano dispersed granules and mineral fiber from hardly melted materials and investigation of properties;
- generation of water vapour plasma and its application for fuel conversion and neutralization of hazardous waste.

Researchers of Laboratory of Plasma Processing have over 40 years experience working in different fields of development, scientific research and application of atmospheric and reduced pressure plasma and are able successfully simulate new plasma technologies, using plasma equipment, designed in the Laboratory. Different composition gas and its mixtures are used for plasma jets formation. Laboratory contains pilot production technological equipment, which is used to change and modify mechanical, tribological, chemical and optical properties of layers of different material surfaces. Constant updating of technical base, development and disposal of available analytic equipment enables to perform research of plasma sources, diagnostics of plasma flows and jets, analysis of gas dynamic characteristics and heat-mass exchange.

Under the basis of acquired knowledge, Laboratory of Plasma Processing is carrying out the following researches:

DEVELOPMENT OF PLASMA SOURCES AND RESEARCH OF PLASMA JET

Laboratory of Plasma Processing develops novel plasma generators up to 200 kW of capacity and improves the construction of existing ones. Recently a novel water vapour plasma generator has been developed. Its thermal and operational characteristics were generalized on the basis of the similarity theory and a variety of processes occurring in the reactive discharge chamber. This allows determining stable operating regime when electric arc heats the overheated water vapour under different pressures. The obtained results show that the generator is suitable for the realization of various processes in the reactive arc zone and may be used for the conversion of solid, liquid, organic and inorganic materials into gas.

Laboratory carries out investigations on heat transfer in plasmatron reactive arc zone, electric arc strength variation in laminar and turbulent arc, the impact of various factors on the characteristics of plasma flows and jets, impact of radiation in the



Supersonic plasma jet flowing from the linear DC arc plasma generator

presence of different plasma forming gases. Operating conditions of linear electric gas arc heaters and plasma chemical reactors have been examined as well as their operating characteristics and new methods for their application in plasma equipment.

DIAGNOSTICS OF PLASMA AND HIGH-TEMPERATURE JETS

Formation of high-temperature and plasma jet, its dynamics and heat exchange characteristics in the channels of different configuration and heat exchanger cells and elements are investigated in the Laboratory. Plasma diagnostics is available by numerical and experimental methods. A numerical research of heated gas jet in the channel was performed applying hydrodynamics software FLUENT. It was used to solve full Navier-Stokes and energy equation based on the dynamic $k-\varepsilon$ model for the fluid jet. However, the numerical research becomes especially difficult and complicated when multiphase jets are running and the solid particles are injected into the jet. This is because of specific plasma properties; therefore, numerical research of two-phase plasma jets are performed applying software package Jets & Poudres, which was developed under the basis of GENeral MIXing (Genmix), improved and adjusted to model plasma jets. Yet, if the task is not considerably simplified, numerical research methods become impossible to use for multiphase plasma jets; thus, the experimental method is given the priority in the Laboratory.

Recently, non-contact method has been widely applied for plasma diagnostics in the Laboratory. One of them is optical spectroscopy method; its main analytical device is an optical spectrometer AOS-4 with an installed detector and optic acoustic channel filter of inner stabilisation. It is a rapid optic measurement system that may be used for the investigation of gas radiation characteristics in wave stretch of 250–800 nm. The system is used also for the examination of plasma element composition, the temperature of electrons and heavy particles.



Characteristics of argon and water vapour plasma jet, flowing from copper anode nozzle of 35 kW capacity plasma generator and determined by optical spectroscopy method. Water vapour flows: above $-G = 129 \text{ I-min}^{-1}$, below $-G = 133 \text{ I-min}^{-1}$



Movement of melt and granules, and formation process of mineral fiber in the subsonic air plasma flow, observed by a high-speed optical camera

An X-series high-speed optical camera with CMOS (Complementary Metal Oxide Semiconductor) sensor is used for multiphase plasma flow visualization and determination of some dynamic characteristics. The camera enables high-speed recording of images in 100 ns interval and also observation of very rapidly moving objects. A high-speed optical camera MotionPro X4 used in Laboratory contains an inner 4 GB memory where data is transferred via USB 2.0 high-speed digital connection or Giga-Ethernet at 1000 Mb/s speed. This ensures quick and easy data transfer to the computer.

FORMATION OF CONSTRUCTIONAL MATERIAL SURFACE LAYERS BY PLASMA TECHNOLOGIES

Synthesis of coatings in plasma flows

Plasma-powder technology, developed in the Laboratory, was applied for catalytic, tribological and protective coating formation as well as for solid ceramic coatings, which are employed for improving the operational characteristics of constructional material surface layers in mechanics, chemistry, energy and medicine. These coatings also increase the resistance to corrosion by 10^2 – 10^3 times, significantly diminish the friction coefficient and reduce the mechanical wear. The use of plasma technology decreases the demand for expensive constructional materials since their large amounts are replaced by cheap materials covered with different thickness coatings.

Having integrated a non- equilibrium atmospheric pressure plasma jet with nonequilibrium temperature components into the equipment presented in Fig, the activated and synthesized materials acquire different energies before reaching the treated surface. Necessary conditions for chemical reactions to combine into blocks in both plasma jet and the substratum surface are created. This enables the synthesis of g phase Al_2O_3 coatings with highly developed active surface, which especially relevant in the formation of catalyst coatings. The surface area of the coating was further enlarged by heating it in a certain temperature.

In the fields of science and production, a worldwide attention has recently been given to the renewable energy technologies, hydrogen energy, programmes of fuel synthesis and saving, issues related to the reduction of environmental pollution and their solution. All these areas require special purpose and composition



Formation of constructional material surface layers in atmospheric pressure air plasma





Catalytic coating (on the left) and its elemental composition (on the right)

catalysts that are used in about 70 % of chemical reactions carried out worldwide. The production of the up-to-date catalytic reactors is a time and finance consuming chemical process performed by precipitating platinum group metals. For this reason, the reactors are expensive, their ceramic substrates are non-durable and the meshes often melt and block the reactors due to poor thermal conductivity. In the new generation of catalytic neutralizers, a metal substrate is substituted for ceramic one and the noble metals are replaced by cheaper metal oxides, zeolites and other materials that are successfully used as effective catalysts.

The mass and heat transfer processes taking place in the catalytic reactors made of coatings were examined using the equipment for studying catalyst coating characteristics developed in the Laboratory. Gas with CO concentrations, characteristic of internal-combustion engine, is emitted and the temperature necessary for catalytic oxidation of the pollutant is reached when the propane-butane gas combustion products mix with an oxidant in the air.

For the purpose of the work, the methodology for the research of dynamic and thermal characteristics of gas in the boundary layer zone was developed; the equipment and facilities for examining the jet structure were assembled. The distribution of velocity, temperature and substance concentration of the reactive gas next to the catalytic wall and the heat-mass exchange coefficients of the jet and the wall were established.

On the basis of oxide catalytic coatings, formed employing plasma method, catalytic reactors efficiently reducing the emission of CO, SO₂, NO_x, HC and other pollutants have been developed. By the catalytic combustion behaviour these reactors are very similar to the ones composed of noble metals. The work related to this issue is continued in accordance with the project of Baltic Sea Region Programme 2007-2013. Presently an innovative efficient catalyst for sulphur compound oxidation is being developed on the basis of TiO.

Carbon derivative coatings

Technological modification of surface layers of constructional materials by forming multifunctional coatings is widely applied in engineering. One of the possibilities of using plasma technology is the synthesis of plasma polymers, i.e. thin membranes precipitated by plasma method that may be applied in a wide range of fields: microelectronics, medicine, biotechnologies, semiconductor manufacturing, etc. Plasma polymers are usually synthesized in a vacuum, but their structures are not thoroughly studied yet.

Due to the low price and good mechanical properties (resistance to corrosion, toughness, small autonomous mass, slight irrigation angle), hydro-halo carbon polymers and hydrogenated carbon membranes or their groups compete with the best up-to-date materials and melts. Taking into consideration the situation in the field of plasma polymer synthesis and research, it should be noted that plasma polymerization process requires more detailed knowledge, especially about the influence of coating parameters on the obtained plasma polymer properties and the stability of their time and temperature. One of the plasma polymer groups is innovative materials composed of plasma polymers mixed with metals or ceramics. Such composite materials form a new class of coatings, made of composites and noncomposites, and are characterized by especially varied electric, optical and mechanical properties. The developed plasma polymers are mostly used as solid and protective coatings. The application of carbon derivatives for polymer synthesis is currently expanding.



Equipment for synthesis of carbon derivatives which generates argon/ acetylene plasma

Although the plasma coating formation process in the atmospheric pressure has been widely used for a long time, it is not fully investigated in terms of physics. It is claimed that the chemical, physical and mechanical properties of the coating as well as its composition and structure are affected by about 50 factors. The prevailing ones are the following: composition of starting materials, materials introduced in plasma jet, dislocation, construction of plasmatron, working characteristics, distance from plasmatron to substrate, temperature, pressure and the type of working gas. Presently a great deal of effort is put in developing solid carbon coatings of various composition and properties on different surfaces (steel, Al₂O₃, quartz glass, etc.) and investigating their properties by available methods.

To carry out the mentioned work, two plasma systems for synthesis of solid ceramic and diamond coatings were developed. They are equipped with modified plasma generators that supply non-equilibrium plasma jet. The systems operate at the atmospheric and reduced pressure of gas, such as nitrogen, argon, hydrogen, acetylene, propane-butane and their mixtures. The coatings on the surfaces of stainless steel, quartz glass and silicon, obtained during the process of synthesis, are characterized by good properties of adhesion. The SEM, XRD, IR and Raman spectroscopy methods were applied for determining the following factors: the coatings surface structure, the size, shape and composition of their particles, their dependence on the composition of gas, constituting and transporting plasma, as well as the place and means of gas introduction into the plasmatron. It was noticed that all spectra of IR photoconductance and reflection have relations common to CH_x , OH, CO, CO_2 and C=C groups.

Following the performed research, the synthesis of supercondenser electrode coatings was realized and carbon derivative coatings were obtained by developing them in the atmospheric-pressure plasma in argon/acetylene ambient. The electrical characteristics of the coatings enable increasing the capacity of supercondensers presently used in practice.

Research on interaction of plasma jet and materials

For the purpose of production of hightemperature ultra thin fibre, reprocessing hazardous substances, formation of various coatings and synthesizing new materials, the interaction of electric arc and plasma jet with amorphous and dispersed materials is analysed. Physical, chemical and mechanical properties of obtained materials are determined.

The plasma processing efficiency depends on the nature of chemical reactions, the value of plasma ambient temperature and velocity, the pressure of material in high temperature zone, etc. The surfaces formed employing plasma method are obtained by laminating many dispersed particles, which before collision with the solid surface must be partly alloyed and plastic. Thus, their shape and structure in the coating is very different. The interaction of particles and plasma jet during contact is defined by flow, deformation, and cooling processes, whereas the variety of fundamental results of particle interaction with plasma jet is manifested by their principal parameters, that is, velocity, temperature and concentrations. It has been determined that parameters of material particles with the same dispersity and composition are very different in the cross-section of coated substrate. In reality, these parameters are non-stationary during the contact. Their functions of distribution are determined by the flow and the formation of two-phase jet conditions in the initial region of the jet. The distribu-



Plasma synthesis (left) of high-temperature fibre and its product (right)

tion of injected particles in the plasma jet along different directions usually becomes anisotropic. These processes describe the structure and features of the produced final product.

MELTING OF CERAMIC MATERIALS AND SYNTHESIS OF HIGH-TEMPERATURE METAL OXIDE FIBRE

Traditional technology and equipment presently used to produce mineral fibre need continuous operation process, complex and expensive alloying furnaces and insulation materials. The quality and composition of fibre produced traditionally are also limited by the melting-point of raw materials; therefore, this method is not suitable for the production of high-temperature thermal insulation fibre, which more and more often used in various fields.

Plasma technology is the only alternative to obtain a high quality high-temperature fibre. Melting and stringing ceramic materials and forming mineral fibre, an experimental plasma device with 70– 90 kW capacity plasma generator has been developed at the Laboratory of Plasma Processing. It enables to form a fibre from dispersed particles, using air as plasma forming gas and auxiliary (Ar, N₂, propanebutane) gas mixtures.

WATER VAPOUR PLASMA TECHNOLOGY

In 2009, the earlier research of the Laboratory was renewed applying water vapour plasma for various needs of energy, environmental protection and industry areas. The advantages of water vapour plasma are obvious: its usage does not form toxic nitrogen oxides that are unwanted in some plasma-technologic processes; moreover, when the temperature is high (4000-5000 K), water vapour mass enthalpy is about 6 times greater than air enthalpy. This suggests that heating water vapour requires 6 times greater capacity than the same amount of air mass jets; therefore, the produced energy of the jet is much greater than of other gas plasma energies used up to now. Another reason why the material processed in water vapour plasma may receive much more energy in the same time is that its thermal conduction coefficient is much greater than of other gas plasma. The comparison of water vapour and air volume enthalpies shows that they are rather similar. On the whole, in order to compare the properties of water vapour and air plasma, they have to be compared on the basis of equal mass volume rather than mass jets.

Initial research suggested that upon formation of coatings and granules of vari-

ous materials, water vapour plasma is especially relevant. If some water vapour (even a small amount) is passed into plasma jet, flowing into plasma-chemical reactor, the output and quality of the end product (e.g. mineral fibre) highly improves. This may be explained by the impact of hydrogen, formed via electrolysis, or dissociated OH group of vapour as well as the influence of more active oxygen, nitrogen or hydrogen atoms on dispersal particles of raw material and melt surface, flowing in the reactor. This is especially important for the formation of organic material coatings (e.g. catalytic) for special purposes. Therefore, it is necessary to explore the impact of water vapour plasma parameters on physical and chemical characteristics of the final product and the formation processes of nano-dispersal structures, microgranules and vapour phase. Further research is directed at the proper investigation of the interaction mechanism of water vapour plasma jet with dispersal particles and jet elements.

LABORATORY ACTIVITY IN THE NATIONAL SPACE PROGRAMME

The researchers of Laboratory of Plasma Processing worked hard by experimenting with various materials, used for producing space shuttle hulls of the former



Water vapour plasma jet, flowing from the copper anode of 35 kW capacity plasma generator

Soviet Union, in plasma jets and flows. The effect of high temperature and velocity to the changes of structure and properties of a particular material was investigated.

Presently for the similar purposes the Laboratory employs analogous plasma equipment with 150 kW capacity. The temperature of plasma jet, flowing from the plasma generator, is 1600–7500 K, while its velocity reaches 150–750 m/s. This creates a possibility to examine the behaviour of various materials in plasma jet, form the surface layers of multi-purposeful constructional materials, develop protective coatings for vide range of application, having different properties and suitable for rocket engineering and space exploration.

In 2010 the research of material testing and experiments were reinitiated. The research on novel materials for use in the surface thermal protection system of reenter space vehicles using low-temperature plasma jet was initiated in cooperation with the Laboratory of Materials Research and Testing under the innovation cheque contract. During the implementation of this study, samples of refractory materials were placed in plasma flow and the impact of high temperature and velocity on the structure and erosion of the materials was investigated. The work in this direction is still continued.

PROJECTS IMPLEMENTED IN THE LABORATORY

In 2009 a new state subsidy funded work *Identification and Assessment of Prevailing Factors Determining the Syn*- thesis of Inorganic Material Oxides Fibre in Plasma Ambient was initiated. Its main objective is to reveal the regularities of various processes during plasma and inorganic material oxides melting and their melts conversion into micro- and nanostructural fibre using numerical and experimental methods. Performing the investigation in reactive gas plasma environment of different composition aims at improving the quality and properties of the mineral fibre being formed. During the implementation of the work, the problem of high-temperature fibre formation was examined in worldwide scientific and technical sources and an experimental dynamic gas device with a plasma generator for special purpose was designed and manufactured. Following the similarity theory, the performance parameters of plasma generator



Research of refractory material behaviour in a high-temperature zone. On the right: a sample after the effect of plasma jet.





Researchers' Night in the Laboratory of Plasma Processing

national programmes and projects:

were studied and generalised as well as the dynamic and thermal characteristics of gas flows outflowing from the generator.

In the experimental equipment of the Laboratory, the process of plasma spray pyrolysis was implemented and its initial consistency patterns were analysed. It was determined that the interaction of plasma flow and dispersal particles takes about 1 ms and the most rapid particle phase change begins at x/d = (3-8) from the outflow of the exhaust nozzle. The mechanism of plasma pyrolysis process was explored and its impact on the formation process of micro- and nano-dispersal particles was determined. A research of heat exchange process in plasma generator and plasmachamical reactor during the formation of fibre was carried out. Applying numerical and experimental methods, the dynamic and thermal characteristics of multiphase jet, flowing from the reactor nozzle, and the level of plasma non-equilibrium were determined. The plasma jet emission spectra, providing information about the element composition of plasma flow, were obtained using the optical spectroscopy method. The research is still in progress.

INTERNATIONAL PROJECTS AND PROGRAMMES

In 2010 the researchers of the Laboratory participated in the following inter-

CM0903

- COST CM0903 activity Utilisation of **Biomass for Sustainable Fuels and** Chemicals (UBIOCHEM). In this activity, the researches of the Laboratory are performing an individual project Water Vapour Plasma for Biomass Conversion and Waste Utilization. Thus, an entirely new plasma technology, which has not been created before, will be developed for converting organic substances into synthetic gas containing a larger amount of hydrogen. Not only different waste, but also hazardous materials will be processed using water vapour plasma technology. Scientists from 18 European countries participate in this activity.
- COST D41 activity *Inorganic Oxides: Surfaces and Interfaces*. This activity is related to the investigation of synthesis processes of metal oxide coatings, their surfaces and inner structure. Its main objective is to improve scientific knowledge and understanding about the qualities of oxide surfaces and structure in microscopic

level; additionally, by invoking theoretical knowledge and practical experience, to investigate the means and methods that enable developing coating with requested qualities and controlling the course precipitation process. 16 European countries participate in this activity.

 Project Dissemination and Fostering of Plasma Based Technological Innovation for Environment in BSR (PlasTEP) of Baltic Sea Region Programme 2007–2013. The main objectives of this project are to develop and use plasma technologies for solving environmental problems. It is also important to develop equivalents that prove the possibility to practically improve air and water quality and to introduce plasma technologies in the field of environmental protection.

Main tasks of the project:

control and reduction of hazardous material emission;




A brake of the 1st workgroup meeting of Baltic Sea Region Programme 2007–2013 project Dissemination and Fostering of Plasma Based technological Innovation for Environment in BSR

- application of plasma technologies for the neutralisation of toxic industrial waste;
- reduction of air and water pollution;
- development of environmental technologies clusters in Baltic Sea region;
- promotion of support and investment into novel environmental technologies;
- incorporation of politicians and government representatives into the project activity
- group formation of industrial and sci-



A poster PlasTEP project **Dissemination and Fostering of Plasma Based Technological** Innovation for Environment in BSR entific partners in the field of environmental protection;

- specialised group formation aiming at reducing NO_x and SO_x emission, neutralising VOCs compounds) and smells as well as cleaning the water;
- spread of knowledge and environmental technologies in the states of Baltic Sea region.

In 2010 a new application for the project *South Baltic Plasma Training Network* of Baltic Sea Region Programme 2007–2013 was submitted and an application for the project *Development of Water Vapour Plasma Device for Biomass Conversion and Hazardous Waste Utilization* (EUREKA) was prepared.

Since 2007, the Laboratory has been taking active participation in the activity of Plasma Technology Network of the Baltic countries. Last year the scientific and technical production of the Laboratory was presented in international (9 papers) and national (5 papers) conferences, 6 articles were published in the ISI indexed journals and 11 articles in the worldwide reviewed publications.

Dr. Vitas VALINČIUS

Head of the Laboratory of Plasma Processing Tel. +370 37 401 986 E-mail: vitas@mail.lei.lt

CENTER FOR HYDROGEN ENERGY TECHNOLOGIES

Main research areas of the Center:

- research in the field of hydrogen energy technologies:
 - synthesis of hydrogen separation membranes and analysis of their properties;
 - synthesis and properties analysis of metals and their alloy hydrides designed for hydrogen storage;
 - synthesis of hydrogen fuel cell elements: anodes, electrolytes and cathodes applying physical vapour deposition methods.

In 2010 state subsidy funded project Synthesis and Property Analysis of Nanocrystalline Metal Hydrides, Designed for Energy Storage and Optical Devices was successfully initiated. The novel idea of this work is to determine the unexplored metastable conditions of magnesium alloys at which the material effectively absorbs/ desorbs hydrogen. To reach this, non-equilibrium physical technologies are going to be applied and during this process (in situ) materials activation is going to be realized by flow of emerging structure (photons, electrons and ions) obtained from plasma. Due to their structural peculiarities (nanocrystalline or amorphous structure, controlled amount of defects, texture), the obtained materials distinguish by their unique qualities of absorption/ desorption and could be used for new generation hydrogen storage devices, batteries and switchable mirrors devices.

During the implementation of the project *Foundation of National Open Access Scientific Center for Future Energy Technologies*, funded by EU SF, Auger electron spectroscope was bought and installed in LEI Center for Hydrogen Energy Technologies in 2010. The purchased Physical Electronics PHI 700Xi Auger electron spectroscope enables carrying out top quality





Physical Electronics PHI 700Xi Auger electron spectroscope

Auger electron spectroscopy. It also has an installed ion gun which can be used for extracting an especially accurate (nanometer-accurate) profile of material element composition. Innovative field emission source of electrons together with special patented coaxial structure of electron column and cylindrical mirror analyser enables achieving an electron beam of only



Project Center for Hydrogen Energy Technologies received the best evaluation by experts

6 nm diameter and a unique synchronous Auger electron measuring in a wide angle range without any shading and other effects, caused by uneven surfaces. Because of the mentioned and previous innovations of Physical Electronics, the company is number one among the researchers searching for top quality.

In co-operation with lectors and students at Department of Physics of Vytautas Magnus University and Department of Physics of Kaunas University of Technology, the Center for Hydrogen Energy Technologies concentrates equipment necessary for investigations, allows teachers at Department of Physics of Vytautas Magnus University and Department of Physics of Kaunas University of Technology to use modern educational aids and prepare highqualified specialists (including all study cycles) and develop competitive research. It is equally important that LEI has become a powerful centre of attraction for young researches.

Pursuant to the proposal under Patent Support Project Group Description (14 Supplement to the Rules), announced by the Ministry of Economy of the Republic of Lithuania and public institution Lithuanian Business Support Agency (LBSA) on 17 May 2010, the researchers of the Center submitted the application for defraying the expenses of European Patent and Patent Issue under Patent Cooperation Agreement, which was positively evaluated. The main objective of the project is to prepare a request to issue a European patent for innovative hydrogenation method of metals and their alloys, developed in LEI. Having received a positive answer after the patent search and examination carried out by EPO, the aim will be to collect all relevant documents for the issue of European patent.



In 2010, the work related to the project **Synthesis of Multifunctional Materials Heterostructures for Hydrogen Fuel Cells**, financed by Research Council of Lithuania, was completed. During the implementation of this project, it was first noticed and realized that intensive material hydrogenation takes place during material restructurisation that is initiated by *dynamic*



Discussion is one of the best ways to solve issues. M. Lelis (left) and Prof. L. Pranevičius

gies. This project revealed that it is possible to escape intermixture limits of materials (magnesium and aluminium), developed by traditional equilibrium methods, due to experimental magnetron sputtering technologies. Moreover, the synthesis of these materials in conformation of thin layer is expected to allow a particular "immobilisation" of this unstable structure and to protect it from disintegration and/or oxidation.

mechanical stress in the coatings. The process sequence is the following:

- (i) hydrogen passes into lattice between its nodes, distorts the lattice and in this way forms mechanical stresses that are sufficient to initiate restructurisation;
- (ii) during the restructurisation, free M links emerge and M-H linkage form;
- (iii) new developing MH phase increases mechanical stresses that further restructure the coating and in this way new M-H links form, etc.

This is a self-supporting process that finishes with total hydrogenation of the coating. If the mentioned sequence is blocked, for example, barrier surfaces impede the process of relaxation, then hydrogenation takes place following the laws of classical diffusion (with modifications, including "diffusion with trap"). The obtained result is going to be used for the development of innovative hydrogenation technology. A patent, tentatively called *Hydride Synthesis in Variable Fields of Mechanical Stresses*, is currently being prepared; however, additional research is required that is presently in progress. This year a project *Hydrogen Extraction from Water Vapour Plasma by Molecular Implantation* was initiated as a part of the programme *Future Energy* financed by Research Council of Lithuania. The work has demonstrated that proton conductive oxide electrolyte fuel cells (PCFC) are capable of successfully substitute solid oxide fuel cells (SOFC) and operating at lower temperatures by noticeably reducing the total price of fuel cell system.



Nordic Energy Research

In collaboration with partners from Nordic countries, the work in the project of The Nordic Energy Research Programme *Nordic Center of Excellence for Hydrogen Storage Materials* was completed in 2010. This fundamental research attempts at synthesising magnesium and aluminium hydrides, containing a small amount of aluminium and magnesium additives, by using **non-equilibrium** technolo-



In 2010, the researchers of the Center actively participated in International Energy Agency Hydrogen Implementation Agreement (IEA HIA) Task 22, *Fundamental and Applied Hydrogen Storage Materials Development Actions*. In this activity, chemical destabilisation of metals and their alloy hydrides was carried out by introducing new elements into materials, which form intermediate derivatives during hydride decomposition and, thus not allowing the system to get fully relaxed to the lowest energy state, or form a destabilized hydride during hydrogenation.

In 2010, the researchers of the Center published 5 articles on research results in the publications on the Institute for Scientific Information (ISI) list and presented 5 papers in international conferences.

Dr. Darius Milčius Head of the Center for Hydrogen Energy Technologies Tel.: +370 37 401 909 *E-mail: milcius@mail.lei.lt*

LABORATORY OF NUCLEAR ENGINEERING

Main research areas of the Laboratory:

- experimental investigation of heat transfer and turbulent transport patterns in single-phase flows: forced and mixed convection, turbulent and transition flow regimes, influence of channel geometry, variable physical properties, roughness, centrifugal forces and transients effect;
- numerical modeling of heat interchange and transfer in single-phase flows in various channels and geological structures;
- management of spent nuclear fuel: modeling 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 and cost of decommissioning and dismantling, 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;
- research related to construction of new nuclear power plant in Lithuania.

EXPERIMENTAL AND NUMERICAL HEAT TRANSFER AND TURBULENT TRANSPORT INVESTIGATION IN CHANNELS AND GEOLOGICAL STRUCTURES

Since the foundation of the Laboratory, research of heat transfer and hydrodynamics has been carried out in energy equipment for different purposes (in the elements of nuclear reactor, various air heaters, etc.). In recent years, the European Union has been stressing the relevance of fundamental research, i.e. the research which is not directed to the development or design of specific equipment, but to checking theories and hypothesis and determining consistent patterns. Fundamental research of heat transfer and hydrodynamics in channels of different geometry has been carried out in the Laboratory for a long time.

It has been observed that in the cases of laminar and turbulent flow, the effect of thermogravitational forces (mixed convection) on heat interchange is manifested in many energy facilities. Under certain conditions the impact evoked by thermogravitational forces on heat interchange usually becomes a reason for accidents in different facilities. For this reason, mixed convection scientific research has been begun in pipes and later in flat channels as well. Additionally, such research was initiated in geological structures while analysing the possibilities of Ignalina NPP spent nuclear fuel disposal. The research is performed using the software package ANSYS FLUENT (ANSYS, USA) which is widely applied in the world for modeling of fluids flows and heat transfer in elaborate two and three-dimensional systems. Various models of the laminar, transition and turbulent transfer were used.

In 2008–2010, as a part of the work Heat Transfer and Flow Hydrodynamic Research in Transitional Flow Zone at Interaction of Mixed Convection and Stable and Non-Stable Air Density Stratification, financed by the state budget grant, experimental and numerical research (using



Participants of **FORGE** project coordinated meeting (Kaunas, 8–9 June 2010)

ANSYS FLUENT software) of mixed convection of opposing flows heat transfer and flow structure were carried out in transitional flow zone of flat leaning channels (tilting angle 30° and 60°). Additionally, numerical research was performed in a vertical channel, subject to mixed convection for single-sided flows. The obtained heat transfer and flow hydrodynamics results change and expand the understanding about the laminar flow transition to the turbulent under the impact of thermogravitational forces.

MANAGEMENT OF SPENT NUCLEAR FUEL

After the decision to use dry storage facility for spent nuclear fuel (SNF) at Ignalina NPP in CASTOR and CONSTOR type casks, the Laboratory started performing studies related to the safety assessment of SNF management, storage and disposal in 1997. The Laboratory carried out criticality assessments for the casks with SNF under normal operational and accident conditions, variation of radionuclides activity during the storage period, radiation doses on the cask surface and at the specific distance from it as well as temperatures of the cask.

Implementing the research on SNF disposal in Lithuania, the Laboratory experts with the assistance of Swedish experts proposed the concepts of deep geological repository in clay and in crystalline rocks for SNF and long-lived intermediate level waste in Lithuania. The concepts on disposal are constantly defined more precisely and optimized taking into account international experience and physical, chemical, thermal and mechanical properties of a specific repository site. While analysing the possibilities of SNF disposal in Lithuania, the costs assessment of geological repository installation was carried out and generic repository safety assessment was initiated.

In 2010, the research related to the radionuclide migration and the processes affecting it in the far-field of the repository (geosphere) were continued aiming at a more optimal evaluation of the impact of geosphere on the safety of SNF repository. A part of research related to the project *Safety Assessment and Geologic Repository Site Characterization Applying Numerical Modeling* (2005–2010) coordinated by IAEA was completed. The data of Veresnia (Ukraine) were employed. Evaluating different flow conditions of under-



ground water in different geological formations, the geofiltration nature of underground water under respective conditions was determined. The input data on the analysed radionuclide flow to the far-field environment of the repository were collected after carrying out the probabilistic assessment of radionuclide migration in the near-field environment following KBS-3H conception of disposal. The results of numerical evaluation revealed that when the region underground water flow is absent in the geologic layers, the unsorbed long-lived iodine isotope ¹²⁹I dispersed from the nearfield environment of repository would reach the river water. If the regional flow is present in the system, a greater amount of radionuclides would reach the river, whereas the delay in the geologic structures would be much shorter. In both cases, the flow to the river would be lesser than the flow via the engineering barriers from the near-field environment of the repository.

In 2010, a great deal of attention was devoted to one of safety assessment as-



Results of probabilistic sensitivity analysis of radionuclide ¹²⁹I parameters



pects, the research of consistent patterns of gas spread from deep SNF repository. The amount of gas in the repository depends on the type of disposed waste and the selected conception of disposal. This research is performed together with 23 partners from 10 EU countries under the project Fate of Repository Gases (FORGE) (2009–2013) financed by the 7th Framework Programme (FP7) of the EU. In 2010, the methodology of gas spread assessment and software package TOUGH2 (LBNL, USA), used for assessing gas spread, were analysed, and a model of gas spread from the repository was also developed as is now being improved.

In 2010, a scientific research *Probabilistic Uncertainty Assessment of Radiation Impact during the Analysis of NPP Dismantling and Managing Radioactive Waste* (2010–2012) financed by the state budget grant was initiated last year. During its implementation, the model of radionuclide migration from RBMK-1500 SNF deep repository, developed in 2007–2009, is being improved. The research also aims at evaluating the influence of uncertainty, related to the increase of cask wall defects, migration on the separate radionuclide from the cask. In 2010, the influence of time uncertainty of the disposal cask defect increase on the assessment results of long-lived radionuclide ¹²⁹I migration was analysed.

Furthermore, complex research of the influence of heat spread and mechanical processes in natural and engineering barriers undersaturated with water were continued.

In 2010, the Laboratory, as a partner of consortium GNS – NUKEM Technologies GmbH (Germany), continued a extensive project *Design and Installation of the Interim Storage Facility for RBMK Spent Nuclear Fuel Assemblies from Ignalina NPP Units 1 and 2* (2005–2011). This project comprises the analysis of all activities related with the design, construction, installation, commissioning, operation and decommissioning of the new SNF storage facility and the performance of all necessary works related to the SNF removal, packaging, sealing and transfer as well as operation of the appropriate equipment for implementation of chosen design concept. It is planned to store approximately 200 new type CONSTOR casks with intact and damaged SNF in the new storage facility.

The Laboratory prepares Environmental 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 2007, Environmental Impact Assessment Report was approved by the Ministry of Environment; in 2009, Preliminary Safety Analysis Report (PSAR) was prepared and agreed upon and the licence for construction of the new SNF storage facility was issued by VATESI. In 2010, PSAR Addendum, which presents the evaluation of safety aspects of damaged RBMK-1500 nuclear fuel assemblies' management and storage, was being prepared.

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 the experts from *SKB International* (Sweden) carried out a number of projects, which included safety assessment of ex-



Temperature distribution in the near-field environment of deep repository during the burying of RBMK-1500 SNF cask

isting waste storage facilities and the possibilities to transform them into repositories. Together with French companies Thales Engineering and Consulting, ANDRA and the Institute of Physics, PHARE project Safety Assessment and Upgrading of Maišiagala Repository in Lithuania was implemented. The Laboratory specialists participated in preparing Safety Analysis Report, developed the database containing information on the radioactive waste, which is stored in the Maišiagala storage facility. and performed a comprehensive nuclide composition analysis. The Laboratory together with Framatome ANP GmbH (Germany) participated in executing the environmental impact and safety assessments for Ignalina NPP cement solidification facility and a temporary solidified radioactive waste storage facility. Additionally, the Laboratory constantly participates in the research programmes coordinated by IAEA.

In recent years, a great deal of attention was devoted for the siting of a new near-surface repository of radioactive waste in Lithuania, and for scientific research related to the radionuclide migration from radioactive waste repositories and its impact on safety. With the assistance of Swedish experts, the Laboratory specialists prepared the set of criteria for choosing a near-surface repository site, improved the reference design of a nearsurface repository and prepared the implementation programme. The impact of *heterogeneous* waste activity distribution on radionuclide migration from model nearsurface repository was investigated.

During 2006–2009, the Laboratory specialists implemented the project **Re***construction of Ignalina NPP Bitumen Radioactive Waste Storage Facility (Building 158) into Repository*. A long-term safety assessment of the planned repository was prepared; it was based on the possible engineering solutions of storage facility reconstruction into repository, components of disposal system. To be more precise, radioactive waste, storage facility and surface engineering barriers planned to be installed over storage facilities and site characteristics were taken into consideration.

In 2010, the Laboratory together with NUKEM Technologies GmbH (Germany) continued the project **New Ignalina NPP Solid Waste Management and Storage Facility** (2006–2011). This facility is intended for solid radioactive waste retrieval, sorting, transportation, treatment (using envisaged technologies), packaging, characterisation and storage. The facility comprises the solid waste retrieval facility located near the existing INPP solid waste storage buildings, the new solid waste treatment facility, the new shortlived radioactive waste storage facility and the new long-lived radioactive waste longterm storage facility.

The Laboratory prepares environmental impact assessment and safety analysis reports for this complex. Environmental Impact Assessment Report was agreed upon and approved by the Ministry of Environment in 2008 and two PSARs, New Solid Waste Treatment and Storage Facilities at Ignalina NPP and New Solid Waste Retrieval Facility at Ignalina NPP were prepared. The former was approved in 2009 and VATESI issued the licence for the construction of the storage facility. Additionally, in 2009 two more PSARs, New Solid Waste Retrieval Facility for Retrieval Units 1 and 2-3 at Ignalina NPP was newly prepared, while in 2010 both PSARs were submitted to authorities for review.

In 2010, the Laboratory, as a partner of Lithuanian consortium (JSC Specialus montažas–NTP, LEI, Pramprojektas, JSC Vilstata) continued implementing the project Installation of Very Low Level Radioactive Waste Repository (Landfill) (2008–





Distribution of temperatures in casks CONSTOR® RBMK-1500/M2 for storage of RBMK-1500 SNF at Ignalina NPP: free standing cask (left) and in storage (right)

2010). Landfill repository is intended for disposal of very low level radioactive waste generated during Ignalina NPP operation and decommissioning. Landfill facility will be comprised of three repository modules and buffer storage where waste will be stored till their disposal. The Laboratory prepared Environmental Impact Assessment Report for the planned economic activity (approved by the Ministry of Environment in 2009) and two PSARs, The Buffer Storage of the Landfill Repository (approved by VATESI in 2009) and The Disposal Modules of the Landfill Repository (approved by VATESI in 2010). Moreover, in 2010, General Data Set on the Buffer Storage of the Landfill Repository was prepared and submitted to the European Commission, whereas General Data Set on the Disposal Modules of the Landfill Repository was submitted to authorities for review.

In 2010, the Laboratory together with partners from French companies *AREVA TA* and *ANDRA* and Lithuanian partners JSC *Specialus montažas—NTP* and *Pramprojektas* continued the project *Low and Intermediate-Level Short-Lived Radioactive Waste Near-Surface Repository (Design)* (2009–2012). The repository is intended for disposal of low and intermediate-level short-lived radioactive waste generated during Ignalina NPP operation and decommissioning. The Laboratory specialists participate in the preparation of planned repository site survey report, design options report and preliminary safety analysis report.

EVALUATION OF DIFFERENT FACTORS RELATED TO DECOMMISSIONING OF NUCLEAR POWER PLANTS

In 1998, the Laboratory researchers started new studies related to the planning of decommissioning of Ignalina NPP. The experts of the Laboratory participated in PHARE project preparing *Preliminary Ignalina NPP Decommissioning Plan* and *Final Ignalina NPP Decommissioning Plan*. In 2004, the Laboratory specialists prepared the drafts of *Ignalina NPP Decommissioning Programme and the Plan of Measures of its Implementation for the period 2005–2009* for the Ministry of Economy.

The Laboratory implemented the project **Development of Radiological Characterization Programme for Equipment and Installations at INPP** together with Institute of Physics. As a part of the project *General Programme of Radiological Sur-* vey and Historical Assessment Report of Radiological Situation at INPP were prepared and submitted to regulatory institutions for review. The Programmes of detailed radiological research for the equipment of V1, G1 units and 117/1 building of INPP were also prepared. Later, detailed radiological research programmes for the equipment of B1, D0, D1 units and 119 building of INPP were prepared. An electronic Microsoft Access database was created which stores all the necessary data for equipment description and drawings showing the locations of radioactivity measuring and sampling. The programmes created and the collected and analysed data on the radiological situation of INPP are vital for pursuing the decommissioning of INPP.

Since 2002, the Laboratory has been performed fire hazard assessments in the nuclear power plants and other important facilities. In consultation with Swedish experts, the Laboratory specialists assessed the fire hazard of Units 1 and 2 of INPP. Fire hazard assessment of some renewed INPP rooms for displaces purposes and newly designed INPP SNF and radioactive waste storage facilities were carried out as well. An external fire impact on the new INPP complex for solid waste treatment and storage was assessed and the fire hazard analysis of the most dangerous areas in



Participants of the 3rd meeting of organizational committee of CARBOWASTE project (Vandellos I NPP, Spain, 27–28 April 2010)

the case of an internal fire was performed. In 2009, the impact of fire during the implementation of Ignalina 117/1 building dismantling and decontamination was evaluated as well as the fire safety of newly designed buffer storages and disposal modules of *Landfill* repository was analysed. In 2010, the impact of fire during the implementation of Ignalina V1 unit dismantling and decontamination was assessed.



In 2010, during the implementation of the above-mentioned newly initiated budgetary work **Probabilistic Uncertainty As**sessment of Radiation Impact during the Analysis of NPP Dismantling and Managing Radioactive Waste and the project Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste (CARBOWASTE) (2008–2012) of the 7th Framework Programme of the EU, numerical research related to the radiological characterization of the constructional materials of RBMK-1500 reactor, namely irradiated graphite, was continued. Previous research determined that the irradiated graphite for the RBMK reactor contains short and long-lived radionuclides and their activity may vary in a wide interval of values depending on different conditions. Since long-lived radionuclides are the most relevant for the evaluation of long-term storage and final disposal of radioactive waste, neutron activation of the graphite in the RBMK-1500 reactor was further analysed by concentrating on the formation mechanisms and possible variation of activity values of long-lived radionuclides in the irradiated graphite.

In 2007–2010, Lithuanian Energy Institute, as a partner of consortium VT Nuclear Services Ltd (UK) – LEI – NUKEM (Germany), implemented the project *Ignalina NPP Building 117/1 Equipment Decontamination and Dismantling*. In 2010, the researchers of the Laboratory participated in preparing the detailed project. Using CORA-CALCOM (NIS, Germany) software package, the equipment of building 117/1, waste amounts and their characteristics were analysed and economic assessment of the planned decontamination and dismantling activities was carried out. *The Detailed Project* was agreed upon and submitted to the contractor in 2010.

In 2009–2010, the specialists of the Laboratory together with the Laboratory of Nuclear Installation Safety and JSC Specialus montažas-NTP, were carrying out a project Environmental Impact Assessment and Safety Justification Reports of the Unit 2 Final Shutdown. This project encompasses the final shutdown of the reactor in INPP Unit 2, removal of fuel from the reactor and storage pools and its transfer to an interim SNF storage facility. Also, isolation and modification of systems and waste management during the defueling phase are included into this project. In 2010, based on the Environmental Impact Assessment Report of this project, the Ministry of Environment made a positive decision about the possibilities of the implementation of planned economic activity. Safety Analysis Report for the INPP Unit 2 Decommissioning Project for the Final



Open Day at LEI. Visitors in the Laboratory of Nuclear Engineering



PhD Candidate R. Kilda in the meeting of Council of Doctoral Dissertation Defense on 23 February 2010

Shutdown and Defueling Phase was submitted to VATESI for review in 2010 and was agreed upon in the same year.

In 2010, Lithuanian Energy Institute, as a partner of consortium Babcock (UK) -LEI - NUKEM Technologies GmbH (Germany), continued the project *Ignalina NPP* **Building V1 Equipment Decontamination** and Dismantling (2009–2011). Specialists of the Laboratory participate in preparing environmental impact assessment report, safety analysis report, technical and detailed projects and developing general data set. In 2010, using software DECRAD developed in the Laboratory, the amounts of dismantled equipment of the V1 building, radioactive and free release waste, transportation and disposal packages, personnel demand, the individual and collective radiation doses, expenses of decontamination and dismantling, and schedules for the implementation of the works were assessed. After estimating surface contamination of facilities, personnel radiation doses were simulated using VISIPLAN 3D ALARA Planning Tool software (SCK-CEN, Belgium). In 2010, Environmental Impact Assessment Report and General Data Set were prepared and submitted to the contractor.

RESEARCH RELATED TO THE CONSTRUCTION OF A NEW NUCLEAR POWER PLANT IN LITHUANIA

In 2007–2009, in consortium with Pöyry Energy Oy (Finland), the Laboratory specialists carried out the research related to the construction of new nuclear power plant in Lithuania. The Environmental Impact Assessment Programme for New Nuclear Power Plant and New Nuclear Power Plant Environmental Impact Assessment Report were prepared. In the EIA Report, possible environmental impacts of the construction and operation of new NPP were assessed in cooperation with other Finish and Lithuanian institutions (Institute of Botany, Institute of Ecology and National Public Health Surveillance Laboratory). According to the EIA Report of 2009, positive conclusions of the competent authorities were made concerning the planed economic activity and, therefore, following this EIA Report, the Ministry of Environment has made a motivated decision on the construction possibilities of new nuclear power plant.

MAIN RESULTS

In 2010, the Laboratory (29 researchers) continued 2 (completed 1) state subsidy funded research works, carried out 12 applied research works and earned more than 1 million LTL.

PhD Candidate R. Kilda successfully defended PhD thesis *Analysis of Radionuclide Migration from Near Surface Repositories for Radioactive Waste.* Two PhD Candidates (A. Šimonis and A. Narkūnienė) have almost finished preparing their PhD thesis.

Researchers of the Laboratory actively participated in different training programmes, coordinating meetings, presented 5 papers at international conferences (USA, Turkey, United Kingdom and Lithuania) and published 11 scientific articles in Lithuanian and international journals and publications.

Prof. Dr. Habil. Povilas POŠKAS

Head of the Laboratory of Nuclear Engineering Tel.: +370 37 401 891 E-mail: **poskas@mail.lei.lt**

LABORATORY OF NUCLEAR INSTALLATION SAFETY

Main research areas of the Laboratory:

- safety assessment of nuclear power plants;
- safety analysis of thermonuclear fusion reactors;
- analysis of new generation nuclear power plants;
- thermal-hydraulic analysis of accident and transient processes;
- assessment of thermal-hydraulic parameters in NPP containments and other premises;
- simulation of radionuclides and aerosols transport in the compartments;
- assessment of nuclear reactor core modifications and analysis of postulated reactivity accidents;
- reliability estimation and control of energy systems;
- level 1 and level 2 probabilistic safety assessment of NPPs;
- strength analysis of constructions, piping and components in complex technical systems;
- single failure analysis and engineering assessment for complex technical systems;
- risk and hazard assessment of industrial objects;
- assessment of security of energy supply;
- probabilistic modelling and analysis of unusual events;
- modelling and reliability assessment of processes in net systems;
- sensitivity and uncertainty analysis of modelling results;
- fundamental research in thermal physics.

In 2010, the researchers of the Laboratory, together with other national and foreign subjects, were implementing the following 26 projects: 3 state subsidy funded scientific research projects; 2 projects funded by the national research programme **Energy for the Future**; 17 international projects (4 projects of EU 6th and 7th Framework Programmes (FP) and 6 international scientific research programmes without external funding); 4 projects funded by Lithuanian economy subjects.

1. NATIONAL RESEARCH PROGRAMME ENERGY FOR THE FUTURE

In 2010 two projects, financed by Research Council of Lithuania, were initiated as a part of national research programme *Energy for the Future.*



The aim of the project **Research and** assessment methodology of energy systems reliability and its impact on energy security is to develop a common scientific assessment methodology and mathematical models of reliability for Lithuanian energy systems. They would enable studying the reliability of energy systems and assessing the impact of reliability on Lithuanian energy security. The main elements in the Lithuanian energy system are electricity, gas and oil distribution networks. During the first year of project



Structure of reliability assessment methodology for pipeline network systems

implementation (August-December 2010), the work, corresponding to three project tasks related to the development of reliability assessment methodology and models of reliability for the mentioned networks, was carried out. While creating the common reliability assessment methodology for electricity networks, special methods and initial methodologies were expanded in 2010. These methodologies are intended for evaluating the reliability of electrical appliances, developing a reliability model for electricity system (network) and models for separate elements of electricity network, assessing the main characteristics of electricity supply and performing the uncertainty analysis of modelling data and results. Heat, gas and oil are transmitted via pipeline systems and their reliability depends on pipe degradation and structural integrity which is affected by thermohydraulic processes in the pipes. For this reason, an initial case of the common methodology (see fig.) and developmental basis and principles for its separate constituents and models were prepared for all pipeline network systems in 2010. However, different heat/energy carrier in the pipes and different technological processes determine different loads, pipe degradation mechanisms and equipment used in these systems. Thus, in 2011 the specificity of each of these networks is going to be analysed in detail and the initial variant of the prepared methodology is going to be improved by considering the peculiarities of heat, gas and oil supply networks. Moreover, next year the reliability assessment methodologies of electricity, heat, gas and oil supply networks are going to be expanded. Apart from that, reliability models and integral methodology

for reliability assessment of Lithuanian energy system encompassing the mentioned aims and their relation is going to be developed as well as assessment methodology of the impact of energy system reliability on energy security.

The first stage of the project **Develop**ment of Methodology for Energy Security Analysis and Integrated Security Level Assessment, which is implemented together with Vytautas Magnus University, will continue till 2012. The objectives of the project are the following:

 to develop an exhaustive methodology for energy security analysis, encompassing the research of challenges and disturbances to energy system, modeling methods of energy system reaction to disturbance and its consequence assessment, and to ad-



just this methodology to Lithuanian energy system;

to develop a system for energy security level assessment (measuring), which would enable obtaining a single integral characteristic assessing both the security level of the whole energy system and the impact of various energy development scenarios on energy security.

In order to reach the set objectives, the tasks covering the entire chain of energy security methodology development were established. The methodology for energy security analysis and assessment would encourage Lithuanian scientists to cooperate in international projects, which compare and evaluate energy security methodologies developed in different countries. Furthermore, the project result would be an excellent reason for scientific research of NATO Energy Security Center, which is currently being established in Lithuania.

2. PREPARING FOR CONSTRUCTION AND OPERATION OF NEW NUCLEAR POWER PLANT IN LITHUANIA

The researchers of the Laboratory participate in both the preliminary work

for new power plant construction, implemented directly under the order of Visaginas NPP and VATESI, and advanced international scientific research projects on nuclear energy that are aimed at developing new nuclear reactors and solving other relevant issues, related to the safety of nuclear energy. Additionally, the researchers take part in projects that seek sharing the knowledge with other national infrastructure organizations for nuclear energy.

These projects are important in strengthening Lithuanian competence in the nuclear energy field which is necessary for every country owning nuclear power objects.



Work for Visaginas NPP

In 2010, under the agreement **Assess**ment of Potential Visaginas NPP Construction Sites in Respect of External Events between JSC Visaginas NPP and LEI, the first stage of the project was completed. Following VATESI/IAEA safety requirements, the identification and description of the analysed external events and phenomena was carried out and at the same time the project management plan was prepared as an interim report.

In accordance with the project management plan, activities were divided into five separate topics and the respectively related research was carried out. The topics are the following: *Topic No. 1: Update* of Hazards and Events Assessment, *Topic No. 2: Detailed Assessment of Gas Explo*sion, *Topic No. 3: Description of Possible* Actions due to Extreme Situation, *Topic No. 4: Description of Possible Application* of Physical Protective Measures and *Topic No. 5: Assessment of Heat Sink Absorber Characteristics*.

As scheduled in the technical task, interim reports for several topics, namely *Topic No. 2: Detailed Assessment of Gas Explosion* and *Topic No. 5: Assessment of Heat Sink Characteristics*, were presented at the end of the second stage of the project. During this stage, the analysis of extreme conditions was carried out and the parameters typical for events and their value limits were determined. Moreover, statistical and other information was collected and analysed, and the events were modeled and assessed.



Participants and organizers of the Workshop RER/9/095-9018-01 initiated by IAEA. (2010 April 19–23)

During the implementation of the third stage of the project, possible consequence analysis of studied events and phenomena, investigation of related hazards and impact visualization was carried out.

The researchers of the Laboratory participated in the TATENA meetings where this work carried out during the last years was presented and discussed. Interim reports of *Topic No. 3: Description of Possible Actions to Extreme Situation* and *Topic No. 4: Description of Possible Application of Physical Protective Measures* and the project of report for *Topic No. 1: Update of Hazards and Events Assessment* were also presented.

The final reports for the mentioned topics were presented during the fourth stage of the project, at the end of 2010. Following the agreement, the fifth stage of the project is due to be completed in 2012. It encompasses the support of adjustment of interim and final reports with authorities and submission of initial data and their description. The results of performed research may be important while making a decisions regarding particular construction site and planning management of their risk. Following the recommendations of IAEA, the analysis of external events should be updated if any additional information emerges in the future.



LEI actively participates in the activities of nuclear energy scientific research and increasing specialists' qualification. 19–23 April 2010 *IAEA Regional Workshop RER/9/095-9018-01 Regional Workshop on Framework and Techniques for PSA Applications and Risk Informed Decision Making* was held in LEI. The workshop was intended for the presentation and discussion of up-to-date methods for finding solutions based on the application of Probabilistic Safety Analysis (PSA) and risk assessment. The reports were delivered not only by foreign experts, but also by the specialists from LEI and VATESI. Although the participants and foreign experts experienced some difficulties to arrive to the workshop due to the volcanic eruption in Iceland which took place at the same time, no other problems were faced during the workshop. Under such conditions, for the first time the workshop was held invoking distance learning tools: the experts from the USA and England presented their material and answered questions at a distance.



European Technical Safety Organisations Network

It was noted in LEI Annual Report 2009 that LEI became the member of *European*



Participants, organizers and lecturers of ENSTTI courses. IRSN France, August 2010

Technical Safety Organisations Network

(ETSON) in December 2009 and the scientists at the Laboratory of Nuclear Installation Safety actively participate in the activities of this network. In order to intensify the technical-scientific dialogue and initiate joint projects, ETSON General Assembly decided to establish expert groups in the main fields of competence of the ETSON partner countries. The Laboratory has delegated competent experts to the following ETSON expert groups:

- Operating Experience Feedback, including Incident and Precursor Analysis;
- Mechanical Systems;

- Severe Accidents;
- Environmental qualification;
- Safety Fluid Systems, including auxiliary systems;
- Human and Organizational Factors;
- Probabilistic safety analysis (PSA);
- Lifetime-Management;
- Thermal Hydraulic Analyses (Transients, Accidents);
- Safety concepts, Defence-in-Depth;
- Core behaviour (operational and accident conditions).

LEI representatives participated in the meetings and other events for expert groups WG11 (Safety concepts, Defence-



With the initiative of Institute for Radiological and Nuclear Safety (IRNS), ETSON organizations established *European Nuclear Safety Training and Tutoring Institute (ENSTTI)* in 2010.

Its founders are the following four technical support organizations: IRSN (France), GRS (Germany), LEI (Lithuania) and UJV (the Czech Republic). The objective of ENSTTI is to provide educational, consultation and practical services by assessing radiological and nuclear safety. The institute encourages technical support organizations to share experience in order to improve nuclear safety by spreading knowledge and practical experience in the field of nuclear safety culture.

In summer 2010 the first two training cources, each 3-week long were organised in Germany (GRS) and France (IRSN) by ENSTTI. The courses were attended by a total of 37 participants from radiological and nuclear safety institutions or nuclear power plants of 14 countries: the Czech Republic, Germany, France, the Netherlands, Poland, Romania, Russia, Japan, the United Arab Emirates, Mexico, Jordan, Republic of South Africa and Pakistan.

in-Depth) and WG8 (Probabilistic safety analysis) in 2010. Last August the 4th *ETSON Summer School* was organized by the Junior Staff Programme in Garching near Munich (Germany) for ETSON organizations employees up to 35 years old. About 40 participants from ETSON and other organizations took part in this summer school which overviewed the following topics relevant for nuclear safety: increasing reactor capacity and operating resources, decommissioning of nuclear facilities, management of radioactive waste and new reactor types.

The researchers of the Laboratory participated in preparing the programme of these courses, the tests for participant selection as well as in selecting and testing the participants, preparing and giving lectures, and formulating questions for participants' knowledge assessment at the end of the courses. The lectures on control of beyond-design-basis accidents in RBMK reactors, Chernobyl disaster and its causes, consequences and improvement of reactors, carried out after the accident, were given. A lecture was also given on decommissioning of Ignalina NPP.

Participation in such activities enables acquiring experience in organizing similar courses and improving ones qualification. Such activities may be necessary after the beginning of Visaginas NPP construction when providing qualification for new staff at the power plant and supervisory institutions.



A member of ENSTTI Scientific Council Dr. Habil. A. Kaliatka awarded a IRSN memento

In 2010, the implementation of the *Transition Facility Projects* was completed. Its objective was to increase the qualification of local specialists in order to ensure Ignalina NPP safety maintenance and assessment, including the phase after the final shut down of the reactor. The scope of the implemented project *Enhancement of VATESI and its Technical Support Organizations Specialists Knowledge through Seminars and Internships* matched the three following objectives:

- to broaden specialists' knowledge of VATESI and its Technical Support Organizations (TSO) in three areas: handling spent nuclear fuel; assessment of instrumentation and control systems and equipment; structural integrity of safety-important systems;
- to prepare recommendations for improving the present legal basis (handling of spent nuclear fuel, instrumentation and control systems and equipment);
- to prepare recommendations for programmes of inspections in the field of structural integrity.

During the implementation of this project, the Nuclear Research Group from

the University of Pisa (Italy) was the partner of LEI.

Preparation of IAEA documentation

LEI actively participates in preparing IAEA technical documentation and international safety standards. The documents present international scientific practice and describe theoretical and practical research that are finally formalised as IAEA safety standards after exhaustive reviews and international coordination. In 2010, after several years of international cooperation and seminars and meetings for discussion of methodological issues, international standards for probabilistic safety assessment, defining the application of Level 1 and Level 2 PSA in NPP, were issued and a IEC DOC for small and medium power reactors was prepared.

In 2010 according to plans for project **IRIS** (International Reactor Innovative and Secure) and the joint agreement between project participants and Westinghouse Electric Company LLC, the research for preparation the conceptual IRIS project was finished. In this stage researchers of LEI participate in preparing methodologies for new reactors comparisons and in One of the most influential activities is the participation in preparing IAEA technical documentation. IRIS project and related research *Westinghouse Electric Company LLC* were completed on 29 November 2010. The implementation of this project took 10 years and over 20 companies and 10 different countries participated in it.



implementing work, related to structural, economical, security and safety analysis of the reactor. In the recent years specialists of the Laboratory of Nuclear Installation Safety have participated in performing IRIS probabilistic safety and economical efficiency analysis and research, devoted to reduce the risk of different external hazards and the uncertainty of obtained results. As the building of new NPP in Lithuania is planned, scientific research in this field is relevant for the study of new reactors construction.



Network of Excellence of Severe Accident Research of Nuclear Power Plants SARNET-2



The work of the project **SARNET-2** was continued in 2010. This project aims at the integration of NPP severe accident and operational research in Europe. Including LEI there are 41 scientific and business institutions from EU countries that participate in this project. The researchers of Laboratory of Nuclear Installation Safety take part in the activity of the three following working groups of the project:

- WP4 ASTEC modelling, adaptation and verification of integrated code ASTEC for severe accidents in NPP;
- WP5 COOL cooling of melted core and remaining derbis;

 WP7 CONT – analysis of processes in containments of NPP.

While implementing these activities, the researchers of the Laboratory participated in the meeting of ASTEC users and modelled the processes in the INNP spent nuclear fuel pools during Beyond Design Basis Accidents. They also analysed the processes taking place in the active zones of nuclear reactors during severe accidents by modelling the FPT1 experiment carried out in PHEBUS experimental stand. The modelling was performed using ASTEC and RELAP/SCDAPSIM software packages. Moreover, a sensitivity and uncertainty analysis was also carried out.

Next year heating and melting of fuel assemblies as well as relocation and water-cooling of melted materials are going to be analysed following the results of QUENCH experiments. A similar repeated flooding of fuel assemblies is also going to be modelled in case of an accident in spent nuclear fuel pools.

During the analysis of nuclear power plant containments, modelling of the processes in water drops spraved in NPP containments and hydrogen mixing in the containments was performed applying COCOSYS software package. The experiments carried out in the stand THAI (reduced containment) were also modelled in order to investigate the interrelation of passive catalyst systems for hydrogen burning with atmosphere (gas and steam mixture). This work, which aims at the investigating the possibilities of using different software for modelling the processes in NPP containments, is carried out together with other five organizations: IRSN (France), FZJ and GRS (Germany), NRG (the Netherlands) and NUBIKI (Germany). The obtained results were submitted to the organizers of the work who are going to

prepare a summarised analysis of all results obtained by the implementing participants. Participation in such comparisons of the modelling results provides a better understanding of the software package and a considerable improvement of user qualification.

The researchers of the Laboratory also participated in another activity which aims at carrying out comparative calculations of hydrogen explosion by using different software. These experiments were performed in ENACCEF experimental facility in France intended for investigating the spread and acceleration of flame in combustible gas mixtures.

In the project SARNET-2 of 2010, the methodology of second-level probabilistic safety analysis was improved; the means and methods of severe accident analysis and assessment and dynamics reliability methods were also promoted. The Laboratory continued the research in PHEBUS-FP programme. Applying COCOSYS code, the Laboratory performs numerical research of the phenomena in PHEBUS containment. In 2010 continuing the cooperation with GRS mbH (Germany), a common model of containment, which enables a detailed analysis of processes during the FPT-2 experiment, was developed. On 3 December 2010, a meeting with the representatives of GRS mbH, H. Wolff, S. Arndt and G. Weber, took place in LEI, where the obtained results were discussed and future works were planed. The responsibility of the Laboratory in this project, which is due to finish in the middle of 2011, is the part of the model related to the description

PHEBUS-FP programme is one

of the largest international research programmes for water-cooled nuclear reactor safety and severe accident research. In 1988, IRSN (France) initiated the programme and presently coordinates it. of thermodynamic processes as well as aerosol and radionuclide transport processes. GRS mbH has already supplemented this model with information on chemical transformations of iodine.

Network of Excellence of Nuclear Plant Life Prediction



In 2010 LEI continued activities of **NULIFE** (Nuclear Plant Life Prediction) network of excellence. One of the main tasks is to create a single organisation structure in the form of a Virtual Institute, capable of providing harmonised R&D at European level to the nuclear power industry and the related safety authorities in the area of lifetime evaluation and management methods for structural components.

This project is also related to the methodology improvement of decision-making, based on risk assessment, and optimization in service inspection. The implementation of the project is carried out by a consortium of participants from 10 contractual organizations and 27 partner organizations. The coordinator of the project is VTT scientific research centre (Finland).

In 2010, the researchers of the Laboratory participated in the activity and organized meetings of working groups Assessment of structural integrity (IA-2-2) and Safety, risks and reliability (IA-2-4). IA-2-2 working group prepared material on Leak Before Break methodology applied for austenitic pipeline of RBMK-1500 reactor circulating contour. The material was used in the report of pilot project **Probabilistic Application of Leak Before Break**. The working group IA-2-4 prepared material for the report on assessment methodology of safety margins and filled a questionnaire about them. Participants of the project submitted an offer for FP7 projects in the fields of material degradation, fracture mechanic and risk assessment. They also prepared the initial version of NULIFE Association (online institute) statute, which is now being coordinated with national laws. The project will be implemented till October 2011.

Research of NPP operation reliability characteristics



In accordance with agreement between EC JRC Institute for Energy and LEI, in 2010 the implementation of research on **Reliability and Data Analysis of Passive** Components was continued and the research report was supplemented. Activities of the project are related to APSA research network (which comprises 14 organizations from different countries) and NULIFE network of excellence of the EU. Taking into account the impact of equipment degradation and change of their reliability characteristics, APSA research network is intended for improvement of the classical probabilistic safety assessment (PSA). Applying an assumption of constant reliability parameters, sometimes in practice and theory an inadequate safety assessment is carried out applying the classical PSA. In order to perform age dependant PSA, larger amount of data, inspection assessment and more detailed models are essential.

In this research network, LEI devoted most of attention to activities, related to component reliability analysis methods (mostly to the Bayes method) and time dependent reliability characteristics assessment as well as application of such methods and estimates in PSA models. Furthermore, the issues of development and application of reliability database and relevant software (e.g. WinBUGS) were considered.

Inspection and qualification research



In 2010, LEI, being the member of **ENIQ** (*European Network for Inspection and Qualification*) coordinated by EC JRC Institute of Energy, continued the participation in activities of working group on risk analysis TGR (Task Group on Risk). The Laboratory presented the activities for risk-informed inspection programme development and optimization in Lithuania and participated in the preparation/review of technical documents describing the best

European practice. TGR group of ENIQ research network is comprised of 20 different organizations. Activity of this network is related to NULIFE network of excellence and other FP7 projects.

International standard No. 49

In 2010 an OECD project *International Standard No. 49*, which aims at analysing the processes of hydrogen burning in NPP containments, was completed. During the implementation of this project, the tests were performed in two experimental facilities: ENACCEF in France (investigation of spread and acceleration of flame in combustible gas mixtures) and THAI in Germany (research on processes possible in NPP containments during severe accidents). The researchers of the Laboratory carried out numerical research using ASTEC code, which includes an up-to-date hydrogen burning model. The obtained results were discussed with other participants of the project in the final meeting. The summarized results of experiments and modeling are going to be published in the report of OECD project.

3. SAFETY ANALYSIS OF THERMONUCLEAR FUSION REACTORS

Scientific research of thermonuclear fusion energy (FUSION) development is one of the priorities of EU FP7. While implementing the research of this field, LEI continued the work described in **7BP EUR-ATOM** – **LEI Association Agreement.** In 2010, cooperating with Max-Plank-Institut für Plasmaphysik (Greifswald, Germany), a W7-X cooling system model for RELAP5 code and plasma vessel model for







COCOSYS code were improved and an integrated model of cooling system and plasma vessel was developed for ASTEC code. The detailed analysis of water hammer enabled submitting an offer to W7-X designers on closure time of the isolation valve. Other work, which is going to be



continued in 2011, was also initiated; its objective is to analyse the leakage through small cracks before the complete break of the pipe.

In 2010, an agreement was signed on Limit Analysis of the Port Welds between the Plasma Vessel and the parts in the W7-X Cryostat System with Max-Plank-Institut für Plasmaphysik. The strength analysis is going to be performed using BRIGADE/Plus (ABAQUS/Standard) software, whereas the finite element software BRIGADE/Plus is intended for solving linear and non-linear tasks when static and dynamic loads are present. Application of the mentioned software enables performing the strength analysis of various geometric constructions. Last year the models of 1 mm thick welds for AEU30 and AEQ20 plasma vessel ports were prepared and their modelling was carried out using Solidworks and Brigade/Plus software. A geometric model of AEK20 plasma vessel ports was prepared; however, the finite element model is still being developed.



LEI researchers next to the W-7 device (Germany, Greifswald)

4. RESEARCH OF CONDENSATION IMPLOSION

The main objective of the continued state subsidy funded research project Numerical and Experimental Research of Condensing Two-phase Flow is to examine condensing stratified coocurrent twophase flow in a closed horizontal cannel and to determine interaction of the processes during the flow. At the same time, the project aims at developing a numerical model for thermal-hydraulic system, which uses condensation implosions for circulation, and to prepare recommendations for the construction of such system. Continuing numerical and experimental research of two-phase flow, the measuring of water temperature profiles was began by using a thermovisor in 2010. This non-invasive method is advantageous due to the large amount of data, definition and visualization of thermal processes.

The results of the experiments of measuring pressure differences in a horizontal channel demonstrated that condensation influences and reduces the stability of interphase surface of two-phase flow. When condensation takes place and steam speed is 7 to 10 m/s, the interface shear is twice as large as in the case of non-condensing flow.

5. APPLICATION OF BEST ESTIMATE METHODOLOGY

A three year state subsidy funded research project Analysis of Processes in Complex Technical, Natural and Social Systems Applying Best Estimate Methodology was initiated in 2010. Laboratory of Hydrology and Laboratory of Energy Systems Research also take part in this project which is a continuation of previous common work performed by the three laboratories. The objective of this project is to apply the uncertainty analysis methodology in the field of engineering and social sciences and for modelling of hydrological processes. Performing the numerical research in technical systems using best estimate methodology, the analysis of processes taking place during severe accidents in nuclear reactors was carried out by modelling the experiments carried out in PHEBUS experimental stand. Moreover, the work related to the application of best estimate methodology for the analysis of processes in nuclear fuel elements was continued, i.e. the analysis of processes in heat-releasing elements of RBMK-1500 during the time when the fuel assembly is in the reactor was presented. The cooperation of the three laboratories, related to acquiring knowledge and applying uncertainty and sensitivity analysis in the field of engineering and social sciences as well as modelling hydrological processes, is going to be continued next year.

6. SECURITY OF ENERGY SUPPLY ASSESSMENT

In 2010 a state subsidy funded research project *Lithuanian Energy Security Research* was continued. Its main objective is to estimate energy security level of Lithuania during various periods of time till 2025 and to compare energy security level to several other countries of the EU, applying energy security assessment methodology prepared in a state subsidy funded research project of 2006–2008. In 2010 the indicator system for energy security level of Lithuania was expanded and



Temperature field of two-phase flow

several scenarios, showing the changes of energy security level in relation to the present energy system, were estimated.



The FP7 project Security of Energy Considering its Uncertainty, Risk and Economic Implications (SECURE), which lasted for three years, was completed in 2010; 15 partners from 11 countries of the EU and European economy zone took part in it. The aim of the project is to develop an energy security methodology, considering the issues of energy supply, assessing geopolitical changes, price formation, market development in and outside the EU, the threat of terrorism, etc. During the implementation of the project, an energy security level assessment methodology for nuclear energy sector was developed, the scenarios of nuclear energy development were created and geopolitical, technical,

economic, and national political influence of the EU on the secure of nuclear energy supply was estimated. In addition, means for evaluating the whole possible impact of nuclear energy security of supply was developed and tested, regarding technical problems, any disturbances and political uncertainties. The project, coordinated by Observatoire Méditerranéen de l'Energie (France), is significant and timely in respect of EU energy security. The obtained results of the project were thoroughly presented in the seminars in Algeria, Brussels, Dubai, Milan, Moscow and Paris.

7. SUPPORT FOR FOREIGN NUCLEAR SAFETY AUTHORITIES

In November 2010, the European Commission financed project *Support for Armenian Nuclear Safety Authority* was completed. 8 countries of the EU participated in this project coordinated by Riskaudit (France). The aim of the project is to provide support for Armenian nuclear regulatory authority (ANRA) regulating nuclear safety in order to ensure nuclear and radiation safety in the country. The implementation of the project is aimed at the following objectives: to support and strengthen national Armenian nuclear safety regulatory system, to promote an effective safety culture following the principles of Convention on Nuclear Safety and to develop the regulating methodology and practice applied in the European countries. The researchers of the Laboratory are working on one of the tasks of this project: the development of ANRA employees training system. In 2010, a meeting of this working group took place in Armenia, where the participants discussed ANRA staff regulations and employees training system under development. In October 2010, all implementing organizations and a representative of the European Commission participated in the final meeting of the project took place in Prague (the Czech Republic). The objectives and tasks of the project were successfully reached.

8. COOPERATION WITH VATESI

According to the agreement *Application of Ignalina NPP Probabilistic Safety Analysis Model in VATESI Activity* between



Researchs' Night 2010. Visitors and Dr. M. Šeporaitis next to the two-phase flow test facility of the Laboratory of Nuclear Installation Safety

VATESI and LEI, the planned technical work was continued and completed in 2010. The software RiskSpectrum RiskWatcherTM (hereinafter called as System of Unexpected Events Analysis - SUEA) was obtained, probabilistic safety assessment (PSA) and analysis model were reviewed and relevant data feasibility assessment was carried out. Ignalina NPP PSA model used by VATESI was adapted for unusual event analysis and application of RiskWatcher software which eases the work with PSA model. In addition to RiskWatcher, RiskSpectrum PSA Professional software should be used: applying the latest available version RiskWatcher 1.22, different software was adjusted and a system of unexpected events analysis, matching all the necessary requirements, was developed.

Having analysed the possibility to relate risk analysis with SUEA, which was implemented using RiskWatcher and applying living PSA and available PSA model, demonstrative-test calculations were carried out. For this purpose, assessment of data relevant for analysis was performed and the process of unusual event analysis was overviewed, considering five different unusual events and selecting an event (2005 m.) which can be analysed with the means of risk analysis. Furthermore, the direct application of living PSA and usage of RiskWatcher software was described.

Moreover, VATESI personnel training was organized, including the presentation of PSA theoretical fundamentals, implementation of PSA model application review and description of PSA and SUEA practical usage possibilities. Consultations together with technical support were provided while implementing the agreement and during the whole period of project realization.

The final report, prepared employing SUEA, may be used as a guiding document; its introduction presents a review of various means of risk monitoring and PSA application worldwide, whereas the other parts describe the international, national and specific experience and viewpoint of the authors. To the best of present knowledge, no similar work has been carried out elsewhere yet.

The final report, including the reference sources, presents the international practice in the field of PSA application, but it should be stated that this worldwide experience is still limited, especially in respect of different types of reactors. For this reason, the procedures which are related to the analysis of exploitation experience and PSA application are given a great deal of attention in the final report. Although such procedures are already in use, they are still being improved in many countries that exploit nuclear power plants. The recommendations, given in the final report, encompass the summarized experience obtained by applying various methods, collecting data and applying PSA in practice. Since an approved PSA implementation and application guide does not exist in Lithuania yet, the best international practice (described in IAEA documents in greater detail) was employed while performing the work.

The described work is beneficial because the implementation and application of PSA determines a better understanding of risk factors and gives directions for the improvement of exploitation and verification of the analysed object. The final result of such work is reduction of risk in NPP. Although due to the additional work related to PSA, a certain increase of expenses may be faced by both the nuclear object and authority, it is commonly agreed that the benefit gained from reduced risk, more optimal control of NPP and more rational use of resources undoubtedly compensates the possible increase of expenses.

9. PROJECTS OF DECONTAMINATION AND DISMANTLING OF IGNALINA NPP EQUIPMENT

In cooperation with partners, the researchers of the Laboratory of Nuclear Installation Safety participate in two of four projects of decontamination and dismantling of Ignalina NPP equipment (B9 projects).

Development of the Ignalina NPP 117/1 Building Equipment Decontamination and Dismantling Project (B9-0) was continued in 2010. It is the first project in Lithuania devoted for dismantling and decontamination of NPP equipment. Project is implemented by Babcock Nuclear Limited (United Kingdom), Nukem Technologies GmbH (Germany) and LEI consortium. The main objective of the project is to prepare an optimal dismantling and decontamination strategy for emergency cooling system of RBMK-1500 reactor and other equipment, which is located in building 117 / 1 of Ignalina NPP, as well as to develop the design and safety justification documentation necessary for implementing the project, and to provide support for the Client during the licensing (i.e. coordinating the prepared project documentation with Lithuanian Authorities) and during implementation of the project. In the frame of this project, personnel of the Laboratory are involved in development of the strategy, basic and detailed design, and safety justification report. LEI is responsible for providing support during project licensing and implementation stages. In 2010, project licensing and provision of support to INPP were completed and the Basic design and Safety justification reports were agreed with Authorities. Moreover, all relevant Detailed Design Documentation, which is going to be applied for performing dismantling and decontamination of INPP equipment, was prepared and agreed with INPP.

On 1 December 2010, the INPP Dismantling and Decontamination Service, together with other divisions of the company, started the works of dismantling and decontamination of high-pressure cylinders of Unit 1 reactor emergency cooling system installed in Building 117/1. This work has been started in accordance with the engineering documentation and licensing documents prepared after the implementation of Project B9-0. Having completed this project, approximately 1000 tones of equipment will be dismantled and decontaminated in INPP Building 117/1.

Development of the Ignalina NPP V1 Building Equipment Decontamination and Dismantling Project (B9-2) was continued in 2010. This project is under implementation of Babcock (United Kingdom), LEI, Nukem Technologies GmbH (Germany) and Ansaldo (Italy) consortium. Its main objective is to prepare an optimal dismantling and decontamination strategy of the equipment, which is located in Ignalina NPP V1 building, as well as to develop all design and safety justification documentation necessary for implementing the project, and to provide support for the Client during the licensing and implementation stages of the project. A number of systems, located in Ignalina NPP V1 building, are to be dismantled and decontaminated, i.e. reactor gas circuit, exhaust gas cleaning system, system of reactor repair cooling tanks, ventilation system and emergency cooling system of reactor. The researchers of the Laboratory also participated in preparation of Basic design, Safety justification reports and initial Detailed Design Documentation. Last year, Basic design and Safety justification reports on dismantling and decontamination of equipment in INNP V1 building was prepared and agreed with the Client. The preparation of Detailed Design Documentation is going to be finished and agreed with the Client next year.



At the end of 2010, the Director of the Institute E. Ušpuras is awarding an employee of the Laboratory D. Laurinavičius an incentive bonus for young researchers

According to the agreement with GNS (Gesselshaft für Nuklear-Service mbH, Germany), a project Modification or Replacement of Support Service Systems of SNF Containers in INPP SNF Pools was initiated in 2010. The work is carried out in cooperation with SC TECOS and car factory SC ASTRA. It is necessary to produce and mount principal equipment, consisting of 6 shock-absorbers (3 shock-absorbers in each INPP Unit), and other service equipment in INPP. The purpose of shockabsorbers is to absorb energy in case of earthquake or accidental fall of containers filled with spent nuclear fuel, ensuring that the loads on building and container constructions will not exceed the accepted limits. Last year, all design documentation on production and mounting of the equipment was prepared and agreed with the Client. Moreover, dismantling of replaceable equipment was carried out in Unit 1; experimental research of mechanical characteristics of second-type shock-absorber materials was performed, and the influence of weld ports and sheet bending (the tubes are produced from welded sheets) on fluidity, strength limits and other qualities was also determined. The experiments demonstrated that the technology, which is going to be used for welding and bending in car factory SC ASTRA, only slightly (2–3%) increases the means of fluidity and



strength limits. The characteristics determined during the experiments were employed for recalculation of shock-absorbers. Next year the work related to the mentioned agreement is going to be continued.

The Laboratory of Nuclear Installation Safety participated in preparing the **Safety Analysis Report on Final Decommission***ing and Defueling Phase of Ingalina NPP* **Unit 2**. Taking into account that Ignalina NPP Unit 2 is decommissioned and fuel is going to be loaded to the spent nuclear fuel storages, the researchers of the Laboratory performed the following work:

- selection of initial events that may cause accidents;
- accident analysis including accidents in reactor before defueling of the active zone and in spent nuclear fuel pools when the fuel assemblies are moved from reactor into the pools;
- estimation of nuclear fuel characteristics;
- assessment of system, structure and component ageing.

In 2010 the researchers of the Laboratory assisted INPP in agreeing the Safety Analysis Report with VATESI: some chapters were supplemented taking into consideration the remarks of VATESI and other Authorities.

10. RESEARCHERS' QUALIFICATION AND PUBLICATION OF SCIENTIFIC RESULTS

In 2010, there were 11 doctoral students in Laboratory of Nuclear Installation Safety and three doctoral thesis were defended: two of them, *Numerical Research of Processes in Heat Releasing Elements of RMBK Reactors* (A. Marao) and *Research on the Application of Condensation Implosion in Passive Cooling Systems* (M. Valinčius), in the field of thermal engineering and the third, *Assessment of Model Parameters of Non-Stationary Processes by Bayes Method* (I. Žutautaitė-Šeputienė), in the field of information technologies, system theory. Together with experienced scientists, the young doctors presented the research results in a book, scientific monograph and science research reports. 42 scientific articles were published (among them, 11 articles in ISI indexed journals) and 35 papers were presented in scientific conferences.

Laboratory researchers participated in the events related to thermonuclear field and presented papers in all main international conferences, where safe operation of nuclear power plants and physical phenomena occurring in them were analysed. Researchers actively participated in different international and national training courses, IAEA seminars, committee and coordinating meetings, activity of FUSION development committees and other organizations and scientific institutions.

> Dr. Sigitas RIMKEVIČIUS Head of the Laboratory of Nuclear Installation Safety Tel.: +370 37 401 924 E-mail: sigis@mail.lei.lt

LABORATORY OF ENERGY SYSTEMS RESEARCH

Main research areas of the Laboratory:

- analysis of macroeconomic development scenarios, modelling and forecasting of energy demand;
- analysis of medium- and long-term energy supply scenarios using widely approved optimisation models;
- evaluation of environmental impacts of the energy sector, analysis of pollution reduction technologies and implementation of environment protection policies;
- energy management and marketing research;
- research of efficiency of renewable energy sources support means;
- generalization of the energy sector restructuring and liberalization experience in the European Union and Central and East European countries and its application implementing 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 the completed state subsidy funded scientific research project *Development of Multiobjective Decision Making Methods and Their Application in Energy and Environmental Policy* multiobjective decision-making support methods applied in the energy and environmental policy were analysed and systemized and their possibilities for application in Lithuania were determined. In the prepared report, some of the methods were improved considering the most relevant environmental issues of the energy sector primarily related to climate change.

Different interests, aims and types of information are often confronted when the decisions about the energy sector have to be taken. For this reason, it is necessary to apply the multiobjective assessment method which enables the decision maker to evaluate the relative importance in combining economic, environmental and social criteria. These methods allow a possibility to select the best solution considering all relevant criteria.

The decisions in the energy sector are taken on different levels, such as the selection of reasonable energy development scenarios and specific energy transformation technologies, implementation of specific projects in different energy systems, etc. The analysis of possible alternatives of solutions requires choosing appropriate criteria and quantitative indicators for evaluation of the solutions, whereas the formation of decision making model is very important in solving the tasks with a great number of criteria. Thus, a multiobjective model for the energy sector and its realization methodology were presented in the report on the basis of the energy and environmental policy priorities and the analysis of multiobjective decision-making support models.

The proposed multiobjective decision-making support model and the methodology prepared on its basis and grounded on the assessment of the influence on energy policy priorities was employed in the mentioned scientific research. It presents the multiobjective assessment and organizational principles of the Lithuanian energy sector sustainability, reasonable energy development scenarios and means for climate change reduction. The application of the prepared methodology enables agreeing the energy and environmental decisions and creates an opportunity to reach a synergetic effect of various national political conceptions and instruments.

The prepared methodology was improved and applied in several projects in-



Chief research associate Dr. A. Galinis is presenting a report in a seminar. Next to him Chief research associate Dr. D. Štreimikienė

tended for the comparative analysis of energy generation technologies, including EU FP7 project *Energy Technological Foresight and Scenario Development (PLAN-ETS)* and *Comparative Assessment of Geological Disposal of Carbon Dioxide and Nuclear Waste in Lithuania*, coordinated by IAEA.

During the implementation of this scientific research, a doctoral thesis Assessment of Market Simulating Means of Climate Change Reduction in the Lithuanian Energy Sector (A. Mikalauskienė) was prepared and defended on the analysed subject. Moreover, Dr. J. Šliogerienė, having offered the theme Development of Intelligent Decision Support System for Energy Generation Technologies Assessment, won the competition for postdoctoral apprenticeship, organized by the Research Council of Lithuania, and was accepted to postdoctoral studies. During the apprenticeship, the research on multiobjective decision making methods will be developed by creating computerized decision support models that enable practical realization of the prepared methodology.

In the scope of a new state subsidy funded scientific research project **Analy-**

sis of Processes in Complex Technical, Natural and Social Systems Applying Best Estimate Methodology, implemented together with the Laboratory of Nuclear Installation Safety and Laboratory of Hydrology, the best estimate methodology was applied in the search of specific energy system solution and a choice of the developmental directions in the district heating system in Kaunas city. The interim report presents summarized information on the following:

- The developed model consisting of two modules: one is for the analysis of the development of heat generation sources in 2010–2030, and the other for selecting the operation modes of heat sources during each year of the analysis;
- The proposed novel principles for calculating the cost of heat generation in separate facilities and for accounting the cost of heat, sold to the consumers in Kaunas;
- The selected options of heat source development having reasonable directions and providing an opportunity to the decision makers to select the best option from the proposed ones and making the strategic planning more flexible.

The state subsidy funded scientific research project *Lithuanian Energy Security Research* was continued. In the prepared interim report, the researchers of the Laboratory have made a strong contribution in preparing a model of the Lithuanian energy security assessment.

SCIENTIFIC RESEARCH WORK FOR THE NATIONAL ECONOMY

In 2009, the Laboratory researchers, together with the Laboratory of regional energy development, won a competition, organized by the newly founded Ministry of Energy of the Republic of Lithuania, fulfilled the aims of the scientific work Municipal Renewable Energy Sources (Biofuel, Hydroenergy, Solar Energy, Geothermal Energy) and Public Waste Use for **Energy Production** and prepared the final report. In this study, the researchers prepared a conception for grounding the deployment of renewable energy sources use based on the consistent analysis of all possible energy flows, starting with realistically possible sources and finishing with the use of different energy types, obtained from those sources, for satisfying society needs. Additionally, non-renewable energy



Flows of renewable energy sources in 2009, thous. toe

sources, used for energy needs, and their environmental impact were also evaluated. Following this conception, the whole of fuel and energy sources must satisfy the consumers' needs at the lowest possible costs, considering the obligations of Lithuania to the European Union and the determined strategic aims. The scope and economic expedience of renewable energy sources use, including public waste, are closely related to the possibilities of use and efficiency of other alternative renewable and non-renewable energy sources. For this reason, only a complex analysis of all possible energy sources (renewable and non-renewable) and their production, import, processing, transformation and use in the consumers' equipment enables determining the scope of every energy source use in Lithuania and separate municipalities, based on economic, environmental, social, political and other aspects. For solving this task, an optimisation model was developed by composing an oriented net-

work graph and applying mathematical MESSAGE software. The branches of this graph represent possible technologies of extraction, transformation, transportation and distribution of energy sources as well as technologies of electricity and heat production, whereas its nodes represent different types of energy sources or produced energy. The mathematical model enables analysing more than 60 different types of energy (renewable and non-renewable) and examining the possibilities for reasonable application of about 8000 technologies and processes in the national energy sector taking into consideration the specific features of each municipality.

During the implementation of the research, a large amount of information, relevant for such comprehensive analysis, was collected. The researchers of the Laboratory collected and summarised data on the stock of lands, fertility, expenses for growing and harvesting crops and energy plants, forests and wood fuel potential, the amount of various waste, technologies for conversion of agricultural products and waste into biogas and biofuel as well as their technical-economic indicators, tendencies of energy consumption in Lithuania, technologies for energy production using renewable energy sources in power system and district heating systems as well as in the sector of decentralised heat supply. The researchers have also prepared the forecast of the final energy demand and distribution of energy consumption in the economic sectors according to the municipalities for the year 2008 and carried out a review of renewable energy sources support means, applied in Lithuania and the EU countries.

While modelling various factors having a great influence on deployment of the renewable energy sources, it was determined that the possibilities of these sources use are not exploited at full extent. It would be reasonable to increase their share in the structure of gross final consumption of energy up to 21%, if the energy sector was based on the free market principles. The deployment of renewable energy sources is mostly influenced by the externalities related to the operational costs of energy objects which are partially evaluated by the EU taxes for CO₂ emissions. Applying optimisation calculations, it was determined that the share of renewable energy sources in the gross final energy consumption should be increased up to 26-27%. The use of renewable energy sources for generation of electricity is especially important in the analysed scenarios because 27-31% of electricity necessary for the country's needs could be generated from these sources in 2020. Considerable possibilities for the use of renewable energy sources also exist in the district heating systems: currently these sources comprise only 19% in their fuel balance, but in a decade the share of renewable energy sources could increase up to 53-62%. Their wider application will enable creating new workplaces, diminish the dependency on the import of primary energy and contribute in solving many environmental problems.

Continuing the research on wider use of renewable energy sources for district heating sector, the researchers of the Laboratory were assigned an important task by The Lithuanian District Heating Association in a scientific research Preparation of Complex Investment Programme 2011–2020 for District Heating Sector and Development of Implementation *Means*. In cooperation with the specialists from Lithuanian Energy Consultants Association and Kaunas University of Technology, the researchers of Laboratory analysed the means required for fulfilling the targets of the EU Directive 2009/28/EC on the promotion of the use of energy from renewable sources and Directive 2010/75/EC on integrated pollution prevention and control (IPPC) as well as the necessary support.

Under the agreement with *JSC Kauno* energija, a scientific research **Revised**

Strategy of JSC Kauno Energija for District Heat System Development 2007-2020: Assessment of Biofuel Deployment Possibility for Heat Generation in Kaunas Integrated Network was prepared. The research includes the following: the analysis of National Energy Strategy and the EU legislation, and the assessment of their possible impact on development of heating systems in Kaunas; the possibilities for development of energy generation sources supplying heat to the integrated network of JSC Kauno energija, considering the requirements of the EU Directive 2009/28/EC, and reasonable use of renewable energy sources in the country; characteristics of the present state of heating supply system; the analysis of the tendencies in heat consumption variation and forecast of long-term heat demand and its distribution in the city; scenarios of fuel price development; the assessment of possible alternatives of heat supply in the city. After carrying out the analysis of modelling results of heat supply system development, trends of expedient biofuel use in Kaunas district heat generation sources were determined.

As an order of the main national energy associations (Lithuanian District Heating Association. Lithuanian Electricity Association, Lithuanian Association of Biomass Producers and Suppliers, Lithuanian Gas Association, Lithuanian Electricity Producers Association and Lithuanian Energy Consultants Association), the annual publication *Energy in Lithuania 2009* on statistical data was published. It presents the up-to-date information describing tendencies in development of the Lithuanian energy sector and its branches in 2005-2009 as well as exhaustive fuel and energy balances and the key indicators of the national energy sector, which are also compared with Estonian and Latvian indicators (2008 and 2009). It also includes a data on the amounts of greenhouse gas, emitted in 2008, and its structure according to the sectors of the signatory countries, enumerated in Annex 1 of the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

Moreover, the comparative indicators of the EU countries, largest world countries and countries of the Organization for Economic Cooperation and Development as well as global economic and energy indicators (GDP, energy consumption per capita, energy intensity, etc.) for the years 2005 and 2008 are presented in the publication. These indicators were prepared following methodology of the International Energy Agency, which does not include electricity losses in the network into electricity consumption, but incorporates nonenergy needs into the balance of the final energy consumption.

In 2005–2008, Lithuanian GDP increased by 21.9%; however, in 2009 it declined by 14.7% and amounted to 69.2 billion LTL (in *chain*-linked volumes) or 20.7 thousand LTL per capita. The primary energy consumption decreased by 8.7% and comprised 8.51 billion toe, whereas the final energy consumption for energy needs declined by 10.0% and equaled to 4.41 billion toe. Furthermore, the final electricity consumption decreased a little less (by



7.4%) and amounted to 8.37 TWh, while the primary energy consumption per unit of GDP rose by 7.1% and the final energy intensity increased by 5.5%.

This publication was prepared in close cooperation with the specialists of *the Statistics Lithuania, Lithuanian District Heating Association, Lithuanian Gas Association* and *JSC Lietuvos energija*. The information invoked in the preparation of the publication was taken from the publications of the *Statistics Lithuania* (Energy Balance, 2006, 2008 and 2010), and annual reports of energy companies as well as from publications and data bases prepared by international organizations (International Energy Agency, Eurostat) in 2010.

Following the agreement with JSC Danet Baltic, the scientific research Feasibility Study of Liquefied Natural Gas (LNG) Import assigned to LEI was completed. Under the order of Science Applications International Corporation (USA) that is responsible for preparation of the mentioned study, the researchers of the Laboratory have carried out a comprehensive analysis of natural gas consumption in the Baltic countries and Kaliningrad area. They have also presented scenarios of natural gas demand that assess influencing factors, such as forecast of economic recession in 2009-2010 and further economic growth, decommissioning of Ignalina nuclear power plant, industrial development, changes in population and energy efficiency, volume of natural gas use for non-energy needs, anticipated use of fuel in power plants and boiler-houses, construction of underground natural gas storage, connection of Lithuanian power system with Swedish and Polish systems, etc.

The organizers of this study were provided with the information on potential building locations of LNG terminal, directions of natural gas supply system development, possible amounts of LNG import and other factors that may be significant in making strategic decisions.

PARTICIPATION IN THE INTERNATIONAL PROGRAMMES



The experience gained during the implementation of the EU Framework Programme projects is universally important for improving Laboratory researchers' competence.

In 2010, a relevant EU FP7 project *Energy Technological Foresight and Scenario Development (PLANETS)* was successfully completed (it was partially financed by Agency for International Science and Technology). The main result of this project is the development of methodology for assessment of energy technologies sustainability which was adjusted for assessing sustainability of electricity generation technologies and transport technologies.



Relevant questions regarding the Lithuanian energy sector development, including aspects of wider use of renewable energy sources, were analysed in international projects of the *Intelligent Energy* -*Europe*. In 2010, the implementation of two projects was continued. The aim of the project *Policy Development for Improving RES-H/C Penetration in European Member States (RES-H Policy)* is to promote the implementation of 2009/28/EC Directive in the EU member states by analysis of different aspects of energy production from renewable energy sources.



RES-H Policy project. Prof. V. Miškinis is giving a presentation



The aim of the second project, *Shaping an Effective and Efficient European Renewable Energy Market (RE-SHAPING)*, is to formulate recommendations for promotional means necessary for ensuring a more rapid development of renewable energy sources in all EU-27 countries and strategies for their implementation. Various promotional strategies, grounded on both national and EU perspective, are being analysed.



The project *Comparative Analysis of the Storage of Nuclear Waste and Carbon Dioxide (CO₂)*, coordinated by the IAEA, was continued (the possibilities of carbon dioxide storage and nuclear fuel burial in Lithuania were analysed, economic-technical assessment of possible storage



Organizational team of the 11th European Conference Energy Economy, Policies and Supply Security: Surviving the Global Economic Crisis

equipment was performed and preliminary recommendations were prepared).

Experience gained in the Laboratory was used at the international level in preparing:

- Specialists to model scenarios of the Malawi energy sector development (Dr. A. Galinis participated in IAEA training courses in Malawi and Qatar as an expert delegated by this agency, responsible for application of MES-SAGE model to solve tasks of longterm energy planning; he also consulted the Malawian specialists preparing the long-term programme of the national energy sector development);
- Specialists to model scenarios of the energy sector development in Ghana (Dr. D. Tarvydas participated in training courses intended for the region of Africa, organised by IAEA in Akra (Ghana) and Abudzha (Nigeria), and in international training courses in Zagreb (Croatia) as an expert delegated by this agency).

Last year in the Council of Technological Sciences, J. Kugelevičius defended his PhD thesis **Research on the Develop***ment and Operation of the Lithuanian Main* **Gas Pipeline** which was prepared in the Laboratory. PhD Candidate V. Lekavičius participated in the training courses on Balmorel model application for the analysis of energy systems development, organized in Denmark.

The researchers of the Laboratory were assigned an especially relevant organizational task in arranging the 11th European Conference Energy Economy, Policies and Supply Security: Surviving the Global Economic Crisis of the International Association for Energy Economics, which took place 25-28 August 2010 in Vilnius. It is the traditional conference every time organized in a different European country in the year when the Global Conference of the International Association for Energy Economics takes place in the other continents. In Lithuania and in all Baltic countries in general, such extensive and relevant conference was organized for the first time. Well-known experts on energy: scientists, politicians, representatives from large energy companies, were invited for a common discussion. They presented the most important issues related to the changes in economics and the energy sector to the society and the members of the association. Over 230 papers were presented in 8 plenary and 46 competitive sessions of the conference. The number of representatives of various scientific, indus-



trial and energy institutions from 38 world countries (USA, Germany, United Kingdom, Italy, Brazil, Japan, Russia, Australia, Switzerland, Mexico, South African Republic and others) reached 350. The International Association for Energy Economics gives a great deal of attention to young researchers: more than 70 students and PhD candidates from different countries presented the results of their research. The PhD student of the Laboratory, Vidas Lekavičius, having presented the results of modelling the heating in Lithuanian detached houses, was awarded in the competition of the best works of students.

The Vilnius conference will provide long-term benefits to the preparation of Lithuanian specialists since the conference material may be accessed on the website (www.iaee2010.org), and in the libraries of Lithuanian scientific institutions and universities. In his concluding remarks, the president of International Association for Energy Economics, Prof. Einar Hope ad-



11th European Conference. Presidium of the press conference

mitted that the Vilnius Conference was one of the most successful among the recent conferences of the Association organized in the European countries. The participation of Lithuanian specialists of energy economy in international cooperative projects has granted the right to organize high-level conference in Lithuania, and provided the world-scale experts with excellent conditions for expanding knowledge about the problems and development of the Baltic energy sector. On 10 December 2010, the Laboratory organized a seminar *Policy development for improving RES-H/C penetration in European Member States (RES-H Policy)* in Lithuanian Energy Institute. 48 specialists from different Lithuanian energy companies and organizations attended this seminar. It was organized according to the project *Policy Development for Improving RES-H/C Penetration in European Member States (RES-H Policy)* of the *Intelligent Energy Europe* programme. The researchers of the Laboratory actively took part in the preparation and implementation of the FP7 project **Re***searchers' Night 2010* (LT-2010), which was carried out together with the Lithuanian Society of Young Researchers, Vilnius University, Kaunas University of Technology and Social Innovation Institute. In the scope of this project, a science-promotional event **Researchers' Night**, which received great deal of attention from citizens and media, was organized.

In 2010, researchers of the Laboratory participated in the conferences in Austria, India, Canada, Sweden and other countries, where 16 papers were presented. Researchers of the Laboratory published 12 scientific articles in Lithuanian and international journals and proceedings of international conferences (2 of them in publications that are included into the list of Information Sciences Institute).

Prof. Dr. Habil. Vaclovas MIŠKINIS Head of Laboratory of Energy Systems Research Tel.: +370 37 401959 E-mail: miskinis@mail.lei.lt

Researchers' Night 2010. The organizers (on the right) D. Meilutytė-Barauskienė, V. Lekavičius and T. Kaliatka are presenting the LEI programme



LABORATORY OF REGIONAL ENERGY DEVELOPMENT

Main research areas of the Laboratory:

- analysis and modelling of energy sector development of municipalities, which enable forecasting in short and medium periods;
- analysis of heat supply indicators, taking into account economic, environmental and social factors and impact of regulation measures;
- formation of methodological principles for integration of local and renewable energy sources into regional energy development programs;
- collection and economic analysis of information on energy sector development at municipal and regional levels;
- IR thermography diagnostics of buildings, energy equipment and technological processes, and certification of building energy efficiency;
- research of energy consumption efficiency indicators and effectiveness of the implemented measures.

RESEARCH OF REGIONAL ENERGY DEVELOPMENT ISSUES

A state funded scientific research project Planning Principles and Implementation Possibilities of Sustainable Energy Development was completed in 2010. It investigated the principles and implementation experience of sustainable regional energy development, state-of-the-art of planning and issues of Lithuanian regions and cities energy sector. The project has also evaluated local energy sources and the possible scope of their use. The project broadly analysed mathematical models applied for planning of regional energy development and the possibilities of their use taking into consideration the needs and available resources of municipalities for planning energy sector. It was determined

that the modelling results, obtained by optimising the development of renewable sources use on national level in order to achieve the national targets and international obligations with the least costs, do not always correspond to the regional (municipal) aims set for sustainable energy development. Therefore, it is necessary to establish common principles and priorities not only on the national, but also regional or municipal levels taking into consideration the level where the specific decisions are made. For this purpose, further research is necessary to unify the national and regional aims and indicators of sustainable energy development so that the received benefit would be evident in a specific area or community. Another equally relevant problem is optimal distribution of available resources between the

means of energy supply and more efficient energy consumption that may be achieved by applying the principles of Integrated resources planning.

Scientific research carried out in 2010 significantly improved methodological concept for assessing the renewability, reliability as well as economic, social and environmental aspects of the use of energy resources by supplementing it with territorial analysis.

The performed work enabled a detailed analysis of theoretical issues that encompass problematic areas related to the aspects of economic theory regarding sustainable energy development. In general, it can be concluded that energy sector has few market segments where objective conditions for competitive market would be possible. Although market is per-



ceived as the most effective measure for resource distribution, it is incapable of sufficiently ensuring the efficiency of energy consumption, use of renewable energy sources, reliability of energy supply and environment protection. For this reason, a focused national policy, directed towards overcoming the shortfalls of energy market, is necessary.

V. Klevas has prepared a monograph *Methodology for Sustainable Energy Development,* which is going to be published in 2011. The essence and the purpose of this methodology is to indicate the missing links in sustainable energy development by analysing energy sector with regard to the energy sources in use, which would stimulate promising economic research and solution directions. Moreover, present and future technologies of energy extraction transformation, transmission and saving as well as organizational forms of their integration into complexes are considered as measures to ensure national economic and social development. The formation of common energy policy, which has been required for many years, is impossible without a common attitude towards the prospective use of separate types of fuel and energy, making strategic decisions and, of course, implementing them. The prepared methodology for assessing aspects of sustainability is going to be applied for defining common purposes of different types of energy use, although they may sometimes appear controversial and difficult to implement.

The work of Dr. Habil. V. Klevas' working group is acknowledged by the scientists of the relevant field and the interest in their activity was evidenced by the following international publications:

V. Klevas, K. Biekša and A. Klevienė's report Local Measures Aiming to Enhance Use of Renewable Energy Sources was included into WREC-2011 programme of Swedish congress, which will take place in 2011; international publishing house In Tech has published Dr. Habil. V. Klevas' chapter Regional Approach for Policies and Measures Aiming to Sustainable Energy Development in Sustainable Energy, ISBN 978-953-7619-X-X, INTECH, 2010; publishing house NOVA Science Publishers has published Dr. Habil. V. Klevas' chapter Analysis of Support Assumptions and Measures for Promotion of RES Demand in Regional Aspect in Regional Sustainable Development.

PROJECTS FOR SUSTAINABLE REGIONAL ENERGY DEVELOPMENT



In 2010 the Laboratory joined the project Regions Paving Way for a Sustainable Energy Europe (ENNEREG), which is a part of the programme Intelligent Energy - Europe financed by the European Union. The project is coordinated by the Danish partner Energy Consulting Network Agency. Its objective is related to the following aims of Covenant of Mayors and the EU energy and environmental protection policy: by the year 2020, to reduce carbon dioxide emissions by 20%, to increase the share of renewable energy sources up to 20% of final energy consumption and to reduce the demand of final energy by 20% by increasing the efficiency of energy consumption. ENNEREG is represented by 12 European regions, including the Kaunas Region. Additionally, three main dimensions of activities are planned:

The first dimension is for 12 partner regions (ENNEREG regions) making a coordinated approach in defining visions and goals suited to the local policy context, the region's resources and the interests of stakeholders. This will lead to a Sustainable Energy Action Plan (SEAP) for each region to serve as a framework for the implementation process.

The second dimension is to encourage regions beyond the consortium to take up the sustainable energy challenge, thereby adding value by multiplying the impact of the ENNEREG project. This objective will be pursued in the form a Replication Programme, where each of the ENNEREG Regions twin with a new region to adopt the relevant project achievements in the new region.

The third dimension is to create an enabling environment, EU Regions 202020, for broader debate on how regions can help meet EU targets in the field of local and regional Sustainable Energy Action, via a multi-pronged approach including: European-level seminars; communication and dissemination of project activities, Good Practice, lessons learnt and results both online and in printed form; online EU Regions 202020 forum; e-Newsletter and printed promotional material. These, and additional project materials and experiences will also be made available on CD-ROM and via partner websites at the end of the project ensuring added value and the wider use of the project results beyond the scope of the EU-funded activity.

The whole material about regions may be found and downloaded on www.regions 202020.eu; in Lithuanian on http://www.regions 202020.eu/news/secnews-1-lt/.

RESEARCH ON THE PERSPECTIVE AND DEVELOPMENT OF DISTRICT HEATING AND COOLING SYSTEMS

Ecoheat4eu

In 2010, a project Ecoheat4EU was continued by Euroheat&Power together with Lithuanian District Heating Association, following the EU support programme Intelligent Energy - Europe. The project aims at identifying and preparing recommendations for eliminating the legal obstacles and implementing the measures of support for promoting the development of district heating and cooling sector in the EU countries. Taking into account the scope of DHC use as a technology in different countries, they are divided into four types: Consolidation countries that are successful examples of DHC development (Denmark, Sweden, Finland), Refurbishment

countries that require modernization of heating sector (Lithuania, The Czech Republic, Romania, Croatia), New development countries where rapid DHC development is possible (Norway, France, Germany, Italy) and Expansion countries that practically do not use this technology (Ireland, Spain, the United Kingdom). Information about legal aspects of different countries and implementation of means related to the promotion of DHC development and respective EU directives (Cogeneration support, Labelling energy efficiency in buildings, Use of renewable energy sources) was collected and summarised. The recommendation projects, prepared for the countries representing different groups, are going to be coordinated with politicians of participating countries and interested stakeholders of District Heating Market.

Ec*heat4 cities

Despite the fact that DHC has been acknowledged as an effective and environment friendly method of heating and cooling supply to the consumers, certain barriers for broader use of DHC in Europe still remain. The main objective of this project under Intelligent Energy-Europe programme is to eliminate the barriers mostly related to the difficulties in assessing and comparing this technology to other options of heat supply, such as individual RES technologies, heat pumps, etc. This is determined by wide scope of possibilities in generation, distribution and supply, which impede planners and investors to assess the project as well as politicians to justify and assess political measures.

Heat consumers often are not aware of the effectiveness and environmental benefits of a specific DHC system. These barriers are to be eliminated by establishing a voluntary labelling scheme of green (ecologic) heating and cooling energy which will indicate the efficiency of energy system, the use of primary energy


sources (fossil fuel and RES), and carbon dioxide emissions. Such labelling will help local politicians, citizens and perspective investors to make energy-efficient heat supply decisions based on renewable energy sources. Moreover, the labelling scheme, comprising of the following ecolabelling rules, will encourage heat suppliers to improve their activity indicators and ease dissemination of information about environmental benefits of DHC and its comparison with other methods of heating and cooling.

The project aims at promoting the implementation of RES Directive in the context of DHC by improving social acceptability of DHC systems, upgrading the existing DHC systems and promoting the use of RES and increase of energy efficiency (EE). The other purposes of the project are to initiate locally-integrated and cost-effective solutions for buildings, measures for energy efficiency and infrastructure, enabling sustainable development of cities and eco-regions (in contrast to individual eco-buildings). From the long-term perspective, the project seeks to contribute to the implementation of DHC development in Europe: increase the use of RES up to 25% (compared to present 14%) till 2020, reduce the dependence of EU sector on the import of energy sources and achieve a complete carbon-neutrality of CO₂ emissions in DHC sector till 2050.

ASSESSMENT OF DEFINING REQUIREMENTS OF ENERGY EFFICIENCY MEASURES

In 2010 a scientific research **Possi**bility Analysis and Impact Assessment of **Requirements for Defining Energy Effi**ciency for Purchasing Organizations ordered by the Ministry of Energy of the Republic of Lithuania was carried out. The research presents the analysis of legalislation and practical application of requirements for energy efficiency in Lithuania and EU counties. It also includes the analysis of Lithuanian public procurement in respect of requirements for energy efficiency (EUE) employed by purchasing organizations.

Life-cycle costs analysis of selected goods, such as light bulbs, circulation pumps, washing machines, drum dryers, dish washers, refrigerators - freezers, home air conditioners and cars, was also carried out.

In this paper, possible impact of mandatory application of EE requirements for

Principal Measures for Energy Policy Implementation in the Public Sector

Regulations Legislative / Normative Measures						
Energy efficiency performance standards*)	Statutory inspections and audits					
Minimum efficiency standards*)	Compulsory planning and payments					
Financial and Fiscal Measures						
Grants and subsidies for energy efficiency and cogeneration*)	Tax exemption / Reduction*)					
Support for planners and architects						
Information / Education / Training						
Labels for equipment and buildings)	Contests and awards					
Information campaigns	EE information centres					
Co-operative Measures						
Voluntary agreements	Purchase of technologies					



Relative life-cycle costs of light bulbs for 1000 lm luminous flux

purchasing organizations was determined and recommendations for expanding the mandatory application of EE requirements and extended the list of commodities and services were presented.

THERMO-VISUAL DIAGNOSTICS OF BUILDINGS, ELECTRICITY SECTOR AND TECHNOLOGIC PROCESSES, AND CERTIFICATION OF ENERGY EFFICIENCY FOR BUILDINGS

Thermo-vision is a non-contact measuring technology for surface temperatures based on measuring heat radiation intensity. This type of research is applied for investigating and maintaining dwelling houses and industrial buildings, incl. roofs, piping, electrical installation, chimneys and mechanical facilities. It is also used for determining the leaking and filling levels in the tanks/containers, observing and control the quality of the processes.

Thermo-visual research is carried out using IR thermography camera *Flir B400* that has a surface temperature measuring range from -20° C to $+350^{\circ}$ C.

A Laboratory expert on certification of energy efficiency in buildings is carrying out the certification of energy performance for buildings.



Thermo-visual research

PHD STUDIES

A PhD Candidate A. Klevienė has completed the studies, prepared and presented a doctoral thesis *Formation of Knowledge Economy Structure in the Field of Sustainable Energy* in an expanded seminar of the Laboratory. This dissertation was certified.

3 other PhD Candidates are studying and preparing their doctoral theses in the Laboratory.

SPREAD OF SCIENTIFIC RESEARCH RESULTS

Researchers of the Laboratory presented a paper at the 11th Conference of European Association of Energy Economics *Energy Economy, Policies and Supply Security: Surviving the Global Economic Crisis* in Vilnius, 3 papers at the International Conference of Young Scientists **CYSENI 2010**, 3 papers at the international conference in Šiauliai University and 3 papers at several national conferences. All papers were published in conference proceedings. A chapter was published in the book SUSTAINABLE ENERGY issued by international publishing house.

Researchers of the Laboratory perform scientific research, advisory activities and provide services in accordance with the contracts with Lithuanian public institutions, companies and organizations.

Dr. Vaclovas KVESELIS

Head of the Laboratory of Regional Energy Development Tel. +370 37 401 931 E-mail: **vkv@mail.lei.lt**

LABORATORY OF RENEWABLE ENERGY

The main research directions of the Laboratory:

- analysis of the use of renewable energy sources (RES) for energy production and assessment of utilization development in implementing the decisions of the European Parliament and the Council directives;
- prediction of wind power plant capacity variation; research and modelling of wind flow variation in the Baltic coast and other regions of Lithuania;
- research of environmental problems of biogas and biofuel production;
- research of solid biomass preparation and combustion technology development;
- search, analysis and promotion of advanced technologies using local and renewable energy sources, preparation of accredited training courses, development of databases, services and consultations for users, spread of information

The research carried out in the Laboratory is related to the development of renewable energy sources (RES) use for energy production in the state. Following the requirements of the European Parliament and the Council directives (2009/28/ EC, 2003/30/EC, etc.) and Strategic Energy Technologies Plan (SET-Plan), the Lithuanian National Energy Strategy (NES) provides for a noticeable enlargement of RES use in Lithuania until 2020, i.e. RES energy production should constitute 23% of total final energy consumption. Biofuels must be used 10% of total amount of oil products consumed for transport. The production of electric power from RES should constitute 10% of total state electricity consumption. New tasks arise while seeking these goals and for this reason the analysis of various scenarios is relevant in the search of optimal solutions. At the same time, importance is also given to the analysis of wind, biomass fuel and alternative fuel development, employing up-to-date statistical data and research results.

In 2009 a state subsidy funded study The Research of Wind Energy Prediction and the Developmental Possibilities of **Biomass Resources Use in Energetics** was initiated. A variation study of wind speed and turbulence variation and wind flow regularities in the coastal region was carried out, using modern wind measuring equipment WICOM-C. Wind speed profiles and their impact on the wind power plants (WPP) were evaluated and the regularities of wind flow variations were examined applying WAsP software and the measurements of wind speed parameters. The analysis of wind power prediction methods was presented and their advantages and disadvantages were examined. Following the newest statistical data, the study

analyses the use of biomass fuel and alternative fuel resources for energy production and their future perspectives in Lithuania.

RESEARCH OF SHORT-TERM PREDICTION OF WIND POWER PLANT CAPACITY VARIATION

As the capacity of wind farms is increasing, the energy system operator will face the problem of system balance, which is approached by invoking the wind farms' power prediction systems in other countries. The research of prediction models, carried out in the Laboratory, will enable selecting the optimal solution. Thus, the data analysis of the numerical weather forecast model HIRLAM was performed and the forecasts were compared with the measurement data of wind speed and WPP capacity. The importance of wind forecast



An example of wind power plant capacity prediction for 48 h

in determining the reserve capacity of national electricity system was evaluated and the possibilities of practical wind forecast application were analysed.

A wind speed and WPP capacity variation prediction model was composed and adjusted for forecasting the variation of wind power plant capacity according to the local conditions. It was determined that the average absolute error of prediction reaches about 10% of wind power plant installed capacity.

Monthly capacity factors of several wind farms were calculated and compared. The results show that the factors change during the year and reach the peak in September-November and January, whereas they are the lowest in February-August.

It was determined that the capacity factor C_p of WPP operating further from the sea is lower due to different wind conditions. This fact is also approved by the comparison of capacity factors of Vydmantai and Seda wind turbines. Although the design of the plants is the same, Vydmantai WPP is noticeably more productive because it is located near the sea, while Seda WPP is settled about 60 km away from it.

It may be noticed that the variation

regularities of the capacity factors of wind power plants, operating in different coastal sites in Lithuania, are analogous, which suggests that wind flows are correlated in the whole coastal region. Having carried out the measurements in one selected site, the wind power parameters of other sites may be approximately estimated.

RESEARCH OF DEVELOPMENTAL POSSIBILITIES OF BIOMASS FUEL USE FOR ENERGY

Solid biomass

The variation of different types of solid



Variation of annual capacity factor of separate wind turbines and wind farms, operating in different regions of Lithuania, in 2009. WT is wind turbine; WF is wind farm

biomass fuel consumption and production scope is analysed in the Laboratory. It was determined that wood fuel consumption in 1990 – 2008 period has increased more than twice, that is, from 284.9 ktoe to 735 ktoe, which corresponds to 2.6% and 7.9% of primary energy consumption of the state. Wood fuel consumption for centralised heating supply also rises annually.



Amounts of wood fuel and RES share in centralised heating supply

Solid biofuel may be used as a raw or processed product (briquettes, pellets). Compressed briquettes and pellets is an effective solution for increasing the density and energetic value of wood waste used for fuel and ensuring the automatic fuel supply to the furnace. Raw material used for biofuel is biomass chips, wood processing waste, that is sawdust, dried and shredded herbaceous plants and straw. The production of wood briquettes and pellets contributes in solving the problem of wood waste utilization faced in sawmills and wood processing companies.

In Lithuania, the production of wood briquettes and pellets was initiated in 1994 and 1999 respectively. In 2008, the briquette productive capacity amounted to 65 thousand t/y, while that of pellets, to 125 thousand t/y.

Forest cutting waste still remains the least used source of wood fuel. 2.5 million m³ of cutting waste emerges annually, while in practice no more than 1 million m³ can be used for biofuel. It is necessary to expand forest territories and their productivity in order to enlarge biomass resources. The most attention should be granted to the quick-growing grey alders as their potential for biofuel production is underused (the territory is nearly 130 thousand ha).

The growth conditions for grey alders are close to optimum in Lithuania as they grow rapidly, early mature, often and richly crop and also sprout well. The amount of biofuel production would rise and the energy would be produced more efficiently if the problems of biofuel collection, storage and transportation were solved. For this reason, reconstruction of boiler rooms into composite cycle type, modernization of gaskets in the private sector (sawdust/ straw for pellets use) and adjustment of coal stoked power plants to biomass and coal mixture burning is also necessary.

Biogas

The Laboratory has been carrying the research of anaerobic technologies of liquid organic waste processing for many years. It was determined that the rational use of these technologies could result in successful solution of *environmental, energetic, social and agricultural problems* related to the reduction of environmental impact caused by industrial activity of companies. The environmental effect purports the fact that organic materials are effectively (up to 40–60%) decomposed in bioreactor under anaerobic conditions. This reduces the negative effect on the environment of processed sewage.

Biogas, produced in 7 biogas power plants, presently operating in Lithuania, is used as fuel in boiler rooms or stationary cogeneration power plants to produce thermal and electric energy. Having removed CO_2 and other extraneous admixtures, biogas has recently been supplied to the natural gas networks or used for transport in many countries. This expands the scope of biogas use and increases the *energy* ef-



Production of wood briquettes and pellets in Lithuania



Orientation scheme of income from biogas produced using organic waste

ficiency of this process. The analysis of biogas production and use efficiency has determined that the energy efficiency was achieved only after the increase of purchase price of the electric power, produced in cogeneration power plants. Following the example of Western European countries, the complex efficiency of Lithuanian biogas power plants is going to be thoroughly evaluated.

The researchers of the Laboratory perform the analysis of innovative technologies of biogas production and their assessment from the social and agricultural perspective. Having increased the biogas production, it is expected that biogas and compressed natural gas is going to be used as fuel for transport.

Biofuel

The information about biofuel production and consumption in the EU countries is constantly renewed and analysed in the Laboratory. Having determined major changes in the market, the assessment of possibilities to develop biofuel industry in Lithuania is carried out and the analysis of technical-economic development of biofuel production till 2030-2050 is also performed.

The analysis of relevant legislation, and biofuel production and consumption suggests that a great deal of difficulties will emerge in the implementation of the obligations of Lithuania to the EU regarding the use of biofuel (to use 5.75% of total amount of consumed fuel till 2010, and 10% till 2020, etc.) if no additional economic and organizational measures are taken.

It was determined that bioethanol should be substituted for synthetic methanol used for biofuel production, which would enlarge the amount of RES used in the area of biofuel consumption.

Usually bioethanol replaces a share of petrol in internal combustion engines;

however, the possibility of bioethanol use for diesel engines has recently been taken into interest. This is done to expand the base of raw materials and to enlarge the share of renewable energy in diesel fuel. Bioethanol can be used in the process of oil and fat esterification and re-esterification as a substitute for the currently used methanol. Biofuel may be regarded as one of strategically important measures to strengthen the economic independence of the country.

PARTICIPATION IN INTERNATIONAL PROGRAMS

Studies related to the development of alternative fuel use in transport, wind energy and rational enhancement of biomass thermal and electric energy consumption are carried out in the Laboratory. Data covering the whole technology cycle from raw material collection, preparation, processing into solid biofuel and combustion in different types of boilers are collected and analysed. At present time RES comprise approximately 9.3% of the primary energy consumption in Lithuania. The biggest share of RES (approximately 92%) accounts for solid biomass, mainly wood; thus most of attention is given to issues



Growth dynamics of biodiesel production in the new EU member states

related to wood fuel production and use. Research is carried out by implementing different EU programs.

International projects carried out in the Laboratory in 2010:

- Market Development of Gas Driven Cars Including Supply and Distribution of Natural Gas and Biogas (MADEGASCAR) 2007–2010 of Intelligent Energy Europe Programme;
- Solutions for Biomass Fuel Market Barriers and Raw Material Availability (EUBIONET III) 2008–2011 of Intelligent Energy Europe Programme;
- Public Energy Alternatives: Sustainable Energy Strategy for Regional Development (PEA) 2010–2013 of Baltic Sea Region Programme 2007–2013;
- Wind Energy in the Baltic Sea Region 2 (WEBSR2) of South Baltic Crossborder Co-operation Programme 2007–2013.

Cooperating with German, Danish, Polish and other science research centres, studies of bioenergy development perspectives in the regions of Europe were carried out. The main objective of performed projects is to provide considerable input to the implementation of EU tasks in the energy sector pursuing that the share of RES in the region and in the total EU energy balance would satisfy the indicators of directives and other regulating documents.



During the implementation of the EU project **MADEGASCAR**, the possibilities and perspectives of natural gas use in Lithuania were examined. The experience of other partner countries in natural gas use was also analysed and quite a number of advantages of natural gas use were determined in comparison to other alternative fuel used for transport, such as:

- The resources of natural gas are much more extensive than oil resources in the world;
- Natural gas is cheaper than the other types of fuel;
- The expenses for fuel are lesser up to 20% in comparison to liquefied petroleum gas and diesel and up to 40% in comparison to gasoline;
- The operational lifetime of compressed natural gas (CNG) engines is longer;
- The level of noise of natural gas engines is lower by 5–6%;
- The quality of natural gas is ensured;
- The amount of exhaustion of CNG cars is less than required by the standards of EUR05;
- The CNG octane number, which is higher than of the other types of fuel, promotes the industry to produce more effective and precise car engines;
- Minimal environmental taxes, because the CO₂ emission is reduced by 20–25%, in comparison to petrol driven cars;
- Natural gas networks are rather well developed in Lithuania;
- The use of natural gas for transport would increase its equality of use during the year.

Vilnius, Klaipėda and Kaunas municipalities have begun to use natural gas for public transport. The process of implementation of this project resulted in cooperation with other EU countries, exchange of experience, building the first gas filling stations and collecting experience in this field in pursuance of sourcing the cheapest fuel. 20 new buses, using compressed natural gas, are going to be purchased in Kaunas. The buses are going to run in the central districts in order to improve the environmental condition of the city.

The objective of **EUBIONET III** is to enhance biomass fuel use in EU countries by searching for ways to overcome mar-



ket obstacles. The analysis of biomass fuel use, future perspectives and basic obstacles is carried out, national biomass programs are analysed and biomass fuel potential is estimated, giving most of attention to industrial and agricultural waste and assessment of potential of new biomass fuel types. Price mechanisms are also analysed, biomass fuel certification and sustainable development criteria are determined.





The scientific research project Public Energy Alternatives: Sustainable Energy Strategy for Regional Development (PEA) of Baltic Sea Region Programme 2007–2013 is implemented by 21 partners from 6 countries of the Baltic Sea region. Among them: 11 governmental institutions, 7 scientific research institutes and 3 coordinating partners. Lithuania is represented by the following five institutions: Lithuanian Energy Institute (LEI), PE Ignalina Nuclear Power Plant Regional Development Agency (INPP RDA), Ignalina District Municipality Administration, Visaginas Municipality Administration and Zarasai District Municipality Administration.



Meeting of the international PEA project partners in Tartu, Estonia

This project creates an opportunity to collect and spread knowledge and experience in energy field as well as encourage the sustainable district development by cooperating on different levels. Its aim is to find appropriate means for reducing the costs of public utilities by using alternative energy sources. The main result of the project is going to be the development of sustainable regional energy strategy and its implementation in one of the regions.



The scientific research project *Wind Energy in the Baltic Sea Region 2 (WEBSR2)* of South Baltic Cross-border Co-operation Programme 2007–2013 analyses the legal basis for the development of wind energy and economic, technical and social issues impeding its development. The problems, related to the accumulation and storage of energy generated in wind power plants, are being solved. Having assessed the existing obstacles, recommendations for the enhancement of energy development in the EU countries are going to be prepared and provided to the municipalities, investors and project developers.

At the end of 2011 Wind Energy Information Point (WEIP) will be established in the premises of the Laboratory and opened for public. It will provide information about various aspects of wind energy. Small wind turbine will be installed and specially designed wind turbine models will be demonstrated enabling to perform experiments and learn wind power basics. Contests and other events for schoolchildren and students will be organized. The activities of WEIP will also include organisation of lectures, workshops, trainings for wind power project developers, investors, local authorities, students and public with aim to promote wind energy in Lithuania.

SCIENCE PROMOTION ACTIVITY

In 2010, during the implementation of international projects in the field of RES,

scientific ideas were spread to promote the society to take interest in the use of RES for energy production. The possibilities of scientific and business cooperation were analysed, various science-promoting events were organized and science representatives were invited to actively participate in informing the society on new achievements in RES use. As a result of international cooperation, 2 seminars on the development of wind energy and biomass fuel use were organized.

In 2010 the researchers of the Laboratory published 7 articles in scientific journals and other science publications; 1 of them was published in the publications included into ISI list. 2 science-promoting articles were printed and the research results were presented in the international and national scientific conferences.

Prof. Dr. Habil. Vladislovas KATINAS

Head of the Laboratory of Renewable Energy Tel.: + 370 37 401841 E-mail: **res@mail.lei.lt**

ENERGY EFFICIENCY RESEARCH AND INFORMATION CENTER

Main research areas of the Center:

- in pursuance of scientific research, to compile, analyze and provide to experts and society the experience of efficient energy production, transmission, distribution and end-use in Lithuania and worldwide;
- projects related to the realization of National Energy Efficiency Programme;
- participation in international projects, organization of conferences and training courses.

RESEARCH OF ENERGY PRODUCTION AND CONSUMPTION EFFICIENCY IN LITHUANIAN

In 2010 a state funded research project The Development of New Energy Production Technologies in Lithuania and the Study of Increasing Energy Consumption Efficiency Possibilities in Public Buildings was continued. The paper involves the sectors of industrial and public buildings that contain one of the largest energy saving potentials.

The enhancement of energy production and consumption efficiency and the development of the use of renewable energy sources are currently some of the priority directions in the strategy of energy development both in Lithuania and the



Fuel and energy used for industrial production in Lithuania in 2004–2009

European Union.

Following the provisions of the European Parliament and Council directive 2006/32/EC on energy end-use efficiency and energy services of 5 April 2006, The National Action Plan for Energy Efficiency of Lithuania was prepared and approved 4 December 2008. This document identifies national energy saving indicators and suggests a strategy for reaching these indicators.

Up-to-date technologies and innovations that enable to use local, renewable and waste energy sources more effectively are going to be applied for energy use efficiency increasing. Their more rapid development in Lithuania would benefit the implementations of national energy saving indicators given in the Action Plan.

The installation of new technologies is closely related to the information that the consumers are aware of: the new technologies will not be effective unless the consumers are persuaded to apply them. The abovementioned Lithuanian and EU documents indicate a necessity to increase



Largest industrial electricity consumers in Lithuania in 2004–2009

the activity of social information since the proper understanding of decisive factors of energy production and consumption effectiveness is essential. Such educational programmes should be introduced in schools, even though this process is only beginning in Lithuania. Special educational programmes on energy possible to integrate into present programmes are vital to compose because all this would create the basis for the change of the behavior of principal future energy consumers.

The research implemented in 2010 presents the data on industry sector development of Lithuania in 2006–2009, fuel and energy consumption and the greatest industrial energy consumers. The data of 2009 was compared to the last year and earlier periods of time; moreover, the analysis of the data was carried out.

The report presents an overview of 24 legal acts (European Union directives, laws of the Republic of Lithuania, National Strategies and plans of their implementation, etc.) regulating the development of the use of renewable energy sources.

A technical-economic assessment of the recent activity of small capacity biocogeneration plants (up to 2 MW_e), already functioning in foreign countries, was performed. Possible construction of bio-cogeneration plant and heat-pump compressor in the centralized heat supply systems of Ažupiečiai and Agricultural schools in Anykščiai was provided technical-economic justification.

It was highlighted that the installation of heat-pumps are not promoted by any means in Lithuania and current buying-in price for electric power (30 ct/kWh, excluding VAT), produced in bio-cogeneration plants, is too low and does not ensure the profitability of these plants.

Students' knowledge about energetics, energy use effectiveness and renewable energy sources was assessed in the chosen schools of Lithuania. The package of Active Learning of Energy Saving that could be introduced to the present educational programmes at schools was prepared and tested during the educational process. Data of energy consumption monitoring of the chosen schools was collected and assessed. A comparison of the average weekly distinctive energy input of the schools for the same period of time was presented and the analysis of the received data was performed.

While implementing **National Energy Efficiency Programme** (2006–2010), a technical-economic justification of biofuel cogeneration plant installation in Ažupiečiai boiler-house, in Anykščiai was carried out. Activities of boiler-houses, operated by Smalininkai L. Meškaitytė primary school and JSC *Jurbarko Komunalininkas*, for the period 2009–2010 were estimated and planned realization prices of district heating were determined. A repeated expert assessment of heating system reconstruction works at the main hall of Vytautas the Great War Museum was performed. Moreover, a technical-economic justification of external air heat-pumps installation in boiler-house of public institution Rokiškis Mental Hospital was carried out.

PARTICIPATION IN INTERNATIONAL PROJECTS



In 2009 a new international project **Product and Process Design for Aml Sup ported Energy Efficient Manufacturing Installations (DEMI)** was initiated. The project is partially financed by the EU's Seventh Framework Programme for Research, Technological Development and



Initial meeting of the international PEA project implementers in Germany, Wittenberg. Dr. V. Gaigalis is presenting a report on the situation in the region

Demonstration Activities. The period for the implementation of the Project, which is being carried out together with 8 partners from 7 EU countries, is 2010–2013. The head of the project is Fundaction Tecnalia Research & Innovation (Spain).

The main objective of the project is to complement the existing product and process design systems with new functions that would enable the engineers to design energy efficient and ecologically optimal discreet manufacturing processes. Such functions would expand the possibilities of monitoring and decision making about the designed and installed processes. This would contribute to minimization and optimization of the environmental impact of technological processes and manufacturing installations during their lifetime.

One of the main issues in optimizing the technological processes energy input (during design) is to acquire information about the current characteristics of energy consumption of the processes. Such information may be received by mounting appropriate intelligent systems operating in the technological processes and at the same time these systems would perform the energy efficiency control function of the processes.

In accordance with the project programme for the first yeara survey of currently functioning industrial processes and product design systems was carried out. The possibilities of these systems were evaluated by determining the energy consumption efficiency of the designed processes.

The survey of the industry processes and product design systems showed that it is impossible to assess future energy consumption and its efficiency in the currently functioning systems. For this reason, it is essential to complement the computer design systems with new programming modules which would enable evaluating energy input during the design of the processes.

One of the most substantial works in this stage of the project was the development of the conception of programming modules for energy input assessment in designed industrial technological processes. A conception of calculation module was also developed and the requirements for data bases, which will include all data on designed technological processes that is necessary for making mathematical models, were prepared. Connective elements to other modules of the system were planned for a single software environment (Matlab, Simulink, etc.).

The requirements for creating a laboratory prototype of the system were prepared. In accordance with the project programme for 2010, the Center took part in 3 project partner meetings (Bilbao, Bremen, Stockholm) where the results obtained by LEI were presented.

Project Public Energy Alternatives – Sustainable Energy Strategies as a Chance for Regional Development (PEA)



In 2010, the Energy Efficiency Research and Information Center and the Laboratory of Renewable Energy together with 21 partners from 6 Baltic Sea region countries (Germany, Estonia, Lithuania, Latvia, Poland and Finland) initiated an international project *Public Energy Alternatives* – *Sustainable Energy Strategies as a Chance for Regional Development (PEA)* of *Baltic Sea Region Programme 2007– 2013*. Apart from LEI, the project is also being implemented by the 4 following Lithuanian institutions from their own funds: public institution INPP Regional Development Agency, Ignalina District Municipality Administration, Visaginas Municipality Administration and Zarasai District Municipality Administration. The period for the implementation of the project, which is partially financed by the EU (European Regional Development Fund), is 3 years.

The objective of the project is to promote regional development by improving their energy condition and accomplishing the tasks of energy saving and efficient energy use. The project is being implemented in cooperation of 11 governmental authorities, 7 scientific institutions and 3 partners that aim at the main objectives of the project by applying the triple helix approach of co-operation, i.e. collecting and sharing knowledge and experience in different horizontal and vertical levels. The goal of PEA is to accumulate, share and implement innovative energy technologies by transmitting the acquired experience to the whole Baltic Sea region (BSR). For this purpose, new educational modules for energy-related leading executives and staff, obliged to implement and further develop the regional strategy and means, were created.

The project intends to prepare technical projects of several public buildings renovation in the region of INPP which will enable assessing energy saving potential and lay a firm basis for building renovation. While implementing the project, the municipalities expect to mount solar collectors on several public buildings which would become the first (pilot) investment of alternative solar energy into the public sector of the region. The realized investments will provide an excellent example of using the alternative energy potential in the region.

The activity will be periodically assessed in this way assuring high quality of results and the work performed. The final result of the work will be the preparation of Regional Energy Strategy and implementation of the planned means, including the collection of Baltic Energy Strategies.

The task of LEI in the preparation of



A seminar of **Bioenergy Promotion Project** of Baltic Sea Region Programme and its participants: M. Johanson (Sweden) is presenting the project, T. Maata (Finland), N. Pedišius and R. Škėma (LEI, Lithuania) are discussing

the regional strategy is to arrange a study of the present situation assessment which would demonstrate regional problems and week and strong sides of the possibilities of regional development, and also to consult the partners about energy consumption efficiency in applying innovative and effective energy production and consumption technologies.

The Baltic Sea Region Bioenergy Promotion Project

The international project, partially funded by the EU Baltic Sea Region Programme resources, was continued in cooperation with the Laboratory of Heat-Equipment Research and Testing in 2010. This project is managed by Swedish Energy Agency and has 10 partners, countries of the Baltic Sea region. The main objective of all partners participating in the project is to promote and support the development of bioenergy production and consumption in the Baltic Sea region. The period for the implementation of the project is 2009-2011. In 2010, statistical data on biomass potential and its use in Lithuania was collected and the EU and Lithuanian legal acts that regulate and promote bioenergy production were assessed.

On 25-26 November 2010, an international conference Promotion of Sustainable Bioenergy Production and Consumption – Policy, Demonstration and Business Solutions in the Baltic Sea Region was organized in Kaunas. In the conference, a great deal of attention was devoted for the discussion of problems of the Baltic countries related to planning and realizing the means of implementation of the National Strategy of Renewable Energy Sources Development. Moreover, the issues related to the EU policy, regional cooperation and business perspectives in the field of bioenergy were approached giving most attention to the issues of sustainability.

According to the topics of the researches carried out in 2010, 1 seminar was arranged, the results of the studies were introduced in 2 scientific articles and 3 scientific papers were read in scientific conferences.

Dr. Romualdas ŠKĖMA Head of the Energy Efficiency Research and Information Center Tel.: +37037401802 E-mail: **skema@mail.lei.lt.**

LABORATORY OF SYSTEMS CONTROL AND AUTOMATION

Main research areas of the Laboratory:

- mathematical modelling of power systems and networks, investigation of their control issues;
- modelling of ICT-based control systems of power systems and optimisational research.

With rapid development of information and communication technologies (ICT), the increasing amount of control and protection automatic equipment, including intelligent electronic devices, is introduced into power systems (PS). The PS control algorithms are getting more complex as they must enable co-ordinated operation of all those devices to run the PS in the scheduled mode and to properly interact with other PS. New approaches are undertaken, for instance, GPS-based wide area protection system, flexible alternating current transmission systems (FACTS), i.e. power electronic controllers to increase the transfer capability of the network and improve PS stability. It is endeavoured to process more information (telemetering data, telesignals) from different PS points in real time in order to:

- to generate control solutions that adequately correspond to the PS status and to send the respective commands to remote PS controllers;
- to choose optimal settings of automated devices.

The general target is to achieve optimal ratio of the centralised and decentralised control of PS by increasing the latter. The enhanced controllability increases the cost-effectiveness of PS operation, reduces emergency risk, allows disturbance localization in national systems and avoiding of its spreading across the interconnected system.

Laboratory of Systems Control and Automation *carries out research and offers services* in the following fields:

- evaluation and analysis of PS parameters, mathematical modelling and simulation of PS, power networks and control systems;
- investigation of advanced PS control methods, new automatic control devices and ICT applications;
- investigation of PS control issues and development of control algorithms (related to frequency, active and reactive power control, static and dynamic stability, loss reduction, electric power quality, emergency prevention, aspects of electricity market);
- PS and network extension modelling and technical policy towards smart electricity grids;
- analysis of demand response and load control opportunities (interruptible loads, virtual power plants, microgrids);
- research and assessment of PS reliability, security and risks;
- optimisation of PS operation under competitive market conditions, development of competitive balancing mechanisms and ancillary services mechanisms;
- assessment of PS control needs by integrating into PS the wind power plants, renewable energy resources and distributed generators.

CONTRACTUAL SCIENTIFIC RESEARCH FOR ENTITIES OF THE REPUBLIC OF LITHUANIA PERFORMED IN 2010

Reliability Study of 10 kV Overhead Lines of SC Rytų Skirstomieji Tinklai, Utena Region, Molėtai Territorial Division, carried out under the order of SC Rytų skirstomieji tinklai, aims at increasing the reliability of distribution network in Utena region, Molėtai territorial division by optimal means. The study is implemented together with the Laboratory of Nuclear Installation Safety and JSC Energetikos tinklų institutas.

It presents a statistical analysis of interruptions in 10 kV distribution networks of SC Rytų skirstomieji tinklai, Molėtai division that occurred in 2005-2009. The analysis is grounded on the interruption registration data provided by the client. Its main goal is to determine the peculiar factors influencing the reliability of the networks from statistical data which was analysed for different periods of time (years, months), different causal events and affected/damaged network equipment type. Moreover, the frequency of interruptions and reliability indices of 10 kV lines as well as of local and distribution substations were analysed and a list of most faulty lines was composed.

In order to optimize the development/ reconstruction of distribution networks up to the desirable reliability levels and evaluate the related investment cost, the original program ENRR (Electricity Network Reliability and Renovation), encompassing the options of *Microsoft Office Excel* 2007 and *Microsoft Visual Basic*, was created. This program was employed for the preparation of renovation scenario of 10 kV distribution network, including evaluation of the cost necessary for achieving the desired reliability level with best cost effectiveness. Within the contract with *JSC VEVP*, the project *Analysis of Transmission Network Stability and Voltage Levels after Connection of Large Wind Power Park* was started. The company is planning to build a wind power park of about 200 MW capacity in Telšiai region. Since this capacity is big (in comparison to the load of Lithuanian PS) and concentrated in a quite small territory, the impact of the park on the operation of the Lithuanian PS has to be evaluated.

This study analyses the static and dynamic stability, voltage levels and variations of the Lithuanian PS. The calculation is intended for modelling the operational modes of electrical energy systems. The outcomes will be used for determining the voltage stability margins and the additional need for compensation of reactive power after connecting this wind park to the 330 kV electricity transmission line Mūša– Telšiai. The technical task of the study was agreed with *SC Litgrid*.



The implementation of the project *Re*search and Assessment Methodology of Energy Systems Reliability and its Impact on Energy Security within the National programme Energy for the Future was started and is carried out together with the Laboratory of Nuclear Installation Safety.

The aim of the project is to develop a common scientific methodology and mathematical models of reliability assessment for all Lithuanian energy systems. They would enable the analysis of the reliability of energy systems and the assessment of the impact of reliability on Lithuanian energy security. The main systems of the Lithuanian energy sector are electricity, heat, gas and oil transmission networks. The following three tasks of the project were being solved during the first reporting period (August-December 2010):

Task 1. Development and research of methodology and models of reliability for electricity networks, electricity supply reliability and risk assessment;

Task 2. Development and research of methodology and models of reliability for heat network reliability assessment;

Task 3. Development and research of methodology and models of reliability for gas and oil networks reliability assessment.

When developing the common methodology of electricity network reliability assessment, the Laboratory aimed at improving the special methods and developing preliminary methodologies intended for:

- reliability assessment of equipment in a separate PS (network);
- development of a generalised PS reliability model;
- analysis of uncertainty and significance of model parameters as well as sensitivity of modelling results;
- development of models for particular elements of electricity networks;
- assessment of major characteristics of electricity supply.



In 2010, the Laboratory (together with Energy Efficiency Research and Information Center and Laboratory of Nuclear Installation Safety) started a *FP7 project Product and Process Design for Ambient*



CYSENI 2010. Young researchers are discussing the presented report

Intelligence Supported Energy Efficient Manufacturing Installations (codename *DEMI*). This is the first *FP7* project implemented in Lithuania in the field of ICT . Eight partners from seven EU countries take part in this project, led by Foundation Tecnalia Research & Innovation (Spain).

The aim of the project is demonstrative and includes the following objectives:

- to develop software tools (mathematical models) for evaluation of energy use of several selected technologies in the stage of product/process design;
- to add the developed software tools to the ICT design packages, already be-

ing applied for these technologies. Changing their parameters will enable the designer to obtain different values of energy use and life cycle cost, and select an economically optimal configuration of product/process.

The success of the *DEMI* project is expected to encourage various European manufacturers to follow the DEMI project and finance the development of their energy use analysis and simulation tools to improve their product/process design.

During the first year of implementation, project's concept was elaborated, the block architecture and functionalities of energy simulator (mathematical model) were defined together with links to other ICT components, which are being collaboratively developed by the foreign *DEMI* partners.

The research results of 2010 were presented in 4 international and 1 Lithuanian conferences.

> Dr. Virginijus Radziukynas Head of the Laboratory of Systems Control and Automation Tel. +370 37 401 943 E-mail: virginijus@mail.lei.lt

LABORATORY OF HYDROLOGY

Main research areas of the Laboratory:

- analysis of climate change and river run-off variation;
- investigations of power plants impact on water environment;
- collection of data of Lithuanian water bodies (rivers, ponds, the Curonian Lagoon, and the Baltic Sea).

OBJECTS AND TASKS OF RESEARCH

The most significant research objects of the Laboratory are Lithuanian rivers and lakes, Kaunas Reservoir, the Curonian Lagoon and the Baltic Sea. The condition of these water bodies is determined by extreme natural phenomena such as global warming, storms, floods and economic activity (energy production, navigation, ponds). Therefore, the assessment of the state of water bodies is one of the most important tasks of research.

Applying the hydrographic and hydrometeorological database and the newest modelling systems MIKE 21 and RiverWare, the Laboratory solves the following tasks:

- environmental impact assessment of anthropogenic activities on water bodies and justification of environmental protection measures;
- hazard and risk analysis of hydrotechnical constructions;
- investigation of quays interaction with water flow and selection of optimal

constructions;

- determination of environmental conditions using water bodies for different objectives;
- estimation of mixing and dispersion of sewage under critical conditions in water bodies;
- exploitation of sea harbours and waterways, maintaining the guaranteed nautical depth;
- sensitivity and uncertainty analysis of two-dimensional hydrodynamic model parameters.

The Laboratory of Hydrology carries out fundamental and applied research in the field of environmental engineering employing numerous hydrographic, hydrologic, morphologic, meteorological and other data, collected by the Laboratory of Hydrology, and modelling system MIKE 21 developed by Danish Hydraulic Institute for modelling the phenomena in water bodies. This enables solving the most important environmental issues in the assessment of the anthropogenic activities impact on environment and justifying environmental protection measures.

In the recent decade, the Laboratory has been implementing work related to the assessment of the impact of climate change on water resources. In 2010, a state funded scientific research project Research of Changes of Hydrological Regime in the Curonian Lagoon due to Environmental and Anthropogenic Factors (supervisor Prof. B.Gailiušis) was initiated. The hydrological regime and water quality of the Curonian Lagoon, which is protected by NATURA 2000, has a great influence on the condition of the Baltic Sea. Water regime of the Lagoon depends on the meteorological conditions (air temperature and precipitation), rivers flowing into the Lagoon, hydrological regime and the changed permeability of the Klaipeda Strait due to the dredging of Klaipeda port. Its development could be also carried out by expanding the port in the northern part of the Lagoon, but in order to perform such activity, first of all, it is necessary to find out the possible changes of water balance in the Lagoon in respect of climate change and anthropogenic factors. On the basis of hydrologic and meteorological database (data is used



Annual variation of river inflow into the Curonian Lagoon during 1961–1972 and 1996–2007

as the material of the research), which has been compiled for many years, the water balance of the Curonian Lagoon of 1961– 2007 was estimated. The changes of total river inflow and the exchange cycle of precipitation, evaporation and water in the Klaipeda Strait during the analysed period of 1961–2007 were investigated applying the methods of statistical analysis.

In 2010 the Laboratory researchers, together with the Laboratory of Nuclear Installation Safety and Laboratory of Energy Systems Research, were implementing a state subsidy funded scientific research project *Analysis of Processes in Complex Technical, Natural and Social Systems Applying Best Estimate Methodology* (supervisor Dr. Habil. A. Kaliatka). Calibration of the Merkys (the Nemunas watershed) hydrological model was performed by using different methods of sensitivity and uncertainty analysis.

RESEARCH OF RIVER INFLOW VARIATION

The Laboratory was implementing the work related to the assessment of global warming effects. The results of the scientific research *Impact of Climate Change on the Condition of Lithuanian Water Resources and Hydroenergy Sector* (2007– 2009) show oncoming significant changes in distribution of seasonal river run-off. The Nemunas run-off formation model was developed using up-to-date software HBV, developed by Swedish scientists. As the processes of global warming take place, the Nemunas run-off is redistributed among the seasons. The analysis of the 21st century air temperature, run-off and precipitation forecast in the Nemunas watershed down to Nemajūnai suggests that since air temperature is constantly rising and amount of precipitation is almost unchanging, evaporation from the watershed will inevitably increase. Average annual run-off will decline by 26%, in winter river run-off will increase by 20%, whereas spring floods will decline by 45% and start earlier, in winter. Having analysed global warming change models and the impact of gas emission scenarios on run-off, it was determined that emission scenarios have

a much greater impact on run-off change than global climate models.

Last year, the European hydrologists celebrated the 200th anniversary of hydrological research. The first water measuring stations were established in Europe in the beginning of the 19th century; however, only a small amount of these stations are still operating. An international symposium Impact of Climate Change on Water Resources – 200 Years for Hydrology in Europe was held in National Institute of Hydrology, Germany. Since long-term data series of water run-off are especially relevant in the analysis of river run-off variation, a paper on the longest observation data series in Lithuania was presented in the symposium. The data for the paper was obtained from the Nemunas water mea-



Long-term variation of the Nemunas run-off near Smalininkai in 1812–2008



Long-term variation of anomalies of annual temperatures and run-off data in the hydrological region of Western Lithuania

suring station near Smalininkai, which is still in operation. The 200th anniversary of this station is going to be celebrated in 2011. The hydrologists of LEI, M. Lasinskas, J. Jablonskis, B. Gailiušis and others have been investigating the tendencies of the Nemunas and other rivers run-off variation using the long-term data of hydrometric research of rivers for many years.

INTERNATIONAL COOPERATION

In 2006–2010 the researchers of the Laboratory actively participated in the scientific project *Climate and Energy Systems* carried out together with Nordic countries. Researchers from Norway, Sweden, Finland, Denmark, Iceland, Lithuania, Latvia and Estonia took part in this project. The main purpose of this research work was to assess the impact of climate change on energy sector. Scientists of the Laboratory participated in the activities of the research group of the statistical analysis of climate and river run-off.

In recent decades, a more noticeable impact of climate change on the water resources has been observed in both Nordic and Baltic countries. Since scientists from different countries employ different methods for the analysis of river run-off variation, the common regularities of larger regions are difficult to define.

In the scope of this project, a hydrological regionalisation of the Baltic countries was carried out and 10 regions were distinguished. In Lithuania the Western, Central and South-eastern hydrological regions were investigated by calculating air temperatures and data of precipitation and river run-off as well as estimating the annual and seasonal anomalies (deviation from the climate averages) of these characteristics. The effect caused by air temperature and precipitation on river run-off during different periods of the year was determined in the whole territory of the Baltic countries. Thus, the greatest positive anomalies of temperature and run-off were recorded in winter. As the winters have become warmer in the recent decades, they cause greater river floods, i.e. the spring river floods emerge earlier. Moreover, the amount of temperature anomalies has recently increased significantly in all Baltic countries (up to 1 °C if comparing 1991-2007 period to the climate norm (the average of 1961–1990)). Due to the growing anomalies, the amount of changes in river run-off declined in all hydrological regions and the annual runoff is distributed more evenly.

Together with scientists from 23 European countries, the researchers of the

Laboratory participate in the COST ES0901 project *European Procedures for Flood Frequency Estimation* (2009–2013). They perform activities in two work groups, namely *Evaluation of statistical methods for flood frequency estimation* and *Impact of environmental change on flood frequency estimates*. Last year, the common methodology of the work in progress was discussed in two meetings of COST project participants at the same time evaluating the tendencies of flood variation in Europe.

European Network of Freshwater Research Organisations EurAqua



In 2008, LEI Laboratory of Hydrology was accepted into EurAqua organization, which consists of the most influential scientific institutions of 24 European countries performing research of water resources. The main objectives of EurAqua are the following:

 To participate in the formation of water research policy in the European Union;

- To formulate and propose the most significant and topical themes on water resources research, which could be included into FP projects;
- To form consortiums with EurAqua scientific institutions by preparing joint proposals for FP projects;
- To prepare scientific articles and technical reviews on problematic areas in European water resources research;
- To organise conferences on relevant topics (the impact of climate change on water resources, flood analysis and forecast in Europe, etc.)

The XXXV meeting of EurAqua members took place on 8–9 November 2010. The participants discussed the political aspects and further use of European water resources, and established topical issues in FP8 related to the most relevant issues of freshwater use and protection.

COOPERATION WITH STATE AND SCIENTIFIC INSTITUTIONS

The Laboratory of Hydrology closely cooperates with the Institute of Environmental Engineering of Kaunas University of Technology and have been publishing scientific journal Environmental Research, Engineering and Management since 1995. The researchers carry out complex environmental research together with the institutes of Ecology, Geology and Geography, and Botany of Nature Research Centre. Aiming at the development of up-to-date infrastructure for the common needs of Lithuanian sea sector scientific research and technological development, the Laboratory of Hydrology contributes to the activity of the association Baltijos Slėnis.

The primary and main objective of the Integrated Science, Studies and Business Centre – **Valley** *Baltijos Slėnis* – concerning Lithuanian sea sector development, is to unite theoretically separate institutions and departments of maritime science. The initiators for establishing the Valley are Klaipėda University, Institute of Geology and Geography, Institute of Ecology of Vilnius University, Institute of Botany, Kaunas University of Medicine, Lithuanian Energy Institute and maritime business companies. Two directions of scientific research and experimental development are planned, that is, sea environment and maritime technologies. In pursuance of integrating the diffuse national scientific potential, working in the field of maritime science, and effectively using the modern scientific research equipment and ship, a National Maritime Science and Technology Centre is going to be established.



MAJOR APPLIED RESEARCH WORKS

The Laboratory carries out applied research work on environment and prepares hydrotechnical construction projects according to agreements with enterprises and organizations:

- Under the agreement with Klaipėda State Seaport Authority, the projects on harbour navigation channel dredging and environmental impact assessment are being prepared;
- Under the agreement with JSC Lietuvos energija, the working instructions of Kaunas Hydroelectric Power Plant reservoir were revised;
- Under the agreement with the Environmental Protection Agency under the Ministry of Environment of the Republic of Lithuania, environmental recommendations for construction and exploitation of small-scale hydro power plants were prepared together with Lithuanian University of Agriculture.

MIKE 21 modelling system was applied for the evaluation of navigation conditions and the environmental impact of Klaipeda and Šventoji seaports development. The most important tasks are the navigation channel dredging, and building and reconstruction of harbours. Applying hydrodynamic model, the harbours and piers are planned in such position that their influence on flow regime would be minimal and would not cause bed and shore erosion at extreme hydro-meteorological conditions.

The Government of the Republic of Lithuania began the construction of Šventoji seaport in 1922. For many years the buildings of the port have been abandoned, but recently a decision has been taken to reconstruct this port and make it suitable for recreation. The first stage of port reconstruction involves the removal of seabed sediments. The work is performed sequentially on the grounds of the analysis of sea

Old Šventoji seaport



Flow structure in Šventoji seaport water territory at westerly 20 m/s wind: a – present conditions; b – changed conditions of water territory during the first stage of port reconstruction (the small port for yachts and boats)

flow structure and silt movement. Suitable conditions are established for small recreational boats and yachts to navigate in the sea and safely moor in the port.

While dredging the water territories of the ports, the excavated soil is dumped in the Baltic Sea. This requires knowledge about the speed of spread, direction and concentration of pollutants which are discharged during dumping. Such information is necessary to avoid the damage to physical, chemical and biological processes, spawn sites and places of recreation. The spread of hazardous materials from two places of the Baltic Sea water territory was modelled at various environmental conditions and concentrations of the materials in the dumping places.

The possibilities of MIKE 21 modelling system application for port development projects are considerable. The modelling results are beneficial for the evaluation of environmental impact and grounding the fact that the selected harbour construction options and waterway dredging will not influence the sensitive ecosystems of the Curonian Lagoon and the Baltic Sea. In 2010, the research results were published in 1 scientific article on the ISI list and 2 articles on the database list approved by the Research Council of Lithuania. The researchers of the Laboratory actively participated in international conferences where they presented 6 papers.

Prof. Dr. Habil. Brunonas GAILIUŠIS Head of the Laboratory of Hydrology Tel.: +370 37 401961 E-mail: hydro@mail.lei.lt



YOUNG SCIENTISTS ASSOCIATION

LEI Young Scientists Association (YSA), an independent public organization of PhD Candidates and young researchers, carries out active work. Under the initiative of the association, the following events are organized annually:

- International Conference of Young Scientists on ENergy Issues CYSENI;
- Open Day at LEI;
- Participation in KTU Career Days organized by Kaunas University of Technology.

In 2010 YSA actively participated in organizing the FP7 project **Researchers' Night: You could be a researcher too** for the first time in the Institute.

CYSENI 2010

On 27–28 May 2010, YSA organized the 7th International Conference of PhD Candidates and Young Scientists **CYSENI** 2010 (Jaunoji energetika 2010). The main objective of the Conference was to promote the scientific activity and cooperation of young researchers and doctoral students as well as to develop the skills of research result presentation. The young scientists were given a possibility to meet their colleagues, become acquainted with their scientific activity and to exchange ideas and



Organizational Committee of the Conference CYSENI 2010

contacts that may appear useful in initiating joint projects and developing the research.

74 scientific articles were submitted to the Conference. Papers were presented by 65 young researchers from various Lithuanian and foreign institutions on the following energy-related topics:

- Hydrogen and fuel cells;
- Renewable energy sources and their use;
- Smart energy networks;
- Energy efficiency and savings;
- Knowledge for energy policy making;
- Investigations in the fields of thermal physics, fluid mechanics and metrology;
- Nanosciences and nanotechnologies, investigations on multifunction materials;
- Investigations of combustion and plasma processes;
- Global change and ecosystems;
- Fusion energy;



CYSENI 2010. Delegation of young researchers from A. V. Luikov Heat&Mass Transfer Institute of NAS of Belarus

Nuclear fission and radiation protection.

Reviewers of doctoral students' articles, experts of the technological sciences also participated in the Conference. In order to improve the public communication skills of doctoral students and young scientists, the participants of the Conference and the representatives of the Board of LEI Young Scientists' Association acted as chairpersons.

One of the important achievements of the Conference is the summary of the research carried out by the participants, preparation of high-quality articles (each article read by 2 reviewers) and their presentation to the scientific society. The articles and their annotations submitted by the participants of the Conference are included into the electronic media (a CD) that will be available at the main science centres and libraries.

The authors of the best articles and presentations were announced as every year. They were given diplomas by LEI Director Eugenijus Ušpuras and LEI YSA chairperson Diana Meilutytė-Baranauskienė. Points are accumulated from official, anonymous, young and presentation reviewers.

Thus, in the group of master students and the first and second year PhD Candidates the best authors were:

- 1. T. Kaliatka (LEI, Lithuania);
- 2. A. Kontautas (LEI, Lithuania);
- E. Karber (Tallinn University of Technology, Estonia)/ A. Shutka (Riga Technical University, Latvia).

In the group of third and fourth year doctoral students and young researchers the best authors were:

- 1. L. Užšilaitytė (Vilnius Gediminas Technical University, Lithuania);
- 2. N. Muellner (Pisa University, Italy);
- M. Malinauskas (Vilnius University, Lithuania).

OPEN DAY AT LEI

Open Day at LEI provides an exceptional possibility to receive more information about the activity, scientific research and experiments carried out by the Institute, listen to the presentations and talk to the representatives of the Laboratories, and, of course, ask questions.

KTU CAREER DAYS 2010

On 17 March, the traditional event, *KTU Career Days 2010* took place in Kaunas



Open Day at LEI. Visitors next to the tire gasification reactor



Visitors of **KTU Career Days** next to the LEI stand

University of Technology and the representatives of LEI also participated in it. *KTU Career Centre* and *KTU Student Union* have organized this event for seven years. Each year *Career Days* attracts attention and is visited by many students from thirteen different faculties of the university, professors, the representatives of the largest Lithuanian enterprises, foreign guests and several thousands of high-school graduates. It is referred to as "a market of businesses and students" which aims at finding out the needs of both sides and exchanging contacts.

The representatives of LEI and members of YSA participated in the event in order to present the Institute and give information to the students about the scientific career possibilities. LEI stand was mostly visited by the students of the following fields: Electrical Power Engineering Technologies, Applied Physics, Applied Mathematics, Electrical Engineering, Chemical Technology and Engineering and Thermal Engineering.

The Institute participated in *KTU Career Days* for the seventh time and it proved as an effective means for the Institute in searching for young perspective employees and for students seeking the possibilities of studying and employment. After *Career Days 2010*, 4 KTU students were admitted to doctoral studies, 3 were employed and 2 worked for practice.

RESEARCHERS' NIGHT 2010

Researchers' Night is a traditional scientific event which takes place in the EU countries annually during the last weekend of September. Its aim is to provide information to the society about the scientists, give a clear, understandable and appealing explanation of their scientific research and its benefits, and to show that they also have time for leisure and entertainment. In 2010, the citizens of 30 European countries visited scientific laboratories and observatories, watched scientific experiments or even tried to perform them, and communicated with scientists. *Researchers' Night* was organized for the sixth



Dr. Regina Kalpokaitė-Dičkuvienė explaining about research on pipes



Visitors watching an experiment with plasmatron







Moment from the IAEA seminar

time in Lithuania: the events in Vilnius, Kaunas, Molėtai and elsewhere were coordinated by the Young Scientists Association of Lithuania.

On 24 August at 6 p.m. the Institute, participating in the project for the first time, welcomed the society and offered a possibility to explore the scientific world filled with innovations. Although the scientists of various ages participated in *Researchers' Night*, the event was initiated by the young, i.e. Young Scientists Association.

The principal idea of all events organized in LEI is bringing science near people, for this reason the guests were enrolled into the activities rather than left as passive observers. Energy issues were not the only ones discussed: the events were aimed at people of various ages and interests so that everyone could learn something new and interesting. Thus, the variety of events and the possibility not only to see, but also participate is what distinguishes *Researchers' Night* from the traditional excursions organized in LEI.

The visitors were offered a great deal to see during *Researchers' Night*. Next to the entrance into LEI, a *European Corner* was arranged providing information about the EU research programmes and international projects carried out by the Institute. The participants were especially interested in getting a *European Researcher's Passport* with their thermovisual photographs that show the warmer and colder areas of the body in different colours. Since the beginning of the night, excursions to the laboratories of the Institute were organized. The employees presented their work and showed real experiments to the participants.

Moreover, the lectures, which took place in LEI hall, encompassed a very wide field of topics: in three hours the visitors could find out about tracking, drug development, nuclear energy and science philosophy. Similarly as in the other events of *Researchers' Night*, not only sharing knowledge, but also lively discussions of all participants, the hosts and guests were encouraged.

Finally, the teams of scientists and representatives of the general public competed in a *Smarty Quiz*. Since its questions demanded intelligence, the most intriguing question was whether the scientists are really very clever. The team of the representatives of the general public won the quiz by one point and proved that everyone could become a scientist. Next year, the Institute hopes to attract even more visitors to this event.

IAEA SEMINAR

On 30 August – 1 September 2010, a seminar was organized in LEI by IAEA in accordance with the regional technical co-

operation project RER/0/031 Strengthening Sustainability of Nuclear Research and Development Institutes in the Modern Science and Technology Environment.

The main objective of the seminar, organized in co-operation with the Government of the Republic of Lithuania, was to explore the possibilities of employing and retaining young specialists in the field of nuclear energy. The seminar was attended by the representatives of 20 countries: Lithuania, the USA, France, Ukraine, Croatia, Montenegro, Italy, Austria, Albania, Armenia, Kazakhstan, Poland, Slovenia, Serbia, Tajikistan, Turkey, Romania, Bulgaria, Georgia, and Russia. The presentations on the current situation in the represented institution were given by the Director of LEI Prof. Dr. Habil. Eugenijus Ušpuras and Dr. Diana Meilutytė-Barauskienė, Dr. Ayman Hawari (USA), Dr. Igor Kadenko (Ukraine), Dr. Stepko Fazinic (Croatia), Dr. Slobodan Jovanovich (Montenegro), Dr. Adrian Florinel Bucsa (Romania) and M. Edouard Hourcade (France).

> Young Scientists Association of the Lithuanian Energy Institute Breslaujos str. 3 LT-44403 Kaunas, Lithuania http://jms.lei.lt, www.cyseni.com

FINANCIAL HIGHLIGHTS

The financial sources of the Institute consist of:

- State Budget subsidies for the implementation of the programmes approved by the Republic of Lithuania;
- Financing received from Lithuanian, foreign and international funds and organizations;
- Financing for scientific research from competitions in programmes;
- Financing received from Lithuanian and foreign enterprises and organizations for contract work, realisation of products and services;
- Funds received for participation in the international research programmes;
- IFunds received as support under the Law on Charity and Sponsorship of the Republic of Lithuania;
- Subsidies received from enterprises and associations for participation in joint activities and training of specialists;
- Support of the EU Structural Funds (SF).

Structure of Income and Total Expenses (thous. LTL)

	2006	2007	2008	2009	2010
Income:					
State Budget Subsidies	6703.9	7902.1	9917.2	9152.5	7896.0
Contracts	10208.6	9439.1	8370.0	9646.4	9356.0
SF Support	225.1	1048.0	8467.0	772.9	5403.6
Other Income	1320.4	1356.2	1136.9	1155.3	99.7
Total:	18458.0	19745.6	27891.1	20727.1	22755.3
Expenses:					
Salaries (soc. ins. incl.)	10709.1	12919.9	15650.0	13722.0	13843.0
Operating Expenses	4696.6	4881.8	5059.0	3749.0	2432.3
Capital Funds	1185.5	2010.4	9757.3	392.0	6122.0
Total:	16591.2	19812.1	30466.3	17863.0	22397.3
Long-term Projects Assets	4744.8	4678.1	2102.9	4967.0	5325.0



Financial Reports may be found on http://www.lei.lt (About LEI: Financial Reports).

Variation of financial sources, thous. LTL



- MITA
 – Agency for Science, Innovation and Technology;

 ŠMM
 – Ministry of Education and Science of Republic
- of Lithuania; VMT – State Metrology Service;
- VATESI State Nuclear Power Safety Inspectorate.

Structure of contracts, services and support to the infrastructure in 2010



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MAIN EVENTS IN 2010

28 January.

Visit of the representatives from Ministry of Education and Science



12 February. Signing project

Signing project funding contract of Integrated Science, Studies and Business Valley SANTAKA



4 March.

Visit of Marjella Wingelaar (NL EVD Internationaal- Agentschap NL, the Netherlands)



8 March.

Signing a co-operation agreement among Association of Local Authorities in Lithuania, Lithuanian District Heating Association, Lithuanian Electricity Association, Lithuanian Biomass Energy Association, Lithuanian Energy Consultants Association, Lithuanian Association of Electricity Producers, Lithuanian Biogas Association and Lithuanian Energy Institute

17 March.

LEI accepted to the Lithuanian Confederation of Industrialists

17 March.

Participation KTU Career Days



22 March.

Election of Institute's Scientific Council



19–23 April.

IAEA Regional Workshop on Framework and Techniques for PSA Applications and Risk Informed Decision Making



29 April.

Open Day at LEI



18 May. Meeting of the RES-H Policy project participants



27-28 May.

7th International Conference of PhD Candidates and Young Scientists on Energy Issues 2010 - **CYSENI 2010**



25–28 August. 11th European Conference Energy Economy, Policies and Supply Security: Surviving the Global Economic Crisis of International Association for Energy Economics



30 August –1 September.

IAEA seminar Young Specialists in Nuclear Research and Development Institutions



15 September.

Institute accepted into the Sustainable Nuclear Energy Technology Platform (SNETP)

24 September.

Researchers' Night 2010





1 October.

Visit of Taiwan delegation



21 October.

Meeting of the Energy Committee of Lithuanian Confederation of Industrial-



16 November.

Institute became a member of Lithuanian Energy Consultants Association (LEKA)

19–24 November.

Defence of state subsidy-funded project reports completed in 2010



30 November. Seminar *The Need of Alternative Energy Sources in Lithuania*



8 December.

Seminar Wind Energy: Developmental Obstacles in Lithuania



10 December. Consultative-national seminar of RES-H Policy and EUBIONET III projects



3 Breslaujos str. LT-44403 Kaunas Lithuania phone: +370 37 351403 fax: +370 37 351271 http://www.lei.lt

