LITHUANIAN ENERGY INSTITUTE



ANNUAL REPORT

LITHUANIAN ENERGY INSTITUTE in 2011

MISSION OF THE INSTITUTE

Perform research and develop innovative technologies in the fields of energy engineering, thermal engineering, measurement engineering, material science and economics, in conducting fundamental and applied research, participating in studies' processes, applying the results of applied scientific research results to industry and business, as well as providing consultations to state, public and private institutions/enterprises on the issues related to Lithuanian sustainable energy development. Actively participate with Lithuanian universities and other higher education schools in preparing specialists for Lithuanian science and economy.

THE OBJECTIVES OF THE INSTITUTE:

- perform permanent fundamental and applied scientific research at international level, experimental development activities, which is a must for sustainable development of Lithuanian energy and other Lithuanian economy branches and for the integration to the European energy systems and European research area.
- while cooperating with business, gov-



ernmental and public subjects, transfer scientific knowledge to technically and commercially beneficial processes and facilities, ensuring the development of innovative energy technologies, cost-effectiveness and safety of energy objects and systems, efficient use of energy resources, reduction of environmental pollution and deceleration of global warming;

- provide accessible state-of-the-art scientific information to the society, promote the Lithuanian economy development based on innovations and knowledge;
- actively participate in the EU program-

mes and international projects, boost co-operation with alike world science research centres.

SHORT-TERM STRATEGIC OBJECTIVES

- 1. The establishment of the National open access scientific center for future energy technologies.
- 2. The development of research science, education and business co-operation.
- To train top quality specialists able to deal with energy issues;
- 4. To maintain and develop the experimental basis.

SCIENTIFIC RESEARCH ACTIVITY OF THE INSTITUTE

- 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 Ignalina Nuclear Power Plant;
- V. Modelling and control of energy systems; energy economy.



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 (LMBA), Confederation of Lithuanian Industrialists (LPK), Lithuanian Thermotechnical Engineers Association (LIŠTIA), National Space Association of Lithuania, Lithuanian Gas Association (DŪA), Association for Energy Economics, Building Product Testing Laboratory Association (SPBL), Hydrogen Energy Association, European Technical Support Organisations Network (ETSON), European Network of Freshwater Research Organisations (EurAqua), The European Association of National Metrology Institutes (EURAMET), Euro-Asian cooperation of national metrological institutions (COOMET), European Nuclear Safety Training and Tutoring Institute (ENSTTI), International Energy Agency Hydrogen Imple-



After signing the cooperation agreement: LEI Director, Prof. Dr. Habil. Eugenijus Ušpuras and Director General Dr. Rimantas Bakas of SC **Kauno energija**



Distribution of researchers according to the research directions

mentation Agreement (IEA HIA), New European Research Grouping on Fuel Cells and Hydrogen (N.ERGHY), and European Sustainable Energy Innovation Alliance (ESEIA).

The Institute also participates in the activities of technological platforms of Hydrogen and fuel cells (H2/FC), Future production, National heat energy and national biomass and biofuel production and employment. It should be emphasized that the Institute joined two international nuclear technological platforms: Sustainable Nuclear Energy Technology Platform **(SNETP)** and Implementing Geological Disposal of Radioactive Waste Technology Platform **(IGD-TP)**.

In 2011 there were plenty of significant events and visits at the Institute. In the beginning of the year the agreement was signed with SC *Kauno energija* regarding co-operation to conduct projects of National research programme *Future energy*, devoted for the development of energy system reliability and energy safety analysis methodology.

The developed methodology will enable to estimate reliability of heat supply network, which is defined by the intensity of failures, duration of their repair, unsupplied heat amount to consumers, number of consumers that haven't received heat and other parameters.

In the beginning of February the Institute was visited by the representatives of Science, Innovation and Technologies Agency. They were acquainted with the accomplishments of the Institute. The guests presented their foreseen activities. The Institute has significant accomplishments in the 7th Framework Programme: out of 40 submitted proposals 23 proposals had succeeded the evaluation threshold (this comprises 57.5% of the submitted proposals), whereas 15 projects are conducted or have been conducted (success rate - 37.5 %). This is a high success rate. Institute is the third institution in Lithuania in terms of the number of FP7 projects following two largest state's universities. It should be emphasized that the researchers of the Institute also implement projects of Intelligent Energy-Europe, The Baltic Sea Region 2007-2013, South Baltic Cross-border Cooperation Programme 2007-2013, IAEA, COST, and EUREKA.

In February the international conference *Science, Business and Studies Integration for Advancement* organized by the Santaka valley took place. The synergy perspectives of scientists, business and academic institutions that enable more efficiently apply scientific accomplishments in developing and implementing new technologies and fostering the sustainable development of knowledge society were discussed in the conference.



NASA representatives visited Center for Hydrogen Energy Technologies

In March the career days of Kaunas University of Technology, where LEI researchers presented to students the career possibilities, took place. LEI researchers also participated in schoolchildren competition **EnIdéja 2011**, organized by Vytautas Magnus University, where students' ideas were valuated by LEI representatives.

Another memorable annual event – the 8th international conference of PhD students and young researchers *International Conference of Young Scientists on Energy Issues 2011 (CYSENI 2011*).

In September the representatives from the Energy Security Centre under the Min-

istry of Foreign Affairs of the Republic of Lithuania visited the Institute. They got acquainted with LEI activities, accomplishments and future perspectives.

In October NASA representatives paid visit to LEI and got acquainted with LEI activities, conducted research and possible common cooperation projects.

A rather popular becomes the annual event – the 7th Framework Programme project **The Night of Researchers**. This event is oriented towards schoolchildren of higher classes and students, however, the organized quizzes and competitions involve younger children/probably future researchers as well.

VALLEY SANTAKA

Lithuanian Energy Institute together with Kaunas University of Technology and Lithuanian University of Health Sciences in 2013 foresee to establish an integrated science, studies and business center (valley) *Santaka*. The aim of the project – employing a well-developed infrastructure and best human recourses to generate new knowledge, technologies and products in the fields chemistry, mechatronics, energy and ICT, and transfer all this to business units, ensuring sustainable development of Lithuanian enterprises and establish-





The promotional video of the valley **Santaka** was also filmed in the Laboratory of Combustion Processes

ment of closely operating innovative small and medium enterprises.

The Institute implements the **Santaka valley** project, the objective of which is to establish a National open access center for future energy technologies, purchasing the most essential experimental equipment and numerical analysis software. The established center would become the European level scientific research and experimental development center, co-operating with business, education and science institutions, conducting fundamental and applied scientific research.

In 2011 **Santaka valley** laboratories were visited by the students, Lithuanian

Confederation of Industrialists and participants of international conference Material Engineering 2011 from Latvia and Estonia, as well as a representative from the Italian National Council of Research. Thus, we aim at wider scale and more comprehensively inform the society as well as potential industrial partners and colleagues in other countries on the conducted Santaka valey project and the possibilities it provides. 22 million Litas are foreseen in the project budget for purchasing equipment, whereas 500 thousand Litas to manage and conduct the project. Financing of the project comprises up to 100% of relevant financed project expenses. The



project is to be completed on the 31st of January 2013.

STATE FUNDED PROJECTS COMPLETED

15 state funded projects were implemented and 5 of them had been completed and defended in 2011.

Investigation of Lithuanian energy security (Project leader Dr. Habil. J. Augutis).

- In the report of the completed project:
- assessment methodology of threats of energy system and their evoked disturbances mathematical model was developed;
- mathematical-economical model of disturbed energy system was developed;
- probabilistic model of disturbed energy system, estimating security barriers of a system, was developed;
- energy security assessment methodology based on indicator and multicriterion analysis was developed.

Experimental and numerical investigation of condensed two-phase flow (Project leader Dr. M. Šeporaitis).

During investigation the following was determined:

- after conducting a numerical investigation, thermal-hydraulic system model was developed, where water circulates due to cyclically occurring condensation implosions;
- experimentally measured pressure drop results revealed that condensation reduces interphase surface stability;
- measurements of transversal water temperature profiles conducted by infrared camera revealed that direct impact of interphase shear reaches 3 mm depth below free surface of water;

 measured and simulated steam velocity profiles revealed that more intense condensation moves velocity maximum toward condensation surface and narrows the hydrodynamic boundary layer.

The Research of Wind Energy Prediction and the Developmental Possibilities of Biomass Resources Use in Energetics (Project leader Dr. Habil. V. Katinas).

The following was determined:

- analysis of the capacity factor variation has shown that large wind farms exploit approximately 26.6 % of installed power at Lithuanian seacoast region. Capacity factor varies in different periods and mostly depends on wind conditions, which are predetermined by geographical location and technical characteristics of wind power plants;
- short-term wind speed and WT power prediction model was developed. The analysis of HIRLAM data application on the short-term wind speed prediction shows that the impact of linear regression correction is most significant for the accuracy of predictions;
- After applying the wind speed prediction for forecasting the Seda wind turbines' (WT) capacity variation, it was determined that the average absolute error for E-40 WT amounted to 9.7% of the WT installed capacity, whereas for E-48 WT 9.9%. Such accuracy is analogous to the accuracy of other WPP prediction models and enables to state that the created model may be employed to other wind farms;
- in Lithuanian private forests 0.7–0.8 mio. m³ of cutting waste may be collected and used for fuel, whereas in adler groves, the areas of which comprise 130 thousands ha (6.4% of the whole forest area), 0.4–0.5 mio. m³ of wood fuel may be prepared annually. While increasing solid biomass production it is a must to solve the issues related to cutting waste collection, storage and transportation, to reconstruct traditional boiler-houses



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Variation of publication number (authors' contribution evaluated)

into the combined cycle ones, to make use of pellets and straw in private agricultural farms.

The Development of New Energy Production Technologies in Lithuania and the Study of Energy Consumption Efficiency Increasing Possibilities in Public Buildings (Project leader Dr. R. Škėma).

The following was revealed:

- while solving the task of energy knowledge integration into current school educational programs, the investigation on energy knowledge of schoolchildren from 16 Kaunas high-schools was carried out. The investigation of energy knowledge in chosen highschools revealed that school children's knowledge on energy, energy efficiency, renewable energy sources is insufficient, thus, there is a must to evaluate the importance and necessity of energy knowledge integration into education programs of highschools;
- the packages of *Active Learning* on economical energy usage were developed and tested during training process. Monitoring data on energy consumption in chosen high-schools were collected and estimated, research results of specific energy consumption of high-schools were pro-

vided and they were analysed;

the average specific energy consumption of the determined period of the high-schools participating in the Active Learning activity varied within the limits 3.5-7.0 kWh/m². The average value of specific energy consumption of these high-schools comprised approximately 4.8 kWh/m², and was 0.3 kWh/m² higher than the average weekly specific consumption of the other national high-schools, providing their data on website www.sustain.no and participating in the Active Learning activity. The highschools with the biggest energy consumption were determined, where reasons for such extensive consumption and means for reducing energy consumption have to be analysed primarily.

Identification and Assessment of Prevailing Factors Determining the Synthesis of Inorganic Material Oxides Fibre in Plasma Ambient (Project leader Dr. V. Valinčius).

The following was revealed:

 using plasma process similarity theory, the operational characteristics of plasma generator, developed for this project, were investigated applying experimental methods; it was deter-



Number of papers in scientific conferences

mined that voltage-current characteristics of plasma generator are dropping. The developed device corresponds to the requirements of air and nitrogen plasma source and is confirmed to be relevant in conducting a process in atmospheric pressure plasma ambient;

 the temperature of internal walls of the developed and tested ZrO futerated plasma-chemical reactor, designed for processing hard melting powdery materials, stabilize within 15 minutes. The downfall of futerated plasmachemical reactor's wall along the flow axis is related to intensive heat transfer process and depends on plasma forming gas flow rate. When increasing the gas flow rate, the temperature of the reactor walls falls.



A unique product **Streamline fuel oil** *injector caps* **Y-3000.1** developed at LEI was awarded the golden medal at competition Lithuanian product of the year 2011 organized by the Lithuanian confederation of industrialists

following the performed research, the synthesis process of ceramic fibre was significantly improved, a new specific experimental device with a direct current plasmatron was developed with the objective to form a fiber from a wide range of materials. Electric, thermal, and operational characteristics of developed plasma system were determined, the experimental fibre formation process in DC facility was conducted, its output was increased, and the properties were improved.

INTERNATIONAL PROJECTS

In 2011 **27** international programme projects were conducted, out of which **9** projects are of 7th Framework Programme:

- *European Fusion Development Agreement* (EURATOM-LEI association).
 Lithuanian representative Dr. Habil.
 E. Ušpuras.
- Network of Excellence for a Sustainable Integration of European Research on Severe Accident Phenomenology, SARNET2. LEI representative – Dr. Habil. A. Kaliatka.
- MATerials TEsting and Rules (MAT-TER). LEI representative – Dr. G. Dundulis.

- Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste, CARBOWASTE. LEI representative – Dr. Habil. P. Poškas.
- Fate of Repository Gases, FORGE.
 LEI representative Dr. Habil. P. Poškas.
- New Member States Linking for an Advanced Cohesion in Euratom Research, NEWLANCER. LEI representative – Dr. A. Šmaižys.
- Nanotechnology Enhanced Extruded Fibre Reinforced Foam Cement Based Environmentally Friendly Sandwich Material for Building Applications, FIBCEM. LEI representative – Dr. J. Česnienė.
- Product and Process Design for Aml Supported Energy Efficient Manufacturing Installations (DEMI). LEI representative – Dr. R. Škėma.
- Researchers' Night 2011: why I became a researcher, LT-2011). LEI representative – Dr. D. Meilutytė-Barauskienė.

EUROPEAN SCIENTIFIC RESEARCH

In 2004–2011 LEI researchers have successfully implemented the following international program projects:

- the 5^{th} Framework Programme 6;
- the 6^{th} Framework Programme 14;
- the 7^{th} Framework Programme 13;
- Intelligent Energy Europe 27;
- International Atomic Energy Agency 9;
- Leonardo Da Vinci 1;
- INTERREG 3;
- COST 14;
- EUREKA–4;
- Nordic Energy Research Programme – 2;
- Baltic Sea Region Programme 2007– 2013 – 4.

DOCTORAL STUDIES

Lithuanian Energy Institute together with the universities prepare scientists in the following fields of PhD studies:

- Power and Thermal Engineering (Technological Sciences, 06T) together with Kaunas University of Technology;
- Environmental Engineering and Land Management (Technological Sciences, 04T) together with Kaunas University of Technology and Aleksandras Stulginskis University;
- Economics (Social Sciences, 04S) together with Kaunas University of Technology and Klaipëda University.

In 1992–2011, 75 (out of 84) PhD Candidates completed doctoral studies and 52 defended doctoral theses. Each year doctoral studies are joined by 23–28 PhD Candidates and 3–5 theses are defended.

In 2011 PhD theses were defended by the following three PhD Candidates:

 30 June. Asta NARKŪNIENĖ (Laboratory of Nuclear Engineering) defended her work *The Investigation of Radio-*



Dr. A. Narkūnienė

nuclide Release from the Hypothetical Repository for RBMK Spent Nuclear Fuel Disposal (Technological Sciences, Energetics and Power Engineering (06T);

 3 November. Agn
 é BERTAŠIEN
 é
 íLaboratory of Heat-Equipment Research and Testing) defended her work
 Investigation of Air Velocity Value Reproduction and Transfer in Flow Regime Change (Technological Sci-



Arrangement of PhD Candidates' according to science directions



Structure of PhD Candidates' number



Dr. A. Bertašienė

ences, Energetics and Power Engineering (06T);

8 December. Audrius ŠIMONIS (Laboratory of Nuclear Engineering) defended his work *Investigation of Personnel Exposure During Dismantling of Nuclear Facilities* (Technological Sciences, Energetics and Power Engineering (06T);

In 2011 Kaunas University of Technology granted the PhD Degree to junior research associate **Arūnas BALTUŠNIKAS** (Laboratory of Materials Research and Testing) for his work *Application of X-ray Diffraction Analysis Methods for the Investigation of Compound Systems Having Variable Mineral Structure* (Technological Sciences, Material Science (08T).



Rector of Kaunas University of Technology, prof. dr. habil. P. Baršauskas granted PhD degree diploma to A. Šimonis



During the farewell celebration of the Old Year E. Ušpuras, director of the Institute, granted the certificate of Honour to PhD Candidate Andrius Tamošiūnas for his significant achievements



Dr. A. Baltušnikas

Admission to doctoral studies takes place at the beginning of July, and in 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 advised 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*

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 and changes of velocity distribution and pressure gradients;
- research of accuracy and reliability of means and methods for reproduction and transfer of reference values 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;
- numerical and experimental research of combustion stages;
- 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 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 Ministry of Economy of Republic of Lithuania and State Metrology Service; the 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 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/.

IN 2011 THE PROVISION OF THE FOLLOWING APPLIED SERVICES WAS ESTABLISHED:

- services related to the conformity assessment of biofuel-fired appliances were notified under the Directive 89/106/EEC.
 Information on this was submitted to the European Commission, EU member countries and EFTA countries that have signed the EEA Agreement;
- services related to the conformity assessment of liquid (other than water) measurement systems were notified under F
 module of the Directive 2004/22/EEC;
- new measurement capabilities of national reference values (Table 1), submitted by EURAMET TC Flows, were analysed in
 order to introduce them to the databases of the BIPM.

Table 1. New measurement capabilities of national standards

Quantity	Measurement range	Extended uncertainty, ± %	Reference means, method
Air (gas) velocity	(0.0560) m/s	8.00.45	Laser and ultrasound velocity meters
Air (gas) volume/rate*	(0.0059700) m³/h	0.130.30	Piston prover, critical nozzles and base
Liquid (water) volume/rate	(0.01100) m³/h	0.0540.082	Veighing method without stopping the flow
Liquid (oil and its	(1150) m³/h	0.0600.065	<i>Volume method and weighing method by stopping the flow</i>
products) volume/rate**	(150) m³/h	0.0400.045	

* – possibility of practical application from 0.03 dm³/h

** – practical application possible to all liquids

RESULTS OF SCIENTIFIC RESEARCH

One of the most important scientific achievements is a comprehensive research on velocity measurement and conditions of reproduction and transfer of its values in broad velocity variation limits at variable flow regime. Its results were described by junior research associate A. Bertašienė in her dissertation *Research of Reproduction and Transfer of Air Velocity Values at Variable Flow Regime*, which was defended on 3 November 2011 (Fig. 1). Laser Doppler technique, ultrasound and differential pressure methods were applied in order to analyse and estimate the following:

> influence of inner structural changes of flow on velocity distribution regularities in transi

tional flow regime;

 dependence of the measurement parameters of the differential pressure devices on the type of separation phenomenon at upflowing of the device, whether it



Fig 1. Defence of the A.Bertašienė's dissertation



Fig 2. Comparison of various coefficients of various differential pressure devices at pre-critical up-flowing: A – standard device without the reproduction of flow separation; B – device with a amplifier and a S type (three-dimensional separation); C – device with a cylindrical head (two-dimensional separation); 1, 2 – solutions at the up-flowing of the sphere and cylinder respectively



Fig 3. Comparison of uncertainties of velocity value reproduction in different countries

is a three-dimensional (spatial) flow separation, or the two-dimensional-like separation (Fig. 2);

 set of factors that determine the differences in measurement results obtained in the national European laboratories and provide conditions for observing the compatibility.

The uncertainties of the velocity value reproduction achieved by the reference velocity measurement mean, laser Doppler anemometer, were very close to the values obtained by the leading national laboratories worldwide (Fig. 3). This proves the high-level of measurements achieved using the national standard.

A considerable progress was made in summarising the impact of liquid viscosity on the accuracy of positive displacement, mass and other types of meters in order to verify the use of the universal measurement method and travelling standards for measurements at operational conditions. The experiments in this area are carried out both in the laboratories and at operational conditions by testing various meters (Fig. 4).



Fig 4. Research on the mass (Coriolis) meter sensitivity for mechanical vibrations and stresses: 1 and 2 – tight connector in DN100 and 15 pipelines respectively; 3 – the same as in DN15, with additional mechanical tension; 4 and 5 – flexible connector in DN100 and 15 pipelines respectively

The research possibilities of biofuel combustion processes have significantly improved as almost all up-to-date equipment, provided in the plans of the valley **Santaka**, has been purchased aiming at the detailed analysis of fuel and combustion products and investigation of the gas flow structure by applying particle visualization method. So far the analysis of combustion process was mainly based on the estimation of the final parameters defining the process, such as coefficient of efficiency and emission to the environment. There was a great lack of data on the characteristics of physical-chemical processes taking place during the combustion of solid biofuel, especially taking into account that it encompasses several stages: gradual warm-up of fuel, drying of fuel, separation of volatile components and combustion. Each stage of combustion includes more interrelated processes which depend on the composition of fuel and its physical properties. The data is particularly necessary due to the importance of renewable energy sources, their variety and an even more complicated control of the combustion process. For this reason, it is crucial to analyse the dynamics of products resulting from the combustion process, obtain fundamental data necessary for the optimization of the process, and provide reasonable recommendations for achieving effective fuel combustion in low capacity solid fuel boilers and reduction of pollution.

Table 2. Possibilities of the new equipment in developing the research on the biofuel and recovered fuel combustion

Title of equipment	Purpose of equipment
Calorimeter for solid and liquid fuel IKA C5000	Determination of calorific value of solid and liquid fuel, including biofuel and recovered fuel. Determination of calorific value analysis of other calorific materials (e.g. sewage sludge, waste, etc.).
CHSN/O elemental analyser Flash 2000	Analysis of the main chemical elements C/H/N/S and O in the solid and liquid fuel, including biofuel and recovered fuel.
ICP-OES (Inductively coupled plasma emission spectrometer)	Analysis of the minor chemical elements in the solid and liquid fuel, including biofuel and recovered fuel.
TGA/GC/MS and DSC analytical equipment for estimating the concentration of ash and volatile fractions	Analysis of ash volatile fractions and its chemical composition in biofuel and recovered fuel. Analysis of physical state transformation of solid recovered fuel.
System of flue gas analyzers (CO, CO ₂ , NOx, SO ₂ , O ₂ , C _H concentrations)	Research of the solid and liquid fuel, and recovered fuel combustion processes. Tests of thermal equipment (boilers, grates, etc.), fired by solid and recovered fuel. Tests of thermal equipment (boilers, grates, etc.), fired by liquid and gas fuel.
<i>Two-dimensional flow visualisation system 2D PIV (Particle Image Velocimetry)</i>	Research of solid particles movement in liquid and gas flows, flow interaction with surfaces and up-flowed objects to increase the efficiency of control equipment and combustion processes, modelling the movement amount and heat transmission processes as well as analysing the inner flow structure.



Fig 5. ICP-OES (Inductively coupled plasma emission spectrometer) for research of biofuel and recovered fuel element composition



Fig 6. Fuel element analyser Flash 2000 for the analysis of main chemical elements C/H/N/S and O

MAIN APPLIED WORK OF THE LABORATORY:

- 1. The work under the annual agreement with the State Metrology Service was successfully carried out in the scope of the programme for the development and use of four national standards. In the end of 2011, new possibilities of the standards, even more closely comparable to the ones obtained by the leading national European laboratories, were presented (Table 1).
- 2. The Laboratory started its activity as a part of the open access scientific Renewable and Alternative Energy Centre. Aiming at the varied range of services for the Lithuanian

8 papers were prepared and presented in international conferences, 8 articles were published and 1 was submitted to the ISI-indexed journal.

manufacturers, the Laboratory performed all necessary procedures and became the notified body in the field of conformity assessment of heat appliances, fired by solid fuel, and liquid (other than water) measurements systems.



Fig 7. Students of Vilnius Gediminas Technical University and Kaunas schools in the Laboratory

- 3. Research and validation of the data remote reading and control system RIS (Fig. 8), produced by *SC Axis Industries*, were carried out. The system devices are ascribed to several levels:
 - water and heat meters, installed in the premises of consumers – 1st level;
 - intermediary meter data storage units -2^{nd} level;
 - signal converters 3rd level;
 - data storage unit or modem, transmitting data to the central server – 4th level;
 - central server for data collection, processing and storage.

To verify the full software protection of the 1st-level heat meters SKM-1M, SKU-01M, SKU-3, SKU-4 and SKS-3 from non-authorised impact, additional detailed research of software was performed in cooperation with the subcontractors, the scientists at Department of Control Technologies, Kaunas University of Technology, even though conventional testing procedures, determined by the European Standards and other legislation, do not provide for such investigation.

The analysis encompassed 22 device setups that ensure the transmission of meter data to the central server at null error,



Fig 8. Scheme of the data remote reading and control system RIS

synchronic reading of meter and server data, and recurrent enquiry control.

4. In 2011, under the agreement No. 106596/12-1270.11.11 with *SC Lietuvos dujos*, critical nozzle equipment (Fig. 9), located at Kaunas Laboratory of Central Calibration and Test Labora-

tory of *SC Lietuvos dujos*, was updated by installing a climatic chamber. Hence, technical possibility to carry out the verification and calibration of household gas meters (G1.6 – G10) with mechanical temperature correctors was ensured. Technical properties of the equipment:

- amount of meters up to the size of G6 verified at once 6 units.
- amount of meters up to the size of G10 verified at once 4 units.
- air in the meters is dry at all operational temperatures: dew point temperature is lower than air temperature;
- flow rate through the verified meters (0.016 ... 16) m³/h;
- operational pressure (0.9 ... 1.1) bar;
- air temperature in the verified meters ensured in the limit of (-30 ... + 50) °C;
- air temperature in the reference inflow of the critical nozzles (20 ± 2) °C;
- measurement uncertainty \pm 0.30 %.
- 5. Three intercomparisons among the total number of 20 Lithuanian laboratories in the field of water and gas flow rate and air velocity measurements were completed.
- 6. Incomes from the applied work completed in 2011 amounted to LTL 1.4 mln.

INTERNATIONAL CO-OPERATION OF THE LABORATORY

In 2011, the Laboratory completed the implementation of the international *Baltic Sea Region Bioenergy Promotion* project as a part of Baltic Sea Region INTERREG III B Neighbourhood Programme partially funded by the EU. The aim of the project was to strengthen a stable, competitive and territorially integrated development of the Baltic Sea region in the field of stable bioenergy usage. Due to its importance and the achieved results, the project was extended for two more years.

The researchers of the Laboratory also worked in cooperation with the Laboratory of Nuclear Installation Safety in order to join an international project related to the use of solar energy in low-capacity equipment and energy accumulation.

Activity in international organizations

Implementing national standard laboratory functions, the Laboratory participated in the activity of technical committees *Flows* of international organizations EURAMET and COOMET in 2011. Dr. G. Zygmantas was newly appointed to represent the Institute in these organizations.

To make a greater contribution to the conformity assessment activity, the researchers participated in the constitutive meeting of the Co-operation of Notified Bodies for European Measuring



Fig 9. General image of the updated equipment

Instruments (NoBoMet) in Paris. A decision was taken to join the activity of this new organization which aims at compatibility in the conformity assessment of products supplied to the European market.

International comparisons

New international comparisons were not organized in 2011; the results of previous comparisons under the EURAMET project No. 1050 and COOMET project No. 412/UA/07 were analysed and agreed upon. The velocity measurements results of the former project closely correspond to the results obtained by other national laboratories. However, the comparison of water volume and rate under the second project has not yet been finished because of the problems, faced by the organizers PTB (Germany) due to supplying measurement equipment to non-European national laboratories. Preliminary results of the Laboratory are positive in comparison to the results obtained by the organizers.

Moreover, an agreement with SP (Sweden) on bilateral comparisons in the field of water flow measurement in 2012 was concluded.

Co-operation in assurance of the quality management system

The year 2011 was the last when the Laboratory was directly accountable for the operation of the quality management system to the *EURAMET TC-Quality* by submission of annual reports in written form and presentation of recurrent reports on the organized *Quality* forums every five years. Thus, the Laboratory started the preparatory work for the new procedure based on bilateral exchange of experts and their assessment.

Dr. Habil. Antanas PEDIŠIUS

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LABORATORY of COMBUSTION PROCESSES

THE MAIN AREAS OF ACTIVITIES 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 production from organic fuel;
- research of thermal destruction 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 abatement.

RESEARCH SCOPE AND OBJECTIVES

The Laboratory activities deal with the problems of waste utilisation, technologies of renewable energy sources, hydrogen energy, fuel synthesis and saving programmes and environmental pollution reduction. The solution of these issues includes the experimental work in combustion and gasification of biofuel and highcalorie material, development of models and numerical simulations in the following areas:

> 1. research of catalytic thermal breakdown of tars produced during biomass gasification;

- development of heat recuperation and combustion equipment in order to substitute natural gas with low-calorie gas;
- adjustment of primary and secondary fuel and air streams in burners in order to reduce NO_x and CO concentration in flue gas;
- 4. simulation of thermal conversion of solid granular fuel.

Although the above-listed activities differ in their research objectives, they are united by the common motive, i.e. fuel gasification process, which is crucial for safe, environment-friendly and economic waste utilisation through incineration or utilisation of biofuel for energy production. These activities can be divided into two categories: disposal (utilisation) of solid or gaseous fuel types by combustion or thermal breakdown.

JET-TYPE HEAVY FUEL OIL ATOMIZER HEADS Y-3000.1

During the last decade, the Laboratory of Combustion Processes proposed a number of solutions for improving heavy fuel oil (HFO) combustion efficiency and reducing the environmentally hazardous emissions. As a result of applied research and experience in burner operations in various HFO boilers, a unique design of streaming HFO atomizer heads was developed: the streaming HFO atomizer heads Y-3000.1, based on more than 10 years of experience in applied research in the Laboratory, exploiting novel aerodynamic solutions, as a unified product for TGME-464 boilers, in response to requirements of the specific customer, SC Orlen Lithuania, to improve combustion of HFO in a TGME-464 boiler. The customer contacted the Laboratory of Combustion Pro-



Jet-type heavy-fuel-oil atomizer heads Y-3000.1 were awarded with a gold metal Lithuanian product of the year 2011

cesses in 2010 with a request for production and calibration of new type atomizers (32 pcs total). The demand for new atomizer heads arose because the properties of utilized liquid fuel changed, fuel viscosity diminished and ignition time shortened due to lower flash point; thus, fuel spraying process had to be adapted to the combustion of this type of fuel. For spraying of liquid fuel in a TGME-64 boiler, the Laboratory of Combustion Processes designed, produced and tested new type atomizers adapted to the existing fuel and steam supply equipment. Proper fuel combustion is achieved in case of complete chemical combustion, when only a small amount of CO (approximately 100 mg/nm³) and 100 mg/nm³ of soot particles remain in flue gas. Nitrogen and sulphur oxides are not desired, because they are the source of acid rains. Using the new atomizers, the combustion process can be adjusted for lower NO, output. After adjusting the peripheral and central air supply in the burner, the fuel supply is the second most important adjustment factor: as the liquid fuel is sprayed, the droplets of a certain size must be produced and distributed in accordance with the air streams. Appart from blowing gas by streams far into the depth of the firebox, there are more possibilities to spread liquid fuel in droplets throughout

the entire firebox. The atomizers for liquid fuel are produced with sets of many openings, producing the converging far-reaching streams. The power plant at SC "Orlen Lithuania" is fuelled by a specific type of HFO selected from the production. During the last several years of cooperation, two different cases related to fuel had to be considered: fuel with high asphaltene content and less viscous fuel containing more graphenes. Each type of fuel required specific equipment: in the first case, the sprayed streams were grouped in pairs in order to make the HFO droplets to travel far in the firebox, thereby meeting the emission requirements for nitrogen oxides. In the second case, the sprayed droplet sizes had to be reduced in order to enhance combustion near the burners and thereby meet the emission requirements for particles in exhaust gas. General operation of the presented product started by familiarization with combustion of the new fuel type in the power plant: flame distribution in the firebox, emissions of NO_x, CO and particles, further followed by theoretical calculations of possibilities to improve capabilities and production of new construction, and calibration at the Institute facility. Finally, experiments at the power plant were carried out and the operation regimes were drawn up. The emission requirements for NO,, CO

and solid particles were met, while maintaining the economical parameters of the boiler operations at the designed levels.

For the production of the streaming HFO atomizers heads Y-3000.1, Lithuanian Energy Institute was awarded a gold medal in the competition *The Lithuanian product* of the year 2011 organized by the Lithuanian Confederation of Industrialists, in the category *Machines and equipment*.



Research Council of Lithuania

RESEARCH OF COMPATIBILITY OF SIMULTANEOUS THERMAL DESTRUCTION OF BIOMASS AND CATALYTIC TAR REMOVAL

In the present-day world, gasification of biomass or various types of waste is considered one of the most promising ways to generate heat and electricity. In order to utilize gas produced by gasification in large-scale or micro-turbines, internal combustion engines for electricity generation, chemical reactors for production of synthetic fuel or chemical substances, it is necessary to treat it from tar droplets and soot. Having this specific problem in mind, a group of scientists from the Lithuanian Energy Institute initiated a project whose main objective was to research the compatibility of simultaneous thermal breakdown (gasification) of biomass and catalytic tar removal in order to design and test an experimental device and identify the optimum operation conditions ensuring the absence of tar droplets in gasification gas. The dolomite and activated carbon catalysts were tested suitable for catalytic tar breakdown. The research of catalytic partial oxidation and autothermal destruction of benzene and naphtalene, the main tar-forming components, was carried



The scheme of the experimental set up for thermal destruction of biomass. 1 – Rotameter; 2 – Heater; 3 – Water evaporator; 4 – Container of wood pellets; 5 – Screw conveyor; 6 – Pyrolysis reactor; 7 – Catalyst load; 8 – Catalytic reactor; 9 – Peristaltic pump; 10 – Glass condensers; 11 – Heating tub; 12– Cooling tub; 13 – Filter; 14 – Gas meter; 15 – "Tedlar" gas bags



Setup for thermal destruction of biomass

out and the efficiency of thermal destruction of these materials depending on temperature, reaction times and catalyst type was determined. The research of simultaneous thermal breakdown of biomass and catalytic thermal conversion of tar was performed as well and the efficiency of thermal destruction of tar depending on temperature, reaction times and catalyst type was determined. This work was performed in the scope of the project **Research of Compatibility of Simultaneous Thermal Breakdown of Biomass and Catalytic Tar Removal (BioSynTar)** funded by the Research Council of Lithuania (MIP 112/ 2010).

ADJUSTMENT OF PRIMARY AND SECONDARY AIR STREAMS IN A BURNER FOR REDUCING NO_x AND CO IN FLUE GAS

In order to reduce atmospheric pollution, the first technological measure is staging of air and gas streams and taking into account the geometric shape of the firebox. In this work, the systems of powerful secondary gas are modified in three ways in a prolonged rectangular firebox. The measurements demonstrated that the flow rate of injected gas and geometrical distribution influences the production of NO_x and must be precisely tuned to the combustion of CO gas. If complete combustion of CO gas is not achieved, it is reasonable to divide the gas streams into finer parts. In the



Temperature distribution along the firebox section through the burner axis

second case, a very fine injection of gas grouped at the burner was used in a firebox with a turning flame torch. The resulting lower CO generation and full combustion of this gas enabled reducing the NO_x output. The calculations showed that long gas streams with higher flow rate along the firebox increase the CO output. Thus, the complete combustion of this gas requires a longer firebox.



Two-component distribution of the secondary gas streams

The Laboratory of Combustion Processes has been adjusting the combustion processes in water heating and steam producing boilers for economical and environment-friendly operation for several years. This work includes the reconstruction of burners: the baffles of primary and secondary air, systems of liquid or gaseous fuel atomization, geometry of ceramic nozzles are modified. The reconstructions are carried out in 4-100 MW capacity boilers with fireboxes of various types and geometrical shapes. Experimental data are used in combustion adjustment work together with theoretical findings: aerodynamics of turbulent flow, heat and mass transfer including chemical reactions, and properties of NO, production. Together with direct measurements in rearranged fireboxes and accumulated data, numerical simulations using FLUENT package is used. This software is suitable for analyzing various situations, but its applicability is limited for problems requiring precise realistic solutions. The main purpose of this work is to identify the characteristics of NO_x production and possibilities to reduce it in natural gas combustion, because the limit value of emission of this gas will be fixed to 100 mg/nm³ from 2016, while the current limit is 300 mg/nm³. This work was performed in the scope of the state funded project *Experimental and Theoretical Research of Combustion and Gasification Processes for Wider Utilisation of Renewable Fuel Sources and Emission Reduction*.

DEVELOPMENT OF HEAT RECUPERATION AND COMBUSTION EQUIPMENT IN ORDER TO SUBSTITUTE NATURAL GAS WITH LOW-CALORIE GAS



The world and especially Europe are currently seeking to reduce the use of natural gas and to increase the utilization of alternative fuels and renewable energy sources. In total, the aim is double the absolute production of energy from 938 million tons of oil equivalent in 1990 up to 1923 million tons of oil equivalent in 2030 by using biomass, waste and renewable fuel types. The substitution of natural gas with alternative gas is problematic because complex multifaceted problems require the development of scientific basis and special equipment for heat extraction, transfer and combustion. The project involves the development of advanced equipment capable of delivering alternative fuel for production purposes. It is planned to develop a special recuperator design suitable for both the oxidizer and the fuel: this



is an important milestone in developing scientific and engineering basis for the substitution of natural gas with alternative fuel. The current challenges are related to the environmental aspects that dictate the conditions for solving the problems of gas supply. The old criteria of gas interchangeability and limitations should be replaced by new modern conditions from both energy and environmental viewpoints, together and in particular. The two main member countries in research of coal and biomass gasification and production of alternative fuel are Germany and Lithuania. Another two member institutions, the leading one (the Gas institute, NASU, Ukraine) and cooperating one (TÜKI, Hungary) are engaged in the development of heat production processes and equipment as well as its applications in high-temperature power plants. JSC Dvarčionių keramika participates in the project jointly with the Laboratory of Combustion Processes as a production enterprise from the industry of construction materials. In the course of the project, a 100 kW reactor capable of producing gas from the fuel of renewable sources will be designed in Lithuania. The method will be improved building upon the experience of the Laboratory accumulated in designing and operating the scrap tyre gasification reactor. Moreover, a recuperator for air preheating will be introduced, the entire reactor system will be produced, the generation process will be analyzed, and the gas quality will be improved using the catalysts. Finally, the entire setup will be tested at the premises of the production partner JSC Dvarčionių keramika. The work output will be generalized by design methods for various cases of usage. This work is carried out in the scope of *Eureka* project *Development of Heat Recuperation and Combustion Equipment in order to Substitute Natural Gas with Low-Calorie Gas*.

The project will be implemented in the scope of the measure VP1-3.1-ŠMM-06-V "MTTP quality and preparation of experts" of the priority 3 "Strengthening the researcher capabilities" of the Human Resource Development Action programme. The project code is VP1-3.1-ŠMM-06-V-01-003.

SIMULATION OF THERMAL CONVERSION OF SOLID GRANULAR FUEL

Thermal conversion of solid fuel is a complex process involving mechanical motion of solid particles, heat transfer, physical and chemical processes inside the particles: heating, evaporation of volatile species and chemical reactions. In the course of developing the software for simulations of these processes, the model of particle conversion was coupled with the model of granular matter dynamics.

The particle dynamics model (discrete element method - DEM) is based on solving the Newton equations of classical mechanics. The model of particle conversion (combustion), the discrete particle model (DPM) was developed by Prof. B. Peters (University of Luxembourg) and includes the following processes: heat transfer between the particles due to thermal contact, heat transfer between the particles due to radiation, heat transfer from the surrounding walls to the particles by radiation, heat transfer between the particles and the surrounding fluid (liquid or gaseous), particle drying, pyrolysis and combustion, mass transfer between the particles and the surrounding fluid.

The simulation results of the particle thermal conversion should be appropriately applied. One of the aspects of analysis is identifying the groups of particles



Configuration of a packed bed of 400 particles on a grate: temperature distribution



Particle groups, distinguished by their sizes, using the "label propagation" community detection algorithm (a) and the configuration and mutual links of the identified communities (b). The thicknesses of lines connecting the groups (the graph edge weights) are inversely proportional to the differences of average particle radii in the groups. The labels indicate the numbers of groups to which the particles belong

featuring similar characteristics. This can be done using the established" community detection" algorithms from graph analysis that are currently widely researched and applied for network analysis in various fields. However, their applicability to specific simulation results require additional research; moreover, those methods should be modified and tailored for specific purposes. Postprocessing of the simulation results is a topic for further research. The standard algorithms known from graph analysis were applied for the analysis, but the results of straightforward application differ noticeably; therefore, this approach is being extended. An improved method and a new simple algorithm were applied, yielding better results compared to the standard algorithms.

In 2011, the Laboratory staff published 3 articles: 1 of them in a journal on the ISI list, 1 in a journal listed in international databases of scientific information and 1 in other scientific periodicals. They also made 7 contributions in international and 1 contribution in a Lithuanian conference.

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LABORATORY of MATERIALS RESEARCH AND TESTING

MAIN RESEARCH AREAS OF THE LABORATORY:

- reliability of power plant facilities and aging management;
- development and research of multifunctional materials and composites;
- testing of materials, assessment and analysis of their qualitative indicators.

RELIABILITY OF POWER PLANT FACILITIES: RESEARCH OF METAL AGEING PROCESSES AND PROPERTIES DEGRADATION DUE TO THE IMPACT OF OPERATIONAL FACTORS

The Laboratory carries out research related to the investigation of the processes of ageing of metal alloys that are used as the constructional elements of power plants and to solve issues of their service life and aging control. Applying mechanical tests, X-ray Diffraction (XRD) and elemental composition analysis, as well as optic and scanning electron microscopy, structural and property changes of steel and non-ferrous metal alloys were studied. Experimental and numerical methods are used to predict operational reliability taking into account material ageing processes and other operational factors. The implementation of this work is focussed on the investigation of the fundamental physical and chemical phenomena affecting structure and properties of metals.



The work, initiated in 2010, under the agreement with JSC GEOTERMA on Preparation and Application of Complex Measures for Work Optimisation and Life-Time Expansion of Absorption Heat Pumps (AHP) was continued. The main tasks of the project are to analyse and identify the factors which influence corrosion process and material costs in the geothermal power plant; to give recommendations for the minimisation of corrosion process and material consumption costs as well for ensuring of stable parameters of lithium bromide solution used in heat pumps. The work includes the analysis of AHP monitoring data, control and maintaining of LiBr solution parameters. In addition, preventive means for reducing the probability of

LiBr solution contamination with thermal and/ or geothermal water are foreseen.

Apart from the mentioned research aimed to optimize performance and increase AHP lifetime, the investigation of the influence of the operational factors on long-term structural integrity of materials was performed. Corrosion research and mechanical testing were used for the assessment of operating condition and justification of further service possibility of cooper-nickel tubes, used in the thermal assembly. In addition, other research on the optimisation and maintenance of operational parameters of equipment was also performed.



The researchers of the Laboratory are continuing the research on degrading effect of hydrogen and hydrides on zirconium alloys, initiated in 1998. Since 2011, the Laboratory is participating in a new Inter-



Simultaneous differential thermal analysis (DTA), thermogravimetry (TG) and X-ray diffraction analyses of insoluble sediment of geothermal water filter

national Atomic Energy Agency (IAEA) project *Analysis of Nuclear Fuel Cladding Resistance to Hydride Cracking During Long-Term Storage.* The aim of this project is to develop experimental procedures in order to assess the conditions of hydride cracking in zirconium alloy fuel cladding and to determine the values of stress intensity and temperature limits at which the failure of fuel claddings can occur. The research is important for solving the issues of ensuring safe operation of nuclear power plants and assessing the resistance of fuel cladding to the hydride cracking during long-term storage of spent nuclear fuel.

Achievements of the project the project MATTER (MATerials TEsting and Rules). On 13 December 2010 a new European Union 7th Framework Programme project MATTER was signed and its implementation was initiated on 1 January 2011. Joint team including researchers from Laboratory of Nuclear Installation Safety takes part in the project. 15 work packages were established according to the project tasks, and the Laboratories participate in two



working groups: "Manufacturing and welding" and "Testing activities in support of design". In the scope of the project, a new research on materials behaviour in the operational conditions of IV generation reactors was initiated. It is aimed at the determination of the highest reliability criteria of application of new materials taking into consideration material ageing mechanisms. One of the main objectives of this experimental research is to identify the allowable fatigue resistance limits and coefficient values of steel welds in nuclear components, operating under high temperature and manufactured by applying upto-date welding technologies. Taking into account the requirements for modern experimental procedures, a research meth-

odology was developed for carrying out the experiments. The fatigue resistance tests are performed under strain controlled conditions at 550 °C using dynamic testing machine Instron (Model 8801, 100kN). During the implementation of this work, new data describing the high temperature creep and fatigue behaviour where obtained which are relevant for predicting the lifetime of welds in the reactor components and assessing the suitability of welding technologies in continuation of further research on the welding materials and assessment of influence of operational factors on the welded components in the nuclear industry.

DEVELOPMENT AND RESEARCH OF MULTIFUNCTIONAL MATERIALS AND COMPOSITES

A state subsidy-funded scientific research *Impact of modifying additives and nano-fillers on structure and properties of constructional composite materials* was initiated in 2011. It analyses the impact of nanosized fillers and other modifying ad-

Dynamic testing machine Instron (Model 8801, 100 kN) and equipment for working at temperature up to 800 °C



ditives on the structure and properties of innovative composites, and compatibility of nano-fillers with the binders. In the first stage of project implementation, the parameters of pure gyrolite and sodium substituted gyrolite crystal lattices, exact positions and the fractional occupancy of their atom sites were determined by applying Rietveld crystal structure refinement method. X-ray diffraction analysis, Rietveld structure refinement and crystal structure modelling methods were combined to prepare a methodology for the determination of the exact atomic positions and the amount of inserted Na⁺ ions in the crystal lattice of low crystallographic symmetry minerals - synthetic gyrolite and sodium substituted gyrolite.

Physical and mechanical properties of both inorganic binder and constructional material may be significantly improved by



changing the amount of any of the modifying additive. Therefore, one of the purposes of this project is to analyse the impact of modifying additives on the structure and properties of a composite constructional material with inorganic binder. Research was focussed on the inorganic binder which is one of the main components of refractory composites used for repair of heat linings.

In order to prolong the lifetime of the composites, several modifying additives were selected, namely silicon dioxide micro-dust, microfiber and layered silicate, each of which has a specific function, i.e.



Gyrolite crystal lattice refined using X-ray structural analysis and Rietveld method

to prevent the formation of macrocracks in the material, to increase material volume or reduce the content of the binder. Whereas the material is to be used under high temperature, the impact of temperature on the physical-mechanical properties of the modified adhesive was evaluated experimentally. Furthermore, X-ray diffraction analysis was carried out, microstructural changes of the binder were investigated according to the selected modifying additive, and the optimal amount of additives in the material was determined.



Structure of inorganic binder with and without modifiers before and after heating at 1000 °C



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 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, as well as sodium substituted gyrolite was used in this research. Surface characteristics of the filler were changed by organic compounds and ultrasound mixing to achieve effective compatibility with polymer matrix. A nanocomposite was prepared from the modified nanosized 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 nanosized gyrolite filler.

Project Nanotechnology Enhanced Extruded Fibre Reinforced Foam Cement



Based Environmentally Friendly Sandwich Material for Building Applications (FIBCEM) of the Project Nanotechnology Enhanced Extruded Fibre Reinforced Foam **Cement Based Environmentally Friendly** Sandwich Material for Building Applications (FIBCEM) of the European Union 7th Framework Programme. The three-year FIBCEM project was initiated in December 2011 with participation of 10 partners from 5 countries: Italy, Spain, the United Kingdom, Denmark and Lithuania. Following the work schedule, the researchers of the Laboratory participate in the activity of the 4th working group, which main objective is to modify nanoclay. The aim of the FIBCEM project is to develop a promising, low-energy consuming technology for the production of foam-cement boards enabling the reduction of carbon dioxide emission.

MATERIALS TESTING, QUALITY ASSESSMENT AND ANALYSIS

Researchers of the Laboratory provide accredited services; perform material testing and assessment of their quality in accordance with the 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.



Laboratory is accredited to carry out tests of:

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

The achievements of Laboratory in 2011 are the following: 7 scientific articles: 4 of them in the publications on the ISI list and 3 in reviewed conference materials were published. The researchers also participated and presented reports in 3 international conferences.

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LABORATORY of PLASMA PROCESSING

MAIN RESEARCH AREAS OF THE LABORATORY:

- development and research of DC plasma sources for a 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 of experience working in different fields of development, scientific research and application of atmospheric and reduced pressure plasma and are able to 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 continues carrying out the investigations of heat transfer in plasmatron reactive arc zone, electric field 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 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 equations based on the dynamic $k-\varepsilon$ model for the fluid jet. However, the numerical research becomes especially difficult 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, 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 methods have 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. It is an optical system for a rapid measurements, that may be used for the investigation of gas emission spectra peaks in a wavelength range of 250– 800 nm. The system is used also for the



Air plasma jet flowing from the linear DC arc plasma generator



Element composition of argon and water vapour plasma jet, flowing from 35 kW capacity plasma generator and determined by optical spectroscopy method. Above: copper anode, water vapour flow $G=2 g \times s^{-1}$; below: steel anode, water vapour flow $G=2.9 g \times s^{-1}$

examination of plasma element composition and emission spectra. An X-series high-speed optical camera RedLake Motion Pro X4 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.

FORMATION OF CONSTRUCTIONAL MATERIAL SURFACE LAYERS BY PLASMA TECHNOLOGIES

Synthesis of coatings in plasma flows

Plasma spray technology, developed in the Laboratory, was applied for catalytic, tribological and protective coatings 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 accelerate the corrosion resistance up to 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. (on the right), 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 γ phase Al₂O₃ coatings with highly developed active surface, which are especially relevant in the formation of catalytic coatings. The surface area of the coating was further enlarged by heating it in a certain temperature.

Catalytic coatings

In the fields of science and production, a worldwide attention has recently



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





Formation of constructional material surface layers in atmospheric pressure air plasma and samples of prepared products

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 catalysts that are used in approximately 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 compounds oxidation is being developed on the basis of TiO₂.



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



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, semiconductors 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, halocarbon 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 a variety of 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.

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 attention is directed towards developing solid carbon coatings of various composition and properties on different surfaces (steel, AI_2O_3 , 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



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

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.



SEM images of carbon coatings obtained by argon-hydrogen-acetylene plasma

Research on interaction of plasma jet and materials

For the purpose of production of hightemperature fibre with especially small diameter, reprocessing of hazardous substances, formation of various coatings and synthesis of new materials, the interaction of electric arc and plasma jet with 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 distribution 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 require 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



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



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 various 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.



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

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 Soviet Union, in plasma jets and flows. The effect of high temperature and velocity to the changes of structure and properties of the given material was investigated, and the tested material was used for the manufacture of the hull for the space shuttle BURAN.



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

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 re-enter space vehicles using low-tem*perature 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.



Researchers' Night 2011 in the Laboratory of Plasma Processing



Excursion in the Laboratory during LEI Open Days



Partner meeting of the Baltic Sea Region Programme 2007–2013 project **Dissemination and Fostering of Plasma Based technological** Innovation for Environment in BSR

PROJECTS IMPLEMENTED IN THE LABORATORY

A state subsidy funded work *Identification and Assessment of Prevailing Factors Determining the Synthesis of Inor*

ganic Material Oxides Fibre in Plasma Ambient (2009–2010) was completed and defended. 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 nano-structural 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.

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 plasma-chemical 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. A thin (up to 5 μ m diameter) ceramic fiber, which can be used as insulation in thermal equipment, as building material for reinforcing concrete or as a filter for precipitation of ultra-small particles, was produced

In 2011 the researchers of the Laboratory participated in the following international programmes and projects:



- COST CM0903 activity Utilisation of Biomass for Sustainable Fuels and Chemicals (UBIOCHEM) till 2013. In this activity, the researches of the Laboratory are performing an individual project Water Vapour Plasma for Biomass Conversion and Waste Utilization. During its implementation, 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.
- Research on carbon nano-derivatives synthesized from non-saturated hydrocarbon plasma No. MIP-59/2010 funded by Research Council of Lithuania and prepared



by under the initiative of the researchers. Period of implementation (2010 - 2012). Implemented in cooperation with KTU.

 International project *Research on formation regularities and properties of multifunctional metal oxide coatings formed by combined laser-plasma methods* carried out under the Lithuanian- Belarus bilateral cooperation programme in the fields of science and technology. The aim of the project is to determine of structure and properties of metal oxide coatings with controlled physical-mechanical and operational characteristics formed by plasma and laser methods.



 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 issues. 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;
- 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 scientific partners in the field of environmental protection;
- specialised group formation aiming at reducing NOx and SOx emission, neutralising VOCs compounds and smells as well as cleaning the water;
- spread of knowledge and environmental technologies in the states of the Baltic Sea region.

PLASTEP PROJECT PARTNERS

In 2011 two new applications were submitted to the invitation of the National Research Programme *Future Energy* (2012 – 2014). An application was also submitted for the project of MITA renewable energy programme. An application for EUREKA project *Development of water vapour plasma equipment for fuel conversion and treatment of hazardous waste* is under preparation. Finally, the Laboratory is also going to prepare an application for the Lithuanian-Swiss research programme.

The personnel of the Laboratory of Plasma Processing consists of 7 scientists with a doctoral degree, 2 young researchers PhD students, 1 junior research assistant and well experienced ancillary personnel: 3 engineers and 2 highly qualified foreman.

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 (10 papers) and national (4 papers) conferences, 7 articles were published in the ISI indexed journals and 14 articles in the worldwide reviewed publications.

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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 2011 a state subsidy funded project Synthesis and Property Analysis of Nanocrystalline Metal Hydrides, Designed for Energy Storage and Optical Devices was successfully continued. In the modern world, the greatest share of energy is obtained from oil, but its resources are finite.

The use of oil causes global problems which could be solved by replacing oil with energy carrier, hydrogen. Hydrogen may be stored in metal hydrides: one of such hydrides currently under the most exhaustive research is magnesium hydride. However, due to the issued related to hydrogen absorption/desorption kinetics and excessively high formation/decomposition temperature, magnesium hydride has not yet been widely used in the energy sector. The most efficient methods for improving the properties of this hydride is to introduce small amounts of various additives (e.g. Ti) and in this way destabilise the Mg-H system.

During the implementation of this work, the researchers aimed at obtaining thin-layer Mg, TiH, structures by applying physical vapour deposition method for the synthesis of magnesium-titanium on silicon plates, which were cleaned before the process using plasma based pre-treatment. The hydrogenation of the obtained structures were performed by applying high-pressure and temperature hydrogenation chamber. The received samples were then tested by profilometer, scanning electronic microscope, energy dispersive X-ray spectrometer, X-ray diffractometer and glow discharge optical emission spectroscope. The results of the experiments demonstrated that the compounds developing in the hydride depend on the material, used for synthesis, and its surface structure.

During the implementation of the EU SF project *Foundation of National Open Access Scientific Center for Future En*-

ergy Technologies, ULVAC-PHIX-ray photoelectron spectroscopy equipment (standard abbreviation XPS or ESCA) Versaprobe 5000 was bought and installed in LEI Center for Hydrogen Energy Technologies in 2010. It is the highest-quality analytical equipment, which distinguishes from other XPS by the lowest probing diameter as its size may be set from 300 to only 10 µm. This enables carrying out high special resolution XPS analysis encompassing the identification of separate elements, resolution of their chemical state and formation of extremely accurate phase maps. Moreover, the spectroscope is equipped with a unique patented function of dual-beam charge neutralisation (low-energy ions and electrons), for this reason, both conductive and dialectric materials may be easily tested. In order to observe the material distribution in depth, an angle-dependent XPS (ADXPS) analysis may be performed, or the sample may be sputtered using the installed argon ion gun and in this way carry out the grading of samples.

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.

On 25 November 2011 the researchers of the Center for Hydrogen Energy Technologies were granted a patent No. 5789 *Hydrogenation method of metals and their alloys* registered in State Patent Bureau of the Republic of Lithuania. The patent application for the metal hydrogenation technology developed by the researchers of the Center is currently processed in the European Patent Office in order to obtain a Europen patent: <u>https://data.epo.org/pub-lication-server/rest/v1.0/publication-d a t e s / 2 0 1 1 0 6 2 9 / p a t e n t s / EP2338834NWA1/document.pdf</u>





ULVAC-PHI X-ray photoelectron spectroscopy equipment (standard abbreviation XPS or ESCA) Versaprobe 5000



Research Council of Lithuania

HYDROGEN IMPLEMENTING AGREEMENT

In 2011 a project *Hydrogen Extraction from Water Vapour Plasma by Molecular Implantation* as a part of the programme *Future Energy* financed by Research Council of Lithuania was completed. 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.

In 2011, 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*. 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.

Last year, the researchers of the Center published 7 articles in the publications on the Institute for Scientific Information (ISI) list.

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LABORATORY of NUCLEAR ENGINEERING

MAIN RESEARCH AREAS OF THE LABORATORY:

- investigation of thermal processes in energy equipment components:
 - forced and mixed convection, turbulent and transition flow regimes, influence of channel geometry, variable physical properties, roughness, centrifugal forces and transients effect;
 - numerical modelling of heat transfer in various channels and geological structures;
 - reduction of emission resulting along with smoke from biofuel combustion using electrostatic precipitators; research of heat and mass transport in the equipment of biofuel-fired objects;
- safety of spent nuclear fuel management: modelling of fuel characteristics, safety and environmental impact assessment of storage and disposal facilities, normative and legislative base;
- safety of radioactive waste management: 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 characterisation 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.

RESEARCH OF THERMAL PROCESSES IN ENERGY EQUIPMENT COMPONENTS

Laboratory carries out investigations of heat transfer and hydrodynamics in energy equipment for different purposes (in the elements of nuclear reactor, various heat exchangers, etc.). Since in both laminar and turbulent flow cases, the effect of buoyancy forces (mixed convection) on heat transfer is manifested in many energy installations, which under certain conditions can be the reason for an accident in different installations, therefore, in order to analyse such problem the laboratory performs experimental mixed convection investigations in pipes and has recently initiated the research in flat channels as well. Additionally, such research was initiated in geological structures while analysing the possibilities of Ignalina NPP spent nuclear fuel disposal. In parallel, investigation is also performed using the ANSYS FLUENT code (ANSYS, USA) which is widely used worldwide for modelling the fluids flow and heat transfer in complex two and three-dimensional systems. The Laboratory uses various models of the laminar, transition and turbulent transfer. In 2011 the numerical investigations (using ANSYS FLUENT code) on heat transfer and hydrodynamics in flat channel for opposing mixed convection flows in the transition region were continued. The obtained heat transfer and flow hydrodynamics results change and expand the understanding on the transition from the laminar to turbulent flow under the impact of buoyancy forces.

Advanced countries pay a lot of attention to the reduction of negative environmental impact caused by various energy objects. The reduction of pollution is an especially relevant issue in solid fuel com-



During a scientific-introductory excursion in biofuel-fired Vilnius thermal power plant VE-2

bustion and one of the means to achieve it is the use of electrostatic precipitator. It is an effective means for cleaning the emitted solid particles (especially small ones which are not captured by other filters (e.g.: cyclonic filters)). Electrostatic precipitators intended for deposition of solid particles and used in industrial and energy equipment are prevailing worldwide for reducing the environmental pollution down to minimum. The filters are usually used in medium or high capacity power plants fired by coal or similar type of fuel. These filters are also relevant for specific industrial companies (concrete production, waste incineration power plants, etc.) which emit hazardous materials together with smoke during the production process. The novelty lies in the combustion of different types of biofuel since depending on the burnt material, the operation (efficiency) of filters changes due to the influence of different sizes and composition of particles emitted with smoke. An exhaustive analysis of these factors enables solving relevant issues related to upgrading technologies of the Lithuanian energy sector.

The Laboratory initiated research in this field in 2011 and carried out the re-

view of electrostatic precipitator usage worldwide.

SAFETY OF SPENT NUCLEAR FUEL MANAGEMENT

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 optimised 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 2011 a great deal of attention was



PhD Candidate D. Justinavičius next to the equipment for drawing samples from rocks in underground research laboratory (IAEA training course, 15-23 June 2011, Prague, the Czech Republic)



devoted to one of safety assessment aspects, the research of consistent patterns of gas migration 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 2011 a model of gas migration from the repository was developed and initial numerical assessment was carried out applying PetraSim software package (the USA).

In 2011 a scientific project *Probabilistic Uncertainty Assessment of Radiation Impact during the Analysis of NPP Dismantling and Radioactive Waste Managing* (2010–2012) financed by the state budget grant was continued. The research on the radionuclide migration from deep SNF repository in case of container defect scenario is performed. The scenario as-



Spent nuclear fuel disposal model

sumes that a disposal container with a small defect (untightness) in its wall may pass the inspection by non-destructive control methods and be placed in the repository. Thus, radionuclide transport from disposal container through the wall defect is modelled. Having spread from the container, the radionuclides migrate through the bentonite layer (engineering barriers) and diffuse to the underground water, which flows in the fracture intersecting the tunnel in crystalline rocks.

During these investigations, the re-

searchers are updating the model of radionuclide migration from RBMK-1500 SNF deep repository, developed in 2007–2009. They also aim at evaluating the influence of uncertainty, related to the increase of container wall defect, migration on the separate radionuclide from the container. In 2011, the influence of defect enlargement time and other parameter uncertainty on the assessment results of long-lived radionuclide ¹²⁹I ($T_{1/2} = 1.57 \times 10^7$ annually), ²²⁶Ra ($T_{1/2} = 1.6 \times 10^3$ annually) migration was analysed. The probabilistic



Radionuclide 129 flux beyond engineering barriers of the repository (results of probabilistic assessment)



During IAEA training course (6-10 November 2011, Peine, Germany): A. Narkūnienė in underground potential repository for the disposal of SNF and high-level waste in the rock salt formation

assessment of radionuclide transport demonstrated that aiming to optimize the analysis of radionuclide ¹²⁹I transport through engineering barriers, it is worthwhile to target the further research on the parameters defining bentonite diffusion, instant release fraction and SNF matrix dissolution rate. Similarly, in the case of ²²⁶Ra the revision of the SNF matrix dissolution rate, bentonite sorption coefficient and the equivalent flow rate of underground water is recommended.

Furthermore, complex investigations of the influence of heat transfer and mechanical processes in natural and engineering barriers unsaturated with water were continued. Numerical research was carried out using software COMPASS (GRC, United Kingdom), whereas radionuclide migration was evaluated applying softwares AMBER (Quintessa, United Kingdom), Petrasim (USA), COMPULINK, CHAN3D, PREBAT-BATEMAN (SKB, Sweden).

In 2011, as a subcontractor to NUKEM Technologies GmbH (Germany), the Laboratory continued an 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 2010-2011, PSAR Addendum, which presents the evaluation of safety aspects of damaged RBMK-1500 nuclear fuel assemblies' management and storage, was being prepared.

SAFETY OF 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 exsting 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 an interim 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 *Reconstruction 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 2011, the Laboratory as subcontractor to 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 at 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 facility. Additionally, in 2009 two more PSARs, New Solid Waste Retrieval Facility. Retrieval Unit 1 and Retrieval Unit 2-3 at Ignalina NPP was newly prepared, while in 2010 both PSARs were submitted to authorities for review. The former was updated following the recommendations of the authorities and approved by VATESI in the end of 2010, while in the middle of 2011, the licence to build the complex was issued. The second PSAR was modified considering the recommendations of the authorities in 2011.

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– 2011). 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). *General Data Set on the Buffer Storage of the Landfill Repository* was completed (approved by the European Commission in 2010), whereas in 2011 *General Data Set on the Disposal Modules of the Landfill Repository* was submitted to the European Commission for review.

Last year, 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.

In 2010-2011, the specialists of the Laboratory made a considerable contribution to the preparation of Design Concept Report, Waste Inventory Report and Site Revalidation Report which were submitted to the Contractor and approved. The results of exhaustive project implementation review were discussed in the meeting with the IAEA experts which took place in November 2011. Moreover, the prepara-



D. Grigaliūnienė and R. Kilda discussing the results of exhaustive project implementation review with IAEA experts (28 November 2011, Vilnius)

tory work of technical design has already been initiated: the specialists of the Laboratory are going to assess the long-term safety of the planned repository and prepare the chapters on the preliminary safety analysis in the scope of technical design.



The Laboratory continued the previous research of radionuclides migration from near surface repositories. In 2011 in the scope of the scientific research project *Probabilistic Uncertainty Assessment of Radiation Impact during the Analysis of NPP Dismantling and Radioactive Waste Managing* (2010–2012) they analysed the migration of separate radionuclides from near-surface repositories in order to evaluate the factors which have the most influence on the uncertainty of the obtained results.

In 2011 during the implementation of the above-mentioned budgetary work Probabilistic Uncertainty Assessment of Radiation Impact during the Analysis of NPP Dismantling and Radioactive Waste **Managing** 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. In 2011, the modelling of axial neutron flux distribution was continued: the axial activity distributions of the main radionuclides in activated graphite were estimated, and the possible spread of their activity values was analysed regarding the amount of initial impurities. Having obtained the initial measurement results of the activity of several radionuclides in the reactor graphite sleeve of

Ignalina NPP Unit 1, the calibration of the developed models was carried out. Similarly as before, the numerical research was performed using MCNP-5 (LANL, USA) and ORIGEN-S (from SCALE-5 software system) (ORNL, USA) software.

The feasibility study of RBMK-1500 graphite final disposal in a repository was analysed in the scope of CARBOWASTE project regarding the alternatives of treatment/non-treatment of the graphite. To assess the specificity of long-term repository operation after placing irradiated graphite, numerical models were developed. They were applied to evaluate the release of radionuclides from graphite and their transport through engineering barriers of the repository. The developed models of the repository environment were implemented using AMBER software (Quintessa, the United Kingdom). The analysis of radionuclide transport is carried out taking into account the results (on radionuclide release from waste, possible waste packaging, radionuclide inventory and activity of irradiated RBMK-1500 graphite, etc.) obtained in the scope of the mentioned project.

By implementing **CARBOWASTE** project in 2011, the researchers were also implementing Multi-Criteria Decision Analysis methodology. Having accumulated initial data on the physical, radiological, arrangement-scheme and other parameters of the equipment and carried out the initial analysis of the data. Alternative strategies of nuclear equipment dismantling were formulated. The analysis was carried out applying software **DECRAD** developed at LEI Nuclear Engineering Laboratory.

In 2011, the IAEA project *Treatment Requirements for Irradiated RBMK-1500 Graphite to Meet Disposal Requirements* (2010-2014) was initiated in cooperation with other countries. The research carried in the scope of this project by the researchers of the Laboratory is mostly related to meeting the disposal requirements for the treatment of irradiated RBMK-1500 graphite in Lithuania.

EVALUATION OF DIFFERENT FACTORS RELATED TO DECOMMISSIONING OF NUCLEAR POWER PLANTS

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 2009 the specialists of the Laboratory prepared Environmental Impact Assessment Report approved by the authorities, while in 2010 they completed General Data Set, made input to Basic Design and Safety Justification Report; the two latter were approved by the relevant authorities. The researchers of the Laboratory also participated in preparing the Detailed Design, which was reviewed and submitted to the contractor. 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. Following the prepared documentation, the **INPP** Dismantling and Decontamination Service, together with other divisions of the company, started the work of dismantling and decontamination of equipment installed in Building 117/1 on 1 December 2010 and completed them in October 2011.

In 2011, 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). In 2010 Specialists of the Laboratory completed General Data Set; in 2011 they prepared Environmental Impact Assessment Report and received its approval from the Ministry of Environment. At the end of 2011 Basic Design and Safety Justification Report were submitted to the authorities that are currently reviewing the documents. The preparation of the *Detailed Design* is going to be completed in 2012.





Image of **DECRAD** software

In 2009, the specialists of the Laboratory developed **DECRAD** software intended for analysis of decontamination and dismantling of nuclear power plants, planning the demand for expenses, costs and personnel, calculation of the personnel radiation doses, planning of radioactive waste disposal and the assessment of other parameters related to the decommissioning. The software may be applied for planning and analysing decommissioning of different power plants, their separate buildings or units. In 2011, the specialists upgraded and improved the software code *DECRAD*. It was successfully applied and is still used in the scope of the project *Ignalina NPP Building V1 Equipment Decontamination and Dismantling*.

In the scope of nuclear power plant shutdown projects, VISIPLAN 3D ALARA Planning Tool (SCK-CEN, Belgium) soft-



Map of dose rate in INPP Unit V1 and an employee dismantling an air heater (modelled using VISIPLAN 3D ALARA Planning Tool)

ware is applied to estimate personnel radiation doses.

One of the most important tasks for the shutdown of NPP is safe dismantling of the equipment. Due to the shutdown Ignalina NPP Unit 1 in 2004 and Unit 2 in 2009, the analysis of the mentioned issues and suitable solutions are especially important. Apart from the already-mentioned specificities, in 2011 a probabilistic uncertainty assessment of radiation impact on the personnel dismantling the pipelines of the Ignalina NPP emergency cooling system was carried as a part of the project Probabilistic Uncertainty Assessment of Radiation Impact during the Analysis of NPP Dismantling and Radioactive Waste Managing (2010-2012).

Since 2002, the Laboratory has 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 Ignalina NPP. Fire hazard assessment of some renewed INPP rooms 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 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 units of *Landfill* repository was analysed. In 2011, the impact of fire during the implementation of Ignalina V1 unit dismantling and decontamination was assessed.

RESEARCH RELATED TO THE CONSTRUCTION OF A NEW NUCLEAR POWER PLANT IN LITHUANIA AND OTHER INTERNATIONAL ACTIVITY OF THE LABORATORY

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 As**sessment 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.

The researchers of the Laboratory continually participate in the research

programmes coordinated by IAEA, namely Improvement of Safety Assessment Methodologies for Near Surface Disposal Facilities (ISAM) (1998–2001), Application of Safety Assessment Methodology for Near-Surface Waste Disposal Facilities (ASAM) (2002–2005), The Use of Numerical Models in Support of Site Characterization and Performance Assessment Studies of Geologic Repositories (2005– 2010), Treatment of Irradiated Graphite to Meet Acceptance Criteria for Waste Disposal (2010–2014).



At the end of 2011, the researchers of the Laboratory in cooperation with 15 partners from 9 European countries initiated the 7FP project **New MS Linking for an Advanced Cohesion in Euratom Research** (**NEWLANCER**) (2011–2013). The main objective of the project is to analyse the research potential of EU new member States and promote scientific cooperation with the EU old member States. The project participants discussed project work packages, their implementation plans and schedule during the kick-off meeting, which took place in November 2011.

Together with 15 other organizations from the EU countries, Canada, the Netherlands and Sweden, LEI started the 7FP project *Sustainable network of Independent Technical Expertise for radioactive waste disposal (SITEX)* (2012–2014) in 2011. Its main objective is to identify efficient means to implement for the establishment of a European sustainable network of independent technical expertise in the field of radioactive waste disposal. It is intended for strengthening general and mutual understanding of different aspects regarding repository safety among the regulatory institutions and organizations providing technical safety expertise and waste management. The network also aims at assessing the demand for independent scientific research, recommendations for technical expertise, etc.

MAIN RESULTS

In 2011, the Laboratory (23 researchers) continued a state subsidy funded research work, carried out 12 applied research projects and earned more than 1 million LTL.

On 30 June 2011, the researcher of the Laboratory, Asta Narkūnienė, successfully defended her PhD thesis *The Investigation of Radionuclide Release from the Hypothetical Repository for RBMK Spent Nuclear Fuel Disposal* in the field of technology sciences, energetics and power engineering direction, and was granted a PhD degree. Audrius Šimonis joined the laboratory researchers also. He defended his PhD thesis *Investigation of Personnel Exposure during Dismantling of Nuclear Facilities* in the field of energetics and power engineering direction on 8 December 2011.

Researchers of the Laboratory were improving their qualification by actively participating in different training programmes and coordinating meetings. They presented 5 papers at international conferences (Sweden, Switzerland and Lithuania) and published 15 scientific articles in the Lithuanian and international journals.

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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;
- failure analysis and engineering assessment for complex technical systems;
- risk and hazard assessment of industrial objects;
- assessment of security of energy supply;
- modelling and reliability assessment of processes in net systems;
- probabilistic modelling and analysis of unusual events;
- sensitivity and uncertainty analysis of modelling results;
- fundamental research in thermal physics.

In 2011, the researchers of the Laboratory, together with other national and foreign subjects, were implementing the following 25 projects: 3 state subsidy funded scientific research projects; 2 projects funded by the national research programme **Energy for the Future**; 17 international projects (6 projects of the EU 6th and 7th Framework Programmes (FP) and 6 international scientific research programmes without external funding); 3 projects funded by the Lithuanian economy subjects.



1. NATIONAL RESEARCH PROGRAMME ENERGY FOR THE FUTURE

In 2011, two projects, financed by the Research Council of Lithuania, were con-

tinued as a part of the 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 the Lithuanian energy systems. They would enable studying the reliability of energy systems and assessing the impact of reliability on the security of energy supply in Lithuania. The main elements in the Lithuanian energy system are electricity, gas and oil transmission networks. Individual methodologies of reliability research, assessment and its application serve as the basis of the general methodology for the reliability and risk assessment of electricity networks, developed during the implementation of the project. The general reliability assessment methodology is composed of special methods and methodologies developed in the scope of this project and intended to perform the following tasks: reliability assessment of individual electrical appliances, reliability research of the whole electrical power system (EPS), probability risk analysis of the main accident scenarios, development and application of a general reliability and risk model, analysis of statistical failure

data and their application for assessing reliability parameters of network substations and their fragments, calculation of failure and reliability indexes of electricity transmission and distribution network, modelling and assessment of EPS static and dynamic operation modes, probability assessment and ranking of EPS operational modes. The developed individual methodologies define the use of reliability research methods and EPS models. To verify the reliability assessment methodologies of electricity networks, test calculations and result analysis were carried out. The analysis demonstrated a possibility to perform a reliability assessment of electricity networks which will enable estimating the impact of EPS reliability on energy security by applying integral assessment of

reliability parameters and impact.

Heat, gas and oil are transmitted via pipeline systems and their reliability depends on the constituent elements, i.e. energy sources, pipelines and installed equipment. Reliability of pipes is closely related to many factors which may have influence on the structural integrity of their systems, and determine their operational lifetime. Failures of transmission and distribution networks, occurring during their operation due to the effect of external factors, corrosion-mechanical processes and loads resulting in thermal-hydraulic processes, not only cause disturbances in supplying energy resources, but may also endanger the safety of people and buildings due to possible explosions. In order to consider all the mentioned factors, an in-



Structure of reliability assessment methodology for pipeline network systems (heat, gas and oil supply networks)

tegrated methodology, encompassing probabilistic and deterministic methods, was developed for the reliability assessment. The developed methodology includes probabilistic safety analysis, system reliability theory, Monte-Carlo modelling, deterministic thermal-hydraulic analysis and deterministic probabilistic strength analysis of constructions, which is carried out using finite element method. Thus, a single methodology as well as the fundamentals and principles of its individual constituent parts and models were developed for all pipeline network systems. During the application of this methodology for different systems, the specificity of the systems is taken into account, i.e. heat/ energy-carrier, pipe degradation mechanisms, ageing of constructions, occurrence of loads, equipment used in these systems, statistical failure data and other factors that enable evaluating the reliability level of the analysed system. The applicability of the developed methodology was tested by carrying out experimental calculations for Kaunas heat supply networks.

Apart from reliability assessment methodologies of individual energy system networks, an integral reliability parameter assessment methodology of the Lithuanian energy system, which encompasses the networks and defines their interrelation, was developed. The basis of this integral methodology is the theory. methods and methodologies of research on reliability data and results. The methodologies define the use of reliability research methods and models of various energy systems (electricity, heat, etc.). In order to develop them, three separate research topics were distinguished, namely integral analysis of reliability parameters and research results; assessment of the reliability impact on the spread of disturbances and hazards in the network; modelling of the reliability impact on the common energy system. Moreover, methodologies and methods were developed for the analysis of the uncertainty of reliability parameters and sensitivity of results, integral assessment of energy system reliability parameters; mathematical modelling of the spread of disturbances in a network system with resistance, assessment of network system nodes resistance and parameters, modelling of the spread of hazards caused by disturbances and assessment of their parameters, modelling of reliability impact on the common energy system, and the analysis of reliability impact on the Lithuanian energy system. Together with the related models these methodologies enable the integral reliability research. Considering methodology and indicators developed within project devoted for the security of energy supply, new indicators for assessing the impact of energy systems reliability on the security of energy supply were proposed.

The project **Development of Method**ology for Energy Security Analysis and Integrated Security Level Assessment, which was implemented together with Vytautas Magnus University, was completed in 2011. The objectives of the project were the following:

> to develop an exhaustive methodology for energy security analysis, encompassing the re

search of challenges and disturbances to the energy system, modelling methods of energy system reaction to disturbances and their consequence assessment, and to adjust this methodology to the 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.

This project is an interdisciplinary work encompassing modelling of energy systems, analysis of technical, economic, environmental, sociopolitical and other threats and their consequences, as well as the assessment of integral energy security level. For this reason, the project was implemented by the researchers of various fields (energy, mathematics, economics, political sciences, sociology). The novelty and originality of this work is signified by the interdisciplinary integration:



Stages of energy security analysis

the assessment of causes and consequences of energy system disturbances is complemented not only with technical and economic information about the system, but also sociopolitical assessment of threats and sociological analysis of consequences. Such integral methodology of energy security analysis has been developed for the first time and, in principle, has no analogues, although the 7FP and other international projects suggest that it is relevant and a great deal of effort is put into developing it.

To achieve a comprehensive energy security modelling and assessment, methodologies and methods were developed and tested by analysing specific examples of the Lithuanian energy system disturbances. As a result of the research, the following was achieved: a methodology for the analysis and assessment of threats to energy system was prepared; probability models for the calculation of threat transformation into disturbances, including the assessment of technical, economic and socio-political threats, were presented; two energy system models were developed for modelling energy disturbances and evaluation of their consequences. The first one is intended for modelling long-term scenarios of energy system development, and minimizing energy production costs and consequences caused by disturbances. The second model is based on probabilistic safety analysis and enables statistical assessment of all possible disturbance scenarios and their consequences. The obtained probabilistic characteristics of consequences provide preconditions for determining the most dangerous disturbances for energy system and the most effective protection measures in regard to energy security.

In the scope of this work, a methodology of energy security level assessment, based on the formation of security indicators and multi-criteria analysis, was also developed. The indicators encompass all aspects of energy security and enable expressing it by a single integral characteristic. The developed mathematical models of the dynamics of indicators and the assessment of their parameters by Bayes method provide for forecasting energy security level until 2025 and comparing the impact of different energy projects on the energy security level.

Moreover, a methodology for the assessment and analysis of threats and their socio-political consequences was also produced. The main geopolitical, competitive, monopolistic and other threats were analysed and a partially quantitative system for the evaluation of socio-political consequences of various threats was developed.

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

The researchers of the Laboratory are implementing both the preliminary work for new power plant construction, carried out directly under the order of Visaginas NPP and VATESI, and advanced international scientific research projects that are aimed at developing new nuclear reactors and solving other relevant issues, related to the nuclear safety. Additionally, the researchers take part in projects that aim at sharing knowledge in nuclear energy area with other national infrastructure organizations. These projects are important in strengthening the Lithuanian competence in the nuclear energy field which is necessary for every country owning nuclear power objects.

Work for Visaginas NPP

In 2011, under the agreement *Update* and Complement of Assessment of Potential Visaginas NPP Construction Sites in Respect of External Events between JSC Visaginas NPP and LEI, additional research was continued by analysing the following external factors: human induced



events, meteorological phenomena and site flooding. The aim of this project is to assess the suitability of potential sites for VNPP construction following the Nuclear Safety Requirements, newly approved by State Nuclear Power Safety Inspectorate (VATESI) of the Republic of Lithuania, and the updated Safety Requirements of International Atomic Energy Agency (IAEA) as well as taking into account the results of up-to-date research and data. All work is divided into five separate tasks/ topics: Update of Hazards and Events Assessment. Detailed Assessment of Gas Explosion, Description of Possible Actions due to Extreme Situations, Description of Physical **Protective Means Application Possibilities** and Assessment of Ultimate Heat Sink Characteristics. In 2011, additional research was carried out by assessing unintentional human induced events, meteorological and flooding hazards, a technical certificate "Survey of Statistical Data and Probabilistic Methods" was prepared, and finally, the initial data and updated final reports of separate topics, agreed with the competent authorities, were submitted to the Client.

The results of the performed research may be important while making a decisions regarding a particular VNPP construction site and planning its risk management. Following the recommendations of IAEA, the analysis of external events should be updated if any additional information emerges in the future.

European Technical Safety Organisations Network

The scientists of the Laboratory of Nuclear Installation Safety have been actively participating in the activities of the



European Technical Safety Organisations Network (ETSON) since 2009.

On 7-8 November 2011, the representatives of LEI and other ETSON organizations participated in the EUROSAFE forum Nuclear Safety: New Challenges, Gained Experience and Public Expectations organized in Paris. In cooperation with ETSON organizations, reports were prepared and presented in a separate seminar "Experience Feedback on the Fukushima NPS Accident". The first report of the seminar "Description of the Accident Scenarios, Current Status of the Reactors" was presented by the Director of LEI Prof. E. Ušpuras. The researchers of LEI also actively participated in the preparation of *Position Paper* of the Technical Safety Organizations: **Research Needs in Nuclear Safety for Gen** 2 and Gen 3 NPPs of ETSON. It introduces

relevant and priority directions of research and development of nuclear energy safety, and highlights the collective opinion on priority research and development in the field of nuclear energy expressed by the related ETSON members (BELV – Belgium, GRS – Germany, IRSN – France, VTT – Finland, UJV – the Czech Republic, LEI – Lithuania, VUJE - Slovakia), associated ETSON members (SSTC – Ukraine, JNES – Japan) and safety regulatory bodies, directly enrolled into safety research programmes (CSN -Spain, SSM – Sweden, KFD – the Netherlands). The document was sent to the European Commission, International Atomic Energy Agency, Sustainable Nuclear Energy Technology Platform (SNETP) and other organizations in order to attract attention to relevant research directions in the field of NE safety and initiate projects for the implementation of such research.

In the second meeting of ETSON General Assembly, organized on 9 November 2011, a decision was made to integrate EUROSAFE working groups into ETSON network as umbrella groups (UG). Apart from three already existing umbrella groups (UG 1 – Preparation of Safety Assessment Manual, UG 2 - Scientific Research Programmes, UG 3 – Know-How Management), one more group (UG 4), intended for the research of Fukushima NPP, is going to be established. LEI and its representatives take active participation in all four ETSON umbrella groups. Twelve expert groups that deal with the most important fields of nuclear safety research were also established in ETSON network and the researchers of the Laboratory actively participate in the following eleven 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 ;
- Lifetime-Management (equipment ageing);
- Thermal Hydraulic Analyses (Transients, Accidents);
- Safety concepts, Defence-in-Depth;
- Core behaviour (operational and accident conditions).



International Reactor Innovative and Secure

In 2011, according to the plans for the project *IRIS International <u>Reactor Inno-</u>vative and <u>Secure (IRIS</u>) and the joint agreement between project participants*

and Westinghouse Electric Company LLC, the previously performed research for the preparation of the conceptual IRIS project was summarised and presented in a separate Chapter Analysis of Emergency Planning Zones in Relation to Probabilistic Risk Assessment and Economic Optimization for International Reactor Innovative and Secure of the book Nuclear Power Plants. IRIS project and the related research of Westinghouse Electric Company LLC were completed on 29 November 2010. More than 20 companies and 10 countries participated in the implementation of the project, which took 10 years. During this time, the researchers of LEI participated in the preparation of inter-comparative methodologies and work supervision related to the structural, economic, strength, safety and security research of new reactors. In the recent years, the 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 various external hazards and the uncertainty of the obtained results. As the building of a new NPP in Lithuania is planned, scientific research in this field is relevant for studying the construction of new reactors. The carried on contribution to IAEA technical documentation can be also mentioned as one of the most important activities.



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

The work of the project **SARNET-2** was continued in 2011 (Grant Agreement was signed in 2009). This project aims at the integration of NPP severe accident and operational research in Europe. 41 scientific and business institutions from EU



Results of droplet size simulation

countries, including LEI, participate in this project. The researchers of the Laboratory 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 debris;
- WP7 CONT analysis of processes in containments of NPP.

While implementing these activities, the researchers of the Laboratory participated in the meetings of ASTEC users and separate working groups. They also modelled processes in the INPP spent nuclear fuel pools in the cases of Beyond Design Basis Accidents, and the ones taking place in the experimental facilities. The experiments of nuclear fuel assemblies overheating and fast cooling of damaged fuel, carried out in PHEBUS and QUENCH experimental facilities, were modelled. The modelling was performed using ASTEC and RELAP5/SCDAPSIM codes. The sensitivity and uncertainty analysis was carried out by applying methodology and SUSA code developed by GRS (Germany). In parallel, the analyses were performed with IRSN (France) SUNSET software as well. The specificity of application of these two methodologies for carrying out the analysis was discussed. A similar to the QUENCH experiments re-flooding of fuel assemblies was also modelled in case of an accident in spent nuclear fuel pools.

For analysis of processes in containments of nuclear power plants the processes of sprayed water droplets interaction with atmosphere as well as hydrogen mixing and combustion in the containments were investigated applying COCOSYS code. The researchers of the Laboratory modelled the experiments of water droplets evaporation (EVAP) and steam condensation (COND) carried out in the THAI facility. Apart from LEI, other 9 institutions took part in the benchmark. The results obtained by the researchers of LEI were in agreement with the results received by the most advanced organizations.

The participation in the SARNET activity, exchange of experience with the colleagues from other organizations and the analysis and modelling of processes carried out in experimental facilities provide a better understanding of computer codes and greater experience in modelling, which is required to carry out the analysis of real nuclear facilities.



Safety Assessment of Innovative Reactors

The 7FP application **Proposal for a** Harmonized European Methodology for the Safety Assessment of Innovative Reactors with Fast Neutron Spectrum Planned to be Built in Europe (SARGEN IV) was submitted to the European Commission in April 2011. It is coordinated by the Radioprotection and Nuclear Safety Institute (IRSN, France) and LEI is one of 22 European institutions which participate in the project. The application was approved by the European Commission in June, and a grant agreement was signed between the EC and the coordinator, IRNS in October. A consortium agreement on this project is going to be signed between the coordinator and every scientific research institution participating in the project in the beginning of 2012.

In the scope of the projects, the researchers of LEI are going to take part in the activities of the following three working groups: (1) review of safety assessment methodologies of innovative reactors; (2) experimental application of the European safety methodologies; (3) development the European Action Plan for the scientific research and technologies of fast neutron reactor safety. LEI is going to coordinate the activity in the Task Review of available international documents for the safety assessment of Generation IV reac*tors* in the first mentioned working group.

PHEBUS-FP programme is one of the largest international research programmes for water-cooled nuclear reactor safety and severe accident research. IRSN (France), which initiated the programme in 1988, is presently coordinating it and the Labora-



General model of PHEBUS containment



Mass of aerosols in the gas phase of the containment



Concentration of iodine (I_{2}) in the containment

tory is continuing the research in its scope. Applying COCOSYS code, the Laboratory performs simulations of the phenomena in PHEBUS containment. In 2011, continuing the cooperation with GRS mbH (Germany), an integral model of containment, which enables a detailed analysis of processes during the FPT-2 experiment, was developed. The researchers of the Laboratory were responsible for modelling thermal-dynamic as well as aerosol and radionuclide transport processes, while GRS mbH complemented the model with the description of chemical transformations of iodine. The performed analysis demon-

strated that the jointly developed model may be successfully applied for modelling of all processes in the PHEBUS containment. It also enabled continuation of the long-term cooperation between GRS mbH and the LEI.

MATTER **MATerials TEsting and Rules**

On 13 December 2010, a new agreement on the EU 7FP project MATerials TEsting and Rules was signed. This project started on 1 January 2011. The laboratory of Nuclear Installation Safety and the laboratory of Materials Research and Testing are participating from LEI. Its main objective is to carry out detailed research of material behaviour during the operation of generation IV reactors. The project includes the following activities:

- Mature materials research focused on testing procedures for the new reactors conditions;
- Supporting experiments of mature materials aimed to liquid metals characterization and to pre-normative qualification.
- Pre-normative activities, comprehensive of experiments, to revise and update the design rules.

The research of the project is divided into 15 work packages and the representatives of LEI participate in two of them, namely the 6th package *Manufacturing and Welding* and the 7th package *Testing Activities in Support of Design*. The fatigue test of the cross-weld specimens in air at 550 °C temperature will be performed. The results of the experiments will be used for calculation of the weld coefficients.

In 2011, the analysis of standard documents and other literary sources related to the research of weld fatigue under controlled strain at high temperature was carried out. Following the most successful research of the European scientific institutions, information obtained during consultations and worldwide standards applied for weld tests and research of their properties, experimental procedures and methodology of weld fatigue under controlled strain at high temperature were developed.



Network of Excellence of Nuclear Plant Life Prediction

In 2010, LEI continued activities of **NULIFE** (<u>Nu</u>clear Plant <u>Life</u> Prediction) net-

work 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 2011, the researchers of the Laboratory participated in the activity of the Expert Groups (IA-2) and specialised group for Proposal Preparation (RA-9). Expert Groups (IA-2) prepared the material on "Leak Before Break" methodology applied for austenitic pipeline of RBMK-1500 reactor circulation contour. The material was used for the formulation of the report on national experience in the application of "Leak Before Break" methodology for the assessment of safe operation of pipelines. Moreover, the researchers took part in the workgroup preparing the report Impact of Passive Components on Security and together with NUCLIFE partners from other countries prepared the proposals for FP projects Improved Safety Assessment Procedures based on Probabilistic Considerations (PROSAFE) and Leak before Break in Long Term Operation (LAGOON).

On 14 November 2011, the association **NUGENIA** uniting the networks of excellence, **SNETP**, **Gen II/III**, **NULIFE** and **SARNET**, was founded. The set aims of the Virtual Institute **NULIFE** correspond to the aims of the established association, i.e. technical maintenance of the II and III generation reactors running in the EU countries and scientific research of their lifetime assessment. 7 areas for research and development were also established, namely: nuclear fuel and waste; structural integrity, material ageing and lifetime; safety and risk assessment; severe (beyond) accidents; core and reactor operation; innovative Gen III design; harmonisation activities.



Research of Reliability Characteristics of NPP Operation

In accordance with the agreement between the Institute for Energy at the Joint Research Centre of the European Commission (EC JRC IE) and LEI, the implementation of the research on Reliability and Data Analysis of Passive Components was completed in 2011 and the research report Age-Dependant Reliability Analysis and Risk Minimization for Passive Components was updated. The performed research is related to the APSA research network coordinated by EC JRC IE and representing the Network for Incorporating Ageing Effects into PSA Applications and also related to the already-mentioned EU NULIFE network of excellence. 14 organizations from different countries participate in the APSA research network. Taking into account the impact of equipment degradation and change of their reliability characteristics, the organizations aim at the improvement of the classical probabilistic safety assessment. The application of the classical PSA on the basis of the assumption of constant reliability characteristics sometimes results in an practically and theoretically inadequate safety assessment. In order to perform age dependant PSA, a larger amount of data, inspection assessment and more detailed models are essential.

Continuing the work in the scope of this network in recent years, LEI has devoted most of attention to activities, related to the 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 probabilistic models. Furthermore, the issues of development and application of reliability database and relevant software (e.g. WinBUGS) were considered.



Inspection and Qualification Research

In 2011, LEI, as the member of ENIQ (European Network for Inspection and Qualification) coordinated by EC JRC Institute of Energy, continued the participation in the activities of working group on risk analysis TGR (Task Group on Risk). The researchers participated in the preparation/review of technical documents describing the best European practice in the field of risk-informed inspection programme development and optimization. TGR group of ENIQ research network is comprised of 20 different organizations. Activity of this network is related to the EU NULIFE network of excellence and other FP7 projects.

3. TRANSFER OF KNOWLEDGE ON NUCLEAR SAFETY AND ORGANIZATION OF TRAINING



European Nuclear Safety Training and Tutoring Institute

The European Nuclear Safety Training and Tutoring Institute (ENSTTI) was established in 2010 by ETSON organizations, urged by the Institute for Radiological and Nuclear Safety (IRNS). Recently there are four members in ENSTTI: BELV (Belgium), IRSN (France), GRS (Germany), and LEI (Lithuania). ENSTTI provides vocational training and tutoring in methods and practices required to perform assessments in nuclear safety, nuclear security and radiation protection. 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.

Last year, ENSTTI organised two events: a winter seminar Nuclear Safety Fundamentals which took place on 7-10 February in Slovakia and 4-week summer training (27 June – 22 July) in Germany (GRS). The researchers of the Laboratory gave lectures on the NPP dismantling strategies and particular issues of Ignalina NPP dismantling. 15 participants from four European organizations, namely Areva, Bel-V, IRSN and GRS, participated in the summer training. In the future, ENSTTI is expected to become even more active since it has submitted applications to IAEA and the European Commission regarding the organization of similar training.

Participation in the mentioned activities enables acquiring experience in organizing similar courses and improving 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.



Transfer of the European Regulatory Methodology and Practice to the Nuclear Safety Authority of Belarus

Continuing the cooperation with the European Technical Support Organizations, in May 2011, LEI signed and agreement with RISKAUDIT IRSN/GRS INTERNA-TIONAL (GEIE), established in France, in regard to the participation in the project Transfer of Western European Regulatory Methodology and Practices to the Nuclear Safety Authority of Belarus - Institutional and Technical Cooperation with Gosatomnadzor to Develop its Capabilities on the **Basis of Transferred Western European** Safety Principles and Practices, organized by the European Commission and RISKAUDIT. Under this agreement, the researchers of LEI take part in the activity of



Workshop in Minsk on the European experience in issuing licenses for nuclear power plant sites



Researchers of the Laboratory in Max-Plank-Institut für Plasmaphysik

the following four working groups: (1) development of nuclear safety legislation; (2) support of nuclear safety licensing by establishing a regulatory institution and developing its functions; (3) training of the employees at the regulatory institution; (4) training of the employees at the educational institutions of the Ministry of Emergency Situations. In cooperation with the project partners, the specialists of the Laboratory participated in the workshops, organized by different working groups, where they presented international nuclear safety reguirements and the experience of the European regulatory institutions and technical support organizations related to nuclear power plant safety assessment and licensing of nuclear objects. Moreover, the researchers of the Laboratory took part in the workshops for training the representatives of Belarus to use software packages applied for the analysis of accidents in nuclear power plants. In total, the researchers participated in five workshops in 2011.

LEI was appointed as the leader of the fourth working group and is coordinating the activity of the Lithuanian, Ukrainian and Finish specialists in organizing and running workshops for the employees at the Ministry of Emergency Situations of the Republic of Belarus. In September 2011, the researchers of the Laboratory organized a five-days workshop in the town Svetlaya Roscha, Belarus. Together with the Ukrainian and Finish partners, they presented the main principles of nuclear safety, and introduced the participants to the functions of nuclear safety, emission of radioactive materials during accidents in nuclear power plants, environmental impact and management of emergency situations. A similar workshop, focused on the emergency preparedness in nuclear power plants (on-site) and off-site as well as public information on accidents, is planned next year.

Such support, provided for the neighbouring country, is necessary in order to ensure timely and efficient supervision of the newly-built nuclear power plants in Belarus by its nuclear regulatory institutions, which is especially important not only to Belarus, but also Lithuania (as the plants are going to be built close to the Lithuanian-Byelorussian border) and all Europe.

4. SAFETY ANALYSIS OF THERMONUCLEAR FUSION REACTORS

Scientific research of thermonuclear fusion energy (FUSION) development is one of the priorities of the EU FP7. While implementing the research of this field, LEI continued the work described in **7BP EURATOM – LEI Association Agreement.** In 2011, cooperating with Max-Plank-



General view of the installed thermonuclear fusion equipment W7-X

Institut für Plasmaphysik (Greifswald, Germany), safety analysis was carried out to assess the capacity of plasma vessel venting system. The analysis of the processes in the cooling system was performed by applying RELAP5 code, while COCOSYS code was used to investigate the processes in plasma vessel.

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 and the project was completed in December 2011. The aim of the project was to prepare the finite element models of port welds of the plasma vessel and perform a strength analysis, which was done using ABAQUS/Standard software, intended for solving linear and non-linear problems under static and dynamic loads. The software also enables carrying out strength analysis of components made from different geometric forms. The structural integrity analysis of the welding connections was analysed for the following ports / port combinations:

- port AEQ20 given 1 mm thick weld;
- port AEK20 given 1 mm thick weld;
- port AEU30 given 1 mm and 6 mm thick welds.

The prepared geometric models were transferred to the finite element software ABAQUS/Standard which was applied for preparing finite element models of port welds of the plasma vessel. The analysis was carried out under the set loads and in the limit case using global scaling factors (SF) 3.0. According to the results of analysis it is possible to conclude that the stability of the all welding between Plasma Vessel and ports will be sustained at all used loading for analysis. In case of limit analysis it was not detected the fact that displacement of the point where loads are applied starts to increase very rapidly and the convergence was never lost during the analysis. The results shows that biggest plastic strain was occurred in port AEU30 with gap 6 mm. The biggest displacement was occurred in this port also. The figures (a-d) present the prepared models of this port weld and some of the obtained results.

5. RESEARCH OF CONDENSATION IMPLOSION

The state subsidy funded research project *Numerical and Experimental Re*search of Condensing Two-Phase Flow



FE model of the welding connection between the port AEU30 and the PV shell with 6 mm gap (a) and the calculation results of the limit analysis (b – displacement distribution in model; c – stress distribution in solid modelled elements (weld, plasma vessel and AEU30 port); d – distribution of equivalent plastic strain at integration points of weld seam)

was successfully completed. During its implementation, a numerical model for thermal-hydraulic system, which uses condensation implosions for circulation, was developed and its practical applicability was justified. This suggests that having analysed and mastered this process, its use for passive return (without external energy) of liquid heat-carrier to the boiler of actual thermal equipment will become possible.



Condensation implosion-driven thermal circulation contour

Some significant results were also obtained from the research of the impact of condensation on stratified coocurrent flow in a closed horizontal channel. It was determined that condensation influences hydrodynamic boundary layer of the steam flow. The impact of condensation on interphase friction was modelled using the data obtained by natural experiments, which enabled the application of the simple numerical single-phase flow model FLUENT3D.

The experimental research was carried out using high-speed thermographic technique, which was applied a specially developed methodology for temperature profile measuring. Recommendations for its usage were provided, and the speed of



FLUENT3D numerical model for single-phase flow



Temperature profiles in a closed horizontal channel

25 measurements per second with the resolution of 10 measurements for 1 mm of the cross-section was achieved.

6. 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*, initiated in 2010, was further continued in 2011. 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 the hydrological processes.

Performing the numerical research in technical systems, the processes taking place during severe accidents in nuclear



Comparison of maximal temperature of fuel tablets, determined during the FPT1 experiment carried out in PHEBUS experimental facility, with temperatures calculated employed best estimate methodology

reactors were modelled. The best estimate methodology, ICARE module of ASTEC code, as well as SUSA and SUNSET packages were applied for modelling the FPT1 experiment carried out in PHEBUS experimental facility. The best estimate analysis demonstrated that having assessed the applied uncertainties of the physical and software parameters, ICARE module is capable to simulate the main processes taking place in the fuel during severe accidents. Specific aspects of the application of different codes were also determined.

In 2011, the uncertainty and sensitivity analysis was carried out to examine the impact of shifting to the broader use of biofuel on the Lithuanian economy. The uncertainty and sensitivity analysis methodology devised by GRS (Germany) and SUSA code were used to determine the parameters that have the greatest influence on both the trade balance and general valueadded. The obtained results are going to be applied for the development and improvement of more implicated tools for energy-economy interrelation analysis.

Best estimate methodology was used for solving issues related to the environmental system: the influence of uncertainty of the elements of long-term water balance of the Curonian Lagoon on the water balance calculation results was assessed. The performed uncertainty and sensitivity analysis revealed the parameters of hydrological modelling that have the greatest impact on the balance; i.e. the parameters that require further revision in order to calculate the water balance of the Curonian Lagoon.

7. SECURITY OF ENERGY SUPPLY ASSESSMENT

In 2011, a three-year state subsidy funded research project *Lithuanian Energy Security Research* was completed. Its main result is the estimation of the Lithuanian energy security level during various periods of time till 2025 and its comparison to the energy security level of the USA.

8. PROJECTS OF DECONTAMINATION AND DISMANTLING OF IGNALINA NPP EQUIPMENT

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

Last year, the Laboratory received an official letter from the INPP about the successful completion of the project *Development of the Ignalina NPP 117/1 Building Equipment Decontamination and Dismantling Project (B9-0)*. It is the first project in Lithuania devoted for dismantling and decontamination of NPP equipment. The project was implemented by Babcock Nuclear Limited (United Kingdom), Nukem Technologies GmbH (Germany) and LEI consortium. The main objective of the project was 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 the Lithuanian Authorities) and during the implementation of the project.

In the end of 2010, the State Nuclear Power Safety Inspectorate (VATESI) granted a permission for initiating the decontamination and dismantling of equipment in the INPP Building 117/1. The possibility to provide support for INPP in carrying out the work was included into the B9-0 project, but the INPP decided not to take it and manage without the help of the Contractor (consortium) in the stage of project initiation. As stated by the representatives of the INPP, this shows the trust of the Client in the work done during the previous stages, i.e. preparing the documentation of the project and agreeing it with VATESI.





Dismantling of equipment in the INPP Building117

Development of the Ignalina NPP V1 **Building Equipment Decontamination and** Dismantling Project (B9-2) was continued in 2011. This project is under the 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 the reactor. The researchers of the Laboratory also participated in the preparation of the Detailed Design Documentation and provided support during the licensing of Safety Justification Report. The preparation of the Detailed Design Documentation is going to be finished and agreed with the Client in 2012; the work related to the licensing of the project documentation is also going to be completed.

According to the agreement with GNS (Gesselshaft für Nuklear-Service mbH, Germany), a project *Modification or Re-* placement of the cask handling Systems in the Spent fuel halls (SPH)at Ignalina **NPP** was continued in 2011. The work is carried out in cooperation with SC TECOS and AB machinery plant ASTRA. During its implementation, 6 shock-absorbers (3 in each INPP unit) and other equipment for cask handling are going to be produced and installed in the spent fuel halls of the NPP. The purpose of the main equipment, i.e. the shock-absorbers, is to absorb energy in case of earthquake or drop of containers filled with spent nuclear fuel, ensuring that the loads on the building and container constructions will not exceed the allowed limits. In 2011, shock-absorbers Type 1, cask service station and steel cover metal overlay of the INPP pool 338/1 were



First-type shock-absorber during and after the production



manufactured. During the manufacture stage of the shock-absorber, technical improvements of equipment (design optimization of lugs for shock-absorbers, etc.) were discussed and adopted in regard to the request of the Client.

9. OTHER PROJECTS



Product and Process Design for Aml Supported Energy Efficient Manufacturing Installations

During the second-year of project implementation, coordinated by LEI Energy Efficiency Research and Information Center, the researchers of the Laboratory developed so called laboratory and early prototypes of Energy Simulator as one of the ICT component of the DEMI project and initiated the implementation of all planned tasks in order to develop the final prototype. Moreover, the development of the model for estimating the energy, consumed in the process of steel construction treatment, was initiated by applying (a partially modified) design and modelling concept of a compressed air system. Practical usage of compressed air modelling as well as modelling of other systems is intended for the preservation of the common structure of model configuration and relevant data.

On the basis of the acquired experience in hybrid system modelling and modern possibilities of ICT, universal software and related modelling methods for designing industrial systems were developed. Such tools of modelling and energy consumption estimation operate in accordance with system configuration, design requirements and boundary conditions, which are remotely defined by Energy Analyzer. System models, representing different controlling of a system and its processes variables (e.g. air pressure and flow) as well as different operation conditions (e.g. consumption of compressed air), are developed using MATLAB (Simulink and SimScape) software and applying tools created for automatic modelling and energy consumption estimation.

Feasibility Study on Application of Decomposition Methods for Complex Networks

In 2011, LEI started a new research in the risk and vulnerability assessment area of critical infrastructures (CI). In the scope of this topic, the Feasibility Study on Application of Decomposition Methods for Complex Networks was initiated in 2011 under the agreement between the Institute for Energy at the Joint Research Centre of the European Commission (EC JRC IE) and LEI. Many of the CI infrastructures, especially the ones in the energy sector, are complicated network systems (e.g. electricity system, gas or oil transportation and distribution systems). The analysis of such integrated systems is complicated and requires vast human and technical resources due to its scope. One of the possible solutions to such problem is the application of decomposition method: the problem is divided into simpler problems according to predefined rules and then the obtained results are recombined in order to obtain solution for the initial problem. During the feasibility study, possible application of the decomposition method for analysis of complex networks as well as the advantages and drawbacks of the method are going to be assessed.

R-Tech RBI Atlas

Risk-Based Inspection Atlas

After coming across the material of the seminar *Future of standardization of*

Risk-Based Inspection and Maintenance in Europe, based on further development of CWA 15740, which was held on 15 February in Munich, the researchers of the Laboratory joined the implementation of the **RBI** Atlas project. The project and seminar were arranged in regard to the already completed and newly organized activity of European Virtual Institute for Integrated Risk Management (EU-VRi).

RBI Atlas project is intended for the European harmonization of the various EU national regulatory requirements in the area of risk-based inspection and maintenance. The inspection and maintenance must ensure that the accepted level of risk related to safety, health, environment and business/production/operation is achieved. The main objective of **RBI Atlas** project is to support the development of the European Standard for the relevant area. The future development of the Standard is based on the frame of the CWA (European Committee for Standardization – <u>CEN Workshop</u> Agreement) 15740:2008 which specifies the essential elements for risk-based assessment of industrial assets according to the RIMAP (Risk-based Inspection and Maintenance Procedures for European Industry) approach. To reach this aim, the company Steinbeis Advanced Risk Technologies (R-Tech) has collected information on the inspection practices followed in various European and non-European countries and represented it in the socalled RBI Atlas. It shows the status of Risk Based Inspection in each country representing it as the current allowed, not allowed or conditional. In order to update the information about the current RBI status and promote the cooperation, R-Tech is searching for competent persons and institutions in different countries. In such way, the information about Lithuania was updated after LEI had joined the project in 2011. For future cooperation, the representative of LEI is informed about other projects and new EU-VRi activity.



The researchers of the Laboratory actively participated in **CYSENI** conference

10. RESEARCHERS' QUALIFICATION AND PUBLICATION OF SCIENTIFIC RESULTS

In 2011, there were 13 doctoral students in Laboratory of Nuclear Installation Safety who, together with experienced scientists, presented the research results in science research reports. 60 scientific articles were published (including 12 articles in ISI indexed journals) and 37 papers were presented in scientific conferences. The researchers of the Laboratory participated in the events related to nuclear energy and presented papers in all main international conferences, where safe operation of nuclear power plants and physical phenomena occurring in them were analysed. The 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.

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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 scope of a new state subsidy funded scientific research project **Devel**opment of Multiobjective Decision Making Model and its Application in the Lithuanian Energy Sector, the multiobjective decision making methodology oriented towards energy sector was improved and a computerised multiobjective decision making model for the Lithuanian energy sector was prepared. It was applied in the power system by carrying out a comparative analysis of power plants, using different electricity generation technologies, on the basis of the determination of market value. The prepared model enables taking into account the majority of factors influencing the value of the object and assessing their impact on the value of the analysed objects. In the interim report of this project, a pilot research of the pre-

pared multiobjective decision making model, intended for the assessment of 4 electricity generation technologies used in Lithuania, was presented by applying the model. To implement the model, the objects of the power system that make use of different electricity generation technologies and primary energy resources were selected. To be more precise, the objects include Kruonis Pumped Storage Power Plant, Kaunas Hydro Power Plant, Lithuanian Power Plant and experimental geothermal power plant. The prepared model was applied in the research project Comparative Assessment of Geological Disposal of Carbon Dioxide and Nuclear Waste in Lithuania coordinated by International Atomic Energy Agency (IAEA).

Moreover, during the implementation of this project, Dr. J. Šliogerienė, who won

the contest of the Research Council of Lithuania for post-doctoral placement *Development of Decision Support System for the Assessment of Energy Production Technologies*, was accepted to the post-doctoral studies. During the placement, she directly contributed to the scientific research project *Development of Multiobjective Decision Making Model and its Application in the Lithuanian Energy Sector* in the development of the computerised decision making model and its application for making decisions in the Lithuanian energy sector.

Continuing the state subsidy funded scientific research project *Analysis 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, research by applying simplified models was carried out in 2011. In the future, the results of this research will be used for developing and improving more complicated tools for the analysis of energy-economy interrelationship. The best estimate methodology was applied for shifting to a wider use of biofuel and the analysis of social and economic effects. This type of research always poses a problem of information limitation; therefore, the principal role goes to the sensitivity and uncertainty analysis aiming at scientifically grounded and reliable results. The interim report of this project describes the methodology, employed for analysing the impact of structural changes in the energy sector on the value-added, employment, payment balance, created in different economic sectors, and presents calculation results, obtained by modelling the increase of biofuel share in the production of district heat.

In the completed subsidy funded scientific research *Lithuanian Energy Security Research*, implemented together with the Laboratory of Nuclear Installation Safety, the researchers of the Laboratory made a considerable contribution to the preparation of the Lithuanian energy security assessment model and generalisation of the application of mathematical modelling for investigating the importance of different energy security factors.



Research Council of Lithuania

The project *Development of Methodology for Optimal Integration of Future Technologies into Energy Sector* of the national scientific programme *Energy for the Future*, implemented in co-operation with the experts of Laboratory of Regional Energy Development and Laboratory of Systems Control and Automation, is especially important for justifying the competence of the scientists of the Laboratory. In the first stage of the project, a conception of optimal integration of future technologies into energy sector, including the stages of planning, installation and operation, was prepared. It increases the objectivity and reliability of future technologies efficiency assessment. During planning, the conception follows an objective assessment of future technologies efficiency obtained from an exhaustive research on long-term development of the energy sector. The conception provides for the implementation of energy technologies integration into the energy sector which would not disturb and, more importantly, promote the growth of the national economy; it is oriented towards analysing the possibilities and scope of future technologies efficiency and their optimal integration into the energy sector not only in the context of long-term development of the sector, but also by assessing the relation of the sector with the overall economy of the country. The goal of such principle of future technologies integration is to intercombine the activities of energy and other economic sectors so that maximal discounted social welfare was achieved during the analysed long period of time. The selection of criteria describing social welfare depends on the set of aims and the understanding of welfare. It is greatly influenced by the amount of the general value-added that may be created in the country and the funds allocated from the national GDP for ensuring the welfare. Thus, the scope of private and public consumption may be seen as indirect index of social welfare. For this reason, the maximization of consumption or minimization of expenses on the development and operation of economic sectors are possible partial substitutes for the maximization of social welfare.

In the package of mathematical models for optimal integration of future technologies into the energy sector, the economy of the country is modelled by applying a dynamic model of general economic equilibrium. Aiming at public benefit by integrating and installing advanced technologies into the energy sector, support schemes often become necessary to motivate separate economic subjects so that by serving their own interests they would target their activity towards satisfying the needs of the society. For the exploitation of future technologies favourable legal and economic conditions as well as support measures are relevant. The conception of optimal integration of future technologies into the energy sector is focused on the assessment of factors influencing different future technologies, reduction of their negative effect, justification and preparation of support measures.

The model of long-term development analysis of the energy sector is formulated by principle of blocks with technological and territorial dimensions. Separate blocks are applied for modelling of primary energy supply systems, systems of primary energy conversion into secondary, measures enhancing energy efficiency in separate industrial sectors, etc. The same database of the model can be used for generation of different modular-level systems, present in separate blocks of the model. This enables a rather detailed modelling of one or several analysed systems, whereas other systems that require less attention in respect of the developmental analysis are modelled in an aggregated manner. Following such principle explains the energy system of a separate region in detail at the same time maintaining the relation with the energy sector and the national economy on the whole. In comparison to other means of integration of future technologies into energy sector, the uniqueness and advantage of the proposed conception is based on the integral, flexible and universal mathematical model of the energy sector, as well as the assessment of threestage life cycle of future technologies and the use of dynamic model of general economic equilibrium for the assessment of energy and economy interrelation.

The multiobjective decision making methodology for the energy sector, assessing the applied methods and the areas of their application as well as analysing operational stages in detail, was prepared. It functions as an additional measure to the proposed conception of optimal integration of future technologies into the energy sector and complements the optimization models system applied for the selection of future technologies. The system is necessary for final selection of the obtained equivalent solutions if this requires the assessment of additional criteria, which were not applied in optimization models, after the calculation has been performed.

The EU support schemes intended for the promotion of wider use of renewable energy sources for electricity and district heat production as well as their development in the transport sector. Depending on the stage the support schemes are applied in, they partially or fully cover either investment or exploitation expenses for future technology installation, or both. The effectiveness of the schemes is determined by the stability of support policy making, reduction of project risk and stable financial source independent from the state budget.

SCIENTIFIC RESEARCH WORK FOR THE NATIONAL ECONOMY

Continuing the research on the 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 focused on the analysis of 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. To solve this task the mathematical model was developed in the Laboratory, encompassing the energy systems of all municipalities in Lithuania and enabling the preparation of investment plan into sources of district heat production, was improved. The implementation of such plan is one of the preconditions for achieving the aims set in the EU Directive 2009/28/EC on the promotion of the use of energy from renewable sources. The paper presents the analysis of the up-to-date legislation affecting the development of district heat supply carried out by the researchers of the Laboratory, the identified methodical principles for preparing the integral investment plan, means necessary for its implementation, and impact assessment. The research demonstrated that the implementation of the investment plan and shift to the wider use of biofuel in district heat supply system will require considerable investment. However, a similar amount of investment would be necessary to update the currently used sources to meet the stricter pollution limits following the requirements of the EU Directive 96/ 61/EC on integrated pollution prevention and control.

In the study, a clear, concrete and grounded Integrated Investment Plan for the district heat supply was prepared. It shows all principal investment projects and the demand of financing until 2020. It was determined that installation of combined heat and electricity production should be used as the main source for the production of district heat. The share of such heat should be increased up to 80% in 2020, whereas in 2011-2020, about 3.7 GW of new and updated heat production sources (1.5 GW of them running on renewable energy)

sources) are to be launched. The total capacity of boiler-houses and combined heat and power plants fired by biofuel will amount to 725 MW and 900 MW respectively in 2020. To implement the reform of district heat supply systems, including the introduction of environmental protection, will require the investment of almost LTL 3 billion in 2011–2020. On the other hand, the implementation of the integrated investment plan in this sector would be especially beneficial for state and municipal budgets due to the attraction of local investments and wider use of biofuel.

Wider use of biofuel for energy production determines the necessity for appropriate organization of its accounting. This issue was analysed in the scientific research Rules for Accounting Solid **Biofuel in Energy Production Sources** under the order of the Lithuanian District Heating Association. The relevance of the rules is governed by many factors: in 2011-2012 the price of heat supplied to the consumers markedly grew due to the increased price of natural gas prevailing in the balance of the district heating sector; the advantages of biofuel and the possibility to reduce the energy production costs are still not fully used; the insulation of multifamily houses is going very slowly, which impedes the reduction of heat demand: due to economic recession the real income of the citizens is diminishing and the income-expenditure balance of households is getting worse; the anticipated wider use of biofuel for heat and electricity production enhance the necessity to establish smooth relationship between suppliers and purchasers, at the same time increasing the transparency in accounting the use of biofuel; the appropriate organization of biofuel accounting provides favourable preconditions for the more efficient use of local energy sources and consolidation of trust not only between biofuel suppliers and purchasers, but also between heat producers and consumers. Aiming at the implementation of the main provision of the prepared rules for biofuel, i.e. accounting the biofuel from its arrival to the company to its use for energy production, the principles were formalised in six chapters as well as forms of biofuel motion suited for such accounting in each company. The key principle of biofuel accounting is the determination of energy value of fuel supplied to the heat and/ or electricity production company following the indexes of biofuel quality and quantity.

The Rules define the relationship and mutual responsibility of the supplier and purchaser, methods of biofuel acceptance, principles of operational and technical accounting, requirements for determining the key quality indexes (moisture content, ash content and net calorific value), regularity and methods of biofuel inventorization.

As an order of the main national energy associations (*Lithuanian District Heat*- ing Association, Lithuanian Electricity Association, Lithuanian Association of Biomass Producers and Suppliers, Lithuanian Electricity Producers Association and Lithuanian Energy Consultants Association), the annual publication **Energy in** Lithuania 2010 on statistical data was published. It presents the up-to-date information describing tendencies in the development of the Lithuanian energy sector and its branches in 2007-2010 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 (2009 and 2010). It also includes data on the amounts of greenhouse gas, emitted in 2009, and its structure according to the sectors in the Annex 1 countries to the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

Moreover, the comparative indicators of the EU countries, largest world coun-

tries 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 2008 and 2009 are presented in the publication. These comparative indicators were prepared following methodology of the International Energy Agency, which does not include electricity losses in the network into electricity consumption, but incorporates non-energy use into the balance of the final energy consumption.

The publication summarises the changes in the national economy and energy sector. In 2000–2008 the Lithuanian economy rapidly grew, but declined by 14.8% in 2009. Next year, in 2010, the GDP increased by 1.4% and amounted to LTL 76.2 billion (in total) or LTL 23.2 thousand per capita. In 2010, the primary energy consumption decreased by 18.9% and comprised 7.04 million toe, whereas the final



Main energy flows in Lithuania in 2010, thous. toe



energy consumption for energy needs rose by 3.7% and equalled to 4.76 million toe. Furthermore, the final electricity consumption decreased by 0.5% and amounted to 8.33 TWh, while the primary energy consumption per unit of GDP dropped by 20.1%, and the final energy intensity increased by 1.5%.

This publication was prepared in close cooperation with the specialists of *the Statistics Lithuania, Lithuanian District Heating Association,* specialists of energy companies and associations. The information invoked in the preparation of the publication was taken from the publications of the *Statistics Lithuania* (Energy Balance, 2008, 2009 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 2011.

Under the agreement with the Ministry of Environment, a scientific research *Experimental Data Analysis of National Greenhouse Gas Emission Account 2010 in Energy Sector* was carried out. The most important practical result of the research is the National Inventory of Greenhouse Gas in Energy Sector prepared following the requirements of the European Parliament and Council decision No. 280/2004/ EC on the mechanism of the monitoring of greenhouse gas emissions in the European Communities and implementing the Kyoto Protocol and the methodology of Intergovernmental Panel on Climate Change.

Following the agreement with JSC Danet Baltic, the scientific research of the international project Feasibility Study of Liquefied Natural Gas (LNG) Import assigned to LEI was completed. Under the order of Science Applications International **Corporation (USA)**, which prepared the mentioned study in 2011, the researchers of the Laboratory have carried out a comprehensive analysis of natural gas consumption in the Baltic countries and Kaliningrad region. 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 the 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.

The scientific research *Hydraulic and Economic Calculation of the Lithuanian Natural Gas Highway Networks Operational Modes* ordered by *Projektų centras*, a member of *Achema Group*, was carried out by the Laboratory. The research presents the characteristic of the current condition of natural gas supply system, discusses the planed alternatives of its development, provides analysis of natural gas use variation for energy and non-energy needs, describes the methodology for regional distribution of natural gas demand, and proposes scenarios of long-term demand for natural gas, grounded on the economic modelling of the energy sector development. On the basis of the calculation of hydraulic gas flows, long-term operation modes of natural gas supply system were analysed as well.

The research *Methodical Recommendations for the Use of Renewable Energy Supply System in Buildings* under the voucher agreement No. 31V-127 was implemented in 2011.

The prepared methodological recommendations will contribute to updating the renewable energy supply systems, and preparing the energy supply projects for buildings in accordance to the requirements of the Directive 2009/28/EC on the promotion of the use of energy from renewable sources and other legislation. The prepared methodology, presented to the company ST projektai, was also applied for the preparation of Feasibility Study of Renewable Energy Heating of Klausučiai Village Community Houses. Such studies are especially relevant for developing renovation projects of energy inefficient buildings and aiming at the reduction of heat consumption in buildings by diminishing the price of the supplied heat at the same time.

PARTICIPATION IN THE INTERNATIONAL PROGRAMMES

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

Relevant questions regarding the Lithuanian energy sector development, including aspects of wider use of renewable energy sources, were analysed in interna-

RES-H POLICY

tional projects of the *Intelligent Energy* -*Europe*. In 2011, the implementation of two projects, *Policy Development for Improving RES-H/C Penetration in European Member States (RES-H Policy)* and *Shaping an Effective and Efficient European Renewable Energy Market (RE-SHAP-ING)*, was continued. Experience accumulated during the implementation of the projects was disseminated by organizing seminars in Latvia and Lithuania.

On 30 March 2011, the experts of the Laboratory together with the Institute of Physical Energetics (Latvia) and the leaders of the *RES-H Policy* consortium arranged a seminar *Improving the Policy Framework for Renewable Heating in Latvia.* Over 30 specialists from various Latvian energy companies participated in the seminar which took place in Latvian Academy of Sciences.

The final conference *Improving Renewable Energy Policy Framework in the Lithuanian Heating Sector* of the project *Policy Development for Improving RES-H/C Penetration in European Member States (RES-H Policy)* was organized on 27 April 2011, in Vilnius. 35 experts from various Lithuanian energy companies participated in it.

On 16 May 2011, the experts of the Laboratory together with the leaders of the *RE-SPAPING* project consortium organized



a seminar Shaping an Effective and Efficient European Renewable Energy Market. It was visited by the representatives of the Ministry of Energy, National Control Commission for Prices and Energy, Lithuanian District Heating Association and other institutions.



The project *Comparative Analysis of the Storage of Nuclear Waste and Carbon Dioxide* (CO_2), coordinated by the IAEA, was successfully completed. The possibilities of carbon dioxide storage and nuclear fuel burial in Lithuania were analysed, economic-technical assessment of possible storage equipment was performed and preliminary recommendations were prepared. The results of the project are going to be published in the IAEA Technical Document.

The researchers of the Laboratory were responsible for the preparation of the Chapter *Geological Disposal Costs of Carbon Dioxide and Spent Nuclear Fuel*. It analyses and summarises the assessment of geological disposal costs of carbon dioxide and spent nuclear fuel in all countries-project partners. Moreover, a service agreement with IAEA on the publication of the project results in a prestigious scientific journal was signed.

In 2011 the researchers of the Laboratory were invited to participate in the preparation of the international project *European Climate Change Policy Monitoring: 2011 Update* under the cooperation agreement with *Ecofys Germany GmbH*. They successfully fulfilled the given task and submitted the assessment of climate change mitigation policy in Lithuania, Latvia, Estonia, Slovakia and Slovenia.

The researchers of the Laboratory greatly contributed to the initiative of the Nordic Council of Ministers and BASREC (the Baltic Sea Region Energy Cooperation founded in 1998) to establish a Baltic Rotating Energy Planning Academy, BALREPA. The members of the Academy are divided into two groups depending on their influence to the making of decisions. Such governing of the Academy enables the representatives of the national and local authorities, energy companies, scientific research organizations and non-governmental organizations to engage in the joint activity, exchange knowledge and experience to facilitate the solution of relevant energy planning issues. The first such workshops in 2011 took place in Kaliningrad and Vilnius. Chief research associate, Dr. Arvydas Galinis gave lectures and shared the accumulated experience in mathematical modelling of longterm development with the participants of the workshop. The employees of the Laboratory, Viktorija Bobinaitė and Paulius Seniūnas took part in the workshop in Vilnius, while Vidas Lekavičius in Kaliningrad. The scientists are also going to participate in other BALREPA workshops which are going to be organized in a different state of the Baltic Region.

Experience gained in the Laboratory is used at the international level:

In July 2011 in the IAEA headquarters (Vienna), a training course was organized to prepare the specialists to model scenarios of the energy sector development. As an expert delegated by this agency, Dr. A. Galinis, responsible for application of MESSAGE model to solve tasks of long-term energy planning, shared his experience with the Georgian specialists who are preparing long-term development programme of the national energy sector. In October he gave lectures and supervised practical training of specialists-instructors of modelling who prepare national experts.

- The assessment of the programmes Energy Modelling, Databases and Strengthening of Capabilities as well as Energy, Economic and Environmental Analysis in the scope of the IAEA Planning and Economic Studies Section is currently in progress (Dr. D. Štreimikiene). The aim of the assessment is to determine the conformity of these programmes to the IAEA priority objectives and the efficiency of their implementation on the basis of many criteria and indicators. An important aspect of the assessment is the preparation of recommendations concerning the improvement of programmes in progress.
- On 8–19 August 2011, Egidijus Norvaiša was improving his gualification in training courses Developing National Long-Range Nuclear Energy Strategies organized by the IAEA in the Argonne National Laboratory, in the USA. He found it useful to familiarize with new tools and methodologies applied for planning of energy systems by focusing most attention to justify the development of nuclear energy. A considerable part of the course was intended for INPRO methodology, applied for the assessment of long-term sustainability of nuclear energy development, focusing on its guidelines and specifications of its use for long-term planning.
- The researchers of the Laboratory actively took part in the preparation and implementation of the FP7 project *Researchers' Night 2011* (LT-2011), which was carried out together with the Lithuanian Society of Young Re-



E. Norvaiša was presented with certificate of the IAEA training completion

searchers, 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 co-operation with the Lithuanian Academy of Sciences and Association for Energy Economics, the Laboratory organized a conference *Lithuanian Energy after Economic Crisis and Ignalina NPP Shutdown*, which took place on 26 September 2011, in Vilnius. The participants discussed the relevant issues of the Lithuanian energy sector and perspectives of energy systems development taking into account the essential changes in energy generation technologies, primary energy supply and consumption as well as international energy market development.

In 2011, the researchers of the Laboratory participated in the conferences in Austria, Chile, Latvia, Sweden, Turkey, Germany and other countries, where 11 papers were presented. The researchers of the Laboratory published 12 scientific articles in Lithuanian and international journals and proceedings of international conferences (5 publications are included into the list of Information Sciences Institute).

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LABORATORY of REGIONAL ENERGY DEVELOPMENT

MAIN RESEARCH AREAS OF THE LABORATORY:

- methodological justification of sustainable energy development conception;
- development of methods and measures for regional energy planning;
- impact assessment of measures for the promotion of sustainable energy development.

OBJECTS AND TASKS OF THE RESEARCH

Strategic documents of the EU and Lithuania stress the importance of scientific research directed towards the main objectives of the energy policy, i.e. the implementation of energy supply security and reliability, more efficient energy production and consumption, wider use of renewable energy sources (RES). Different countries apply different promotion and regulation measures which stimulate the demand of respective technologies, products and services in the market. Only when the demand is high enough, the basis for progressive technologies and solutions is obtained and the successful development as well as implementation of strategic objectives is ensured.

The assessment of impact of promotion measures often lacks objective criteria. The businesses aim at more favourable conditions to secure their investments and ensure the profitability, while the state support to the development of some technologies distorts the market competitiveness and increases the consumers' expenses. On the other hand, insufficient support and great risk of investment deter potential investors, which results in the absence of potential benefits from the application of new technologies.

The attention is currently focused on the technological progress which notably outpaces the implemented state, organizational and fiscal measures. Balancing all promotion measures to make them versatile, rather than single-targeted, is also an important task. At present, many countries are forced to alter the economical promotion policy, because the increased technology supply has generated the interest of businesses and investment due to the applied favourable energy purchase tariffs. However, an uncontrolled development of such technologies would increase energy production costs which are paid by all energy consumers. The justification of promotion preconditions and measures requires assessing their benefits and longterm usefulness regarding different aspects, which would serve as the basis for the development of economic, regulatory and organizational promotion system. The main objective in justifying the scope of promotion measures is to estimate or otherwise determine their public benefit which reveals itself through energy supply security and reliability, accessibility to all consumers, solution of urban and rural social issues, averting negative environmental impact, etc.

Nevertheless, the assessment of expedience and impact of promotion measures is still a new area; thus, searching for solutions requires following the international-level or indirectly related research and methods enabling a more versatile assessment of the measures. This holds for both the assessment of future usefulness of technologies, and the applied organizational and regulatory forms of the measures. The effectiveness of various regional or urban programmes, use of waste energy, regulation of emissions, energy efficiency and eco-labelling schemes of appliances, equipment or systems as well as buildings must be analysed following a general assessment methodology.

The supply of many perspective energy saving and RES-based technologies is limited by the slowly increasing demand; formation of the demand for RES technologies is a rather poorly investigated issue. The users of RES technologies to whom different support measures should be applied have not been clearly identified yet. The users of RES may encompass both power plants of district heating companies (boiler-houses or CHP plants) and separate buildings using biomass, geothermal installations or solar collectors for generating heat and hot water.

The scientific problem is related to the objective assessment of the public benefit due to the RES development capable of revealing the advantages which could not be disclosed by assessing financial benefits and solving the environmental and social problems at the same time. Singlevalued identification of solutions is usually impossible since the problem itself is diverse. This requires versatile knowledge which could be systemized and purposefully disseminated.

The work carried out in 2011 enabled improving the understanding of the methodology by supplementing it with theoretical analysis widely describing the methodology formation process. The prepared methodology has broad application perspectives. Energy sector is analysed as all flows of energy resources, currently used and possible to use or save (saving is an alternative energy source), and influencing the national development in terms of economic, social and environmental aspects as well as reliable supply and renewable energy. The essence and purpose of the methodology are to determine the missing links in the development of sustainable energy development by analyzing the overall energy sector in respect of energy sources. This opens the door for promising directions of economic research and solutions by approaching the existing and



Dr. V. Kveselis is presenting a report in the meeting of the European Parliament ITRE Committee

future technologies for energy production transformation, distribution and saving as well as their organizational interconnection into complexes as the means stimulating the national economic and social advancement.

The necessity for the formation of general energy policy has been highlighted for several years, but it is impossible without a common attitude towards the perspective of using separate types of fuel as a part of making strategic solutions as well as implementing them. The combination of different, sometimes even opposite and hardly-achievable, aims is what the methodology for assessing aspects of sustainability is targeted at.

The performed work provided a possibility for 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 the current energy sector has few market segments where objective conditions for competitive market would be possible. The common feature in respect of sustainable development is that although the market is perceived 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. One of the most important advantages of such work is that the topic enables directing the efforts of the scientists and researchers, working in different fields and solving energy issues, and the research of students, doctoral candidates and researchers towards the common goal.



Prof. Dr. Habil. V. Klevas, together with the scientists of the Faculty of Economy and Management at Kaunas University of Technology, prepared an application for *Long-Term Institutional Support for Eco-* nomic Research Programme. The Research Council of Lithuania of 2011-2013 acknowledged it as the best application out of 5 and assigned to prepare the final version of the programme for the implementation from 2012. V. Klevas submitted an application to *RCL Scientists Initiative to Develop Projects* 2011-2012 under the topic "Economic Justification of Demand for Renewable Energy Sources". It was acknowledged as deserving financing and was initiated.

INTERNATIONAL COOPERATION

The researchers of the Laboratory not only carry out national research, but also participate in many international projects contributing to the former and the spread of information. The greatest amount of research is performed in the scope of *Intelligent Energy – Europe* programme.



In 2011 the Laboratory continued the project **Regions Paving Way for a Sustainable Energy Europe (ENNEREG),** financed by the European Union. 12 European regions, supporting the initiative of the Covenant of Mayors and participating in the project, initiated the implementation of the energy and environmental protection goals set by the European Union, i.e. to reduce carbon dioxide emissions by 20%, increase the share of renewable energy sources up to 20% of final energy consumption, and improve the efficiency of energy consumption by 20%. The researchers prepared a Sustainable Energy Action Plan for Kaunas Region, representing Lithuania, and presented it during the meeting with the representatives of municipalities. The Plan is aimed to facilitate the fulfilment of new obligations of the municipalities provided for by the Law on Renewable Energy to prepare and implement the Renewable Energy Action Plans which are an essential part of Sustainable Energy Action Plan. Sustainable energy development is also carried out in other regions of the country; cooperation with Šilutė municipality has been initiated.

The most important activity of the project is the dissemination of information about sustainable energy in the society. On 11-15 April 2011, the EU Sustainable Energy Week was organized in all the EU countries. Together with Kaunas Regional Energy Agency, the project implementers who participated in the event conducted a science promotion conference about renewable energy for the students and teachers of Kaunas City schools, and visited the event organized for Sustainable Energy Week in Kaunas Juozas Urbšys Catholic Secondary School. Special attention given to the education of the young is important in terms of they are the most receptive social group. Moreover, information about the possibilities to develop renewable energy production using local agricultural materials was provided for farmers and producers of biofuel. The project implementers prepared a considerable amount of educational material aimed at various social groups.

To browse and download the whole material for the regions, visit *www.regions202020.eu*. This material aimed at regional communities is also available in the Lithuanian language on *http://www.regions202020.eu/news/ secnews-1-lt/*.



In 2011 the project *Ecoheat4EU*, partially financed by the EU programme *Intelligent Energy* – *Europe*, was completed. Its aim was to demonstrate that modern district heating and cooling (DHC) systems may be very useful in implementing the objectives of national and European energy and environmental protection policy. DHC promotes effective energy consumption and enables a wide scope integration of renewable energy sources in the city area. These two aspects provide for the reduction of carbon dioxide emission.

One of the essential preconditions for increasing the benefits of DHC supply is consistent, effective and non-discriminatory legislation. However, sometimes this



Sustainable Energy Day at Juozas Grušas Catholic Secondary School



Meeting with the representatives of Kaunas Region municipalities



Seminar for farmers during the exhibition Circle of Solutions 2011

is complicated to achieve due to the difficulties related to the nature of DHC systems. For this reason, the project implementers prepared recommendations for all countries participating in the project by summarizing legislation and determining balanced legal mechanisms oriented towards the promotion of modern DHC supply system development in each of the 14 countries-participants that are the main target of the project. The benefits of the DHC in every country were estimated regarding three different time reference points as follows: results for 2007 were justified by the level of demand for district heating supply and actual fuel mix used for heating in 2007 using the accessible and reliable statistics; updated systems 2007 were justified by the comparison of the demand level for district heating in 2007 with the forecasted fuel mix used for heat supply in 2030. This situation, intermediate in terms of time, was proposed in order to determine only the benefit due to the replacement of fuel mix used for heat supply. The third time reference point, forecasted development in 2030, was justified by the forecasted heat demand level in 2030 with and without the use of the advanced fuel mix for heat supply.

The three-situation model was selected to illustrate the fact that the current European DHC systems may be improved by both the replacement of fuel mix used for heat supply (integration of RES and waste energy resources) and the increased heat sales. The benefit of DHC was estimated via comparing the primary energy supply, energy import and carbon dioxide emissions with the situation where DHC and cogeneration are absent. It was accepted that in such situation the total amount of energy is generated in coal-condensing power plants, while the respective heat is produced from fuel oil and natural gas fuel mix in boiler-houses.

Ec*heat 4 cities

Another project related to heat supply sector is Ecoheat4Cities. Its long-term objective is DHC development in the future perspective of increasing sustainability aiming at justifiable systems, appropriate consultations regarding efficient decision making, integrating RES and energy effectiveness. A more specific aim is to eliminate non-technological obstacles: the lack of know-how and objective system indicators that impede the use of DHC potential.

District heating and cooling (DHC) supply is an effective and environmentfriendly means to provide heating and cooling services to the consumers, commercial institutions and industries. DHC provides means for achieving the aims of the European energy policy by making especially efficient use of primary energy and integrating renewable energy sources. Nevertheless, some obstacles to the broader use of DHC on the European level still remain. Non-technological obstacles impeding the DHC development in the European cities is the fact that this energy sector is perceived as not transparent enough. This is because its comparison to other heating and cooling markets (individual RES technologies, heat pumps, etc.) is complicated. Local DHC systems and different generation options, distribution and supply pose difficulties for local planners and investors in the assessment of projects, while politicians face problems in justifying, deciding and assessing the impact of policies. Similarly, consumers lack knowledge about the energy efficiency and environmental benefits of DHC.

Ecoheat4Cities aims at eliminating the non-technological obstacles by improving the acceptability of DHC for the consumers and developing a voluntary "green" energy (heating and cooling) labelling scheme. The developed scheme will assess energy efficiency and the use of renewable energy sources, whereas the presentation of such information to local politicians, citizens and potential investors will enable the choice of energy efficient and renewable energy-based technological solutions.



Overview of the share of renewable and non-fossil fuels in fuel mixture in 14 countries participating in Ecoheat4EU project was provided in three analyzed situations

DHC benefits: Reduction of CO₂ emission



Reduction of annual carbon dioxide emission in 14 countries participating in Ecoheat4EU project assessed in three analyzed situations



Information for DHC companies and citizens about the benefits, advantages and recommendations for the improvement of the system prepared in the scope of **Ecoheat4eu** and **Ecoheat4cities**

A "green" labelling scheme is under development to motivate DHC supply companies to advertise their services from the primary energy sources perspective. The European consumers, including private and public sectors, will be able to easily define the environmental benefit of central DHC supply. The criteria for labels are to be determined to enable a simple comparison of DHC with other methods of heating and cooling, similarly to the currently applied and future schemes of energy efficiency and "green" labelling.

> Project website: http://ecoheat4cities.eu

MAIN APPLIED RESEARCH OF THE LABORATORY

Improvement of energy efficiency is a relevant factor determining the energy costs and competitiveness of the companies. In food and beverage production companies, the energy costs comprise a considerable share in the total balance of production costs. Its reduction is one of the long-term goals of the company which may be achieved via implementing advanced technologies and improving the control of technological process via information systems enabling the optimization of energy costs. The systems can operate only under proper informational supply: they require sensors recording energy flows and a suitable automatic control algorithm monitoring and controlling energy flows. The formation of such algorithm is based on the analysis of collected data and determination of functional links between technological production processes and energy costs. Under the order of JSC **Benco Baltic Engineering Company**, the *Analysis of Energy Use efficiency and Influencing Factors* was carried out by investigating cooling production efficiency in a selected food company. Cooling consumption measurements for separate consumers and a feasibility study of operational efficiency of cooling compressors and the need for additional efficiency measures were carried out.

The work was partially financed by Agency for Science, Innovation and Technology under the *Innovation Voucher Scheme.*

SERVICES PROVIDED BY THE LABORATORY

Thermo-visual diagnostics of buildings, electricity sector and technologic processes

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 residential houses and industrial buildings, incl. envelopes, roofs, piping, electrical installation, chimneys and mechanical facilities. It is also used for determining the leaking and filling levels in the tanks/containers,



Instantaneous power of cooling and electricity in the analysed time interval
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 °C.

Certification of energy efficiency for buildings

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



Example of the energy efficiency certificate for buildings

PHD STUDIES

A PhD Candidate E. F. Dzenajavičienė has completed the studies, prepared and presented a doctoral thesis **Research of** *Efficient Biofuel Use for Sustainable Development of Municipal Energy Sector* in an expanded seminar of the Laboratory. This dissertation was certified.



Thermo-visual research

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

DISSEMINATION OF SCIENTIFIC RESEARCH RESULTS

V. Klevas prepared a monograph *Methodology for Sustainable Energy Development* which is going to be published in 2012. In 2011 the researchers of the Laboratory participated and presented papers in local and international conferences; in total, 2 papers were presented in the Lithuanian and 6 in international conferences. Their articles were published in the conference material as well. The researchers have submitted or already published 2 articles and 1 chapter of a book in the reviewed articles on international databases. Since the researchers pay much attention to educating the scientific and technical community and society on relevant energy issues, they composed 2 science-promotion articles and several leaflets.

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

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LABORATORY of RENEWABLE ENERGY

MAIN RESEARCH DIRECTIONS OF THE LABORATORY:

- 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;
- analysis of the use of renewable energy sources (RES) for energy production and assessment of utilization development;
- development of sustainable regional energy strategy;
- 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.

In 2011 a state subsidy funded study The Research of Wind Energy Prediction and the Developmental Possibilities of **Biomass Resources Use in Energetics** was completed. Long-term data of wind speed and direction measurement, recorded using special equipment in coastal region, were analysed and variation regularities of energetic wind parameters were examined at different levels above the ground. The analysis of digital weather forecast data was carried out and compared to the measurement data of wind speed and wind power plant capacity (WPP). A model for short-term forecasting of WPP capacity was also developed. Moreover, following the up-to-date statistical data, the possibilities of using biomass and alternative fuel resources for energy production were analysed, technical-economic assessment of wind energy use was carried out,

the scope of use and developmental tendencies of different renewable energy sources (RES) for heat, biofuel and ele**c**tricity generation were evaluated. The environmental and social aspects of RES usage were also examined.

RESEARCH ON ENVIRONMENTAL IMPACT AND EFFICIENT USE OF RENEWABLE ENERGY SOURCES FOR ENERGY PRODUCTION

To implement the requirements of the European Parliament and Council Directive 2009/28/EB, and Strategic Energy Technology Plan, the Lithuanian National Energy Strategy provides for a notable increase in the use of renewable energy sources (RES) for energy production. Till 2020 the share of RES in final energy consumption is expected to reach 23 % (no less than 20 % in electricity sector, 60 % in central heating and 10 % transport).

In order to achieve these aims, it is necessary to examine different scenarios of RES technology development and analyse the scope and perspectives of RES usage. The Laboratory carries out research related to wind, biomass, biogas and solar energy use: RES conversion processes and their efficiency, developmental possibilities and up-to-date technologies are analysed, feasibility studies are prepared, wind energy parameters are measured, statistical data on RES usage are collected and analysed, recommendations of the implementation of demo projects and regional energy strategies in the scope of RES usage are prepared.

Recent data of Department of Statistics show that hydroenergy, wind and biomass energy sources are most widely



Current and forecasted electricity production using different RES

used for electricity generation from RES in Lithuania.

In the future, the major share of electricity, produced using RES, will be provided by wind and hydroenergy. Since the development of hydroenergy in the major rivers is restricted under environmental requirements, whereas most of the smaller rivers are already exploited, a great deal of attention is also going to be devoted for biomass energy development.

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

In Lithuania, the capacity of wind farms is rapidly increasing: it is expected that their total installed capacity will reach 500 MW in 2020, i.e. its contribution to the electrical energy system will be



General structure of wind speed and WPP capacity variation prediction model

notable. Due to the constantly changing WPP capacity, the balancing of the system is becoming a difficult task which requires a short-term prediction of WPP capacity variation for facilitation. The Laboratory carries out the research on different methods of wind speed and WPP capacity prediction; it has developed and is currently improving a prediction model. The possibilities for practical application of the model for the Lithuanian wind farms were also analysed.

Integrated methodology applied in the model enables assessing the impact of local landscape, surface roughness and atmosphere stability on the accuracy of the forecasts. It was determined that the absolute error in WPP capacity prediction amounts to about 10% of the installed capacity. Statistical methods that enable specifying the forecasts in the range of several hours are also investigated.

RESEARCH OF WIND POWER PLANT OPERATION EFFICIENCY

Since wind speed varies, WPP does not operate at its full capacity most of the time. Thus, the Laboratory examines the variation of WPP capacity usage. Monthly capacity factors of wind farms were calculated and compared. The results show that the factors change during the year and reach the peak in January-March, while being the lowest in April-August.



General structure of wind speed and WPP capacity variation prediction model

It may be noticed that the variation regularities of the capacity factors of wind power plants, operating in different sites in Lithuania, are analogous, which suggests that wind flows are correlated not only in the whole coastal region, but also in other regions of Lithuania. The results of this research may be followed while planning the construction sites for new wind farms and predicting the annual amount of generated energy. Accurate calculations of annual productivity of wind farms are performed in the Laboratory using professional software WAsP. It is also employed for the analysis of wind speed and direction measurement data and the assessment of wind energy resources in various regions of Lithuania.

RESEARCH OF DEVELOPMENTAL POSSIBILITIES OF BIOMASS FUEL USE FOR ENERGY

The production scope of different types of solid biomass fuel and technologies used for heat and electricity production are analysed in the Laboratory. As an energy source, biomass may be used in solid (solid biomass), liquid (biofuel) and gas (biogas) states.

The main resources of biomass include wood waste (forest cutting, wood processing and building waste) and agricultural waste (straw). Solid biofuel may be used as a raw or processed product (briquettes, pellets, biomass chips, sawdust). 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.

The share of biomass in the total amount of RES used for energy production is the greatest.

It was determined that wood fuel consumption in 1990–2010 period has increased more than twice, that is, from 284.9 ktoe to 934 ktoe, which corresponds to 2.6% and 13.3% of primary energy consumption of the state.



Gross inland consumption of RES in 2010

The use of biofuel in central heating supply(CHS) system. Following the requirements of the Lithuanian National Energy Strategy and EU Directives, it is necessary to increase the share of RES and other local resources in the production of central heating at the same time diminishing the emission of greenhouse gases. The Lithuanian District Heating Association and Biofuel Producers and Suppliers Association have an ambitious goal: to increase the share of RES and other local energy resources in the balance of fuel for heat production up to 70% of the total primary energy till 2020. In order to achieve this aim, it is necessary to develop an additional network of biofuel power plants having the capacity of about 1560 MW; the required investment amount to about LTL 1.1 billion.

Currently fossil fuel prevails in the Lithuanian heating sector, whereas natural gas and fuel oil comprised the major share of total fuel until 2003 and the use of wood and sawdust increased since 2004.

Type of fuel	1996	2000	2001	2002 %	2004	2006	2008	2010	
Natural gas Fuel oil Wood and sawdust Other	59.1 37.9 0.3 2.7	80.3 16.4 1.2 2.1	74.8 21.1 1.5 2.7	75.5 18.5 3.8 2.2	80.5 6.9 10.9 1.7	79.9 5.4 13.0 1.7	76.7 4.1 17.4 1.8	74.4 4.6 18.1 1.9	

Comparison of fuel used in central heating supply system

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 many *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 anaero-

bic conditions. This reduces the negative effect on the environment of processed sewage.

Different organic liquid waste is processed in 5 biogas power plants, presently operating in Lithuania, while biogas, produced in 5 more plants operating in dumping grounds, is used as fuel in 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 as alternative fuel for transport in many countries. The Laboratory carries out exhaustive integrated assessment of biogas power plant efficiency by analysing the experience gathered in the Lithuanian and European power plants.

Moreover, the Laboratory carries out the process analysis of advanced technologies for biogas production and the perspectives of biogas production development is examined.

Biofuel

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 goals of using biofuel in transport sector (to use 15% of total amount of consumed fuel till 2020, and 20% till 2025) 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.



Guiding income scheme of biogas production from organic waste

Amount of biofuel to be consumed in 2005–2025 under relevant legislation

	2005	2007	2009	Year 2010	2015	2020	2025	
Requirements for biofuel amount %	2.0	3.5	5.0	5.75	10.375	15.0	20.0	
Scope of bioethanol production thous. t annually	7.2	12.6	18.0	20.0	35.0	50.0	70.0	
Scope of biodiesel production thous. t annually	13.8	24.15	34.5	40.0	70.0	100.0	140.0	

Usually bioethanol replaces a share of petrol in internal combustion engines; however, the possibility of bioethanol use in the process of oil and fat esterification and re-esterification as a substitute for the currently used methanol has recently been taken into interest. It was determined that during the process of biodiesel production, about 10% of technical glycerol, up to 3% of free fat acid and twice more of rape oil-cake (rape meal) than biodiesel are produced. The research demonstrated that technical glycerol may be used as liquid fuel and mixed with other oil products. Rape oil-cake may be applied for the production of protein feed, or for polymer films together with technical glycerol. Free fat acid, which results from biodiesel production, may be returned to the process by re-esterificating it with methanol and acid catalysts. The described measures can notably reduce the cost of biodiesel production.

The Laboratory, which also belongs to the open-access Alternative and Renewable Energy Centre, offers scientific research services related to the RES use and installation of up-to-date technologies, feasibility studies of wind energy and environmental impact assessment. The students are also welcomed to placements in the Laboratory where they can make use of the research data obtained by the researchers.



Wind speed and direction measurement equipment financed by valley Santaka is being prepared for use





Moments at the lecture given to the VMU students by Laboratory researchers

Cooperation with Vytautas Magnus University (VMU)

In cooperation with VMU Faculty of Natural Sciences, the researchers of the Laboratory gave lectures for the VMU students about RES technologies and their use in Lithuania. Practical activities were also carried out for the students of the departments of Physics and Environmental Sciences. Students were introduced to the specificity of electricity generation in wind turbines and operational principles of photovoltaic cells. The students take active interest in the development of RES use, work on placements, write course papers and thesis; in the future, with the help of Laboratory researchers, they plan further research and select study directions related to the use of RES technologies.

PARTICIPATION IN INTERNATIONAL PROGRAMS

RES energy development issues important to Lithuania are analysed in the projects of international programmes. Studies related to the development of alternative fuel use in transport,



Students actively participated in practical activities

wind energy and rational enhancement of biomass thermal and electric energy consumption are carried out in the Laboratory. Cooperating with German, Danish, Polish and other science research centres, studies of bioenergy development perspectives in the regions of Europe were performed. The main objective of the current projects is to provide considerable input to the implementation of the 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 rates given in the directives and other regulating documents.

International projects carried out in the Laboratory in 2011

- Market Development of Gas Driven Cars Including Supply and Distribution of Natural Gas and Biogas (MADEGASCAR) 2007–2010 of Intelligent Energy Europe Programme (completed in 2011).
- 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 Cross-border Co-operation Programme 2007-2013.

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. The use of natural gas for public



transport has begun in Vilnius, Klaipeda and Kaunas (the testing phase). The process of implementation of this project resulted in cooperation with other EU countries, building the first gas filling stations in Vilnius and Klaipeda and collecting experience in this field in pursuance of sourcing alternative and economical fuel.



The objective of **EUBIONET III** is to enhance biomass fuel use in EU countries by searching for ways to overcome market obstacles. The analysis of biomass fuel use, future perspectives and basic obstacles was carried out, national biomass programs were analysed and biomass fuel potential was estimated, giving most of attention to industrial and agricultural waste and assessment of potential of new biomass fuel types. Biomass fuel certification and sustainable development criteria were also determined. The main activities of the project:

- analysis of national biomass programmes and assessment of biomass fuel potential, giving most of attention to industrial and agricultural waste;
- establishment of certification and sustainability criteria of biomass fuel in cooperation with marketmakers;
- promotion of new CEN standards of biomass fuel;
- assessment of appropriate use of biomass resources by analyzing the availability of raw mate-

rials in the industrial, forestry and agricultural sectors.



The scientific research project *Public Energy Alternatives: Sustainable Energy Strategy for Regional Development (PEA)* 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 and Zarasai District Municipality Administration.

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, planning developmental guidelines and taking into account the attitude towards regional development. The aim of the project 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)* analyses the legal basis for the development of wind energy and economic, technical and social issues impeding its development. Additionally, 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 Lithuanian and the EU countries are going



Meeting of Ignalina nuclear power plant region municipalities and other concerned representatives with PEA project partners to discuss strategy and perspectives of the energy development in the region



to be prepared and provided to the municipalities, investors and project developers.

Wind Energy Information Point (WEIP) will be established in the premises of the Laboratory and opened for public. Its aim is to provide objective, science-based information about wind energy technologies, their impact on the environment and public health in seminars, lectures, excursions, training courses and other events. WEIP will also collect and provide wind power project developers and investors with information about the Lithuanian legislation, project funding possibilities, economic conditions, environmental impact and societal aspects.

SCIENCE PROMOTION ACTIVITY

In 2011, 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. Various science-promoting events were organized and researchers of the Laboratory prepared a lecture cycle and gave information about RES use for energy generation for business representatives, students and pupils.

A seminar Innovative Sustainable Heating and Cooling Systems was organized in Kaunas where more than 70 specialists of various fields were introduced to 9 reports.



International EUBIONET III project seminar

The condition of energy, central and local heating of the buildings in Lithuania and Europe was analysed, renewable energy action plan was discussed and the activity of the *European Technology Platform* on Renewable *Heating & Cooling was assessed.* Moreover, review on biomass use for heating and cooling, prepared during the implementation of EUBIONET III project, was presented, current state of the European biofuel standards and EN plus certification proceedings of sawdust pellets were evaluated. Finally, biomass combustion boiler technologies in Lithuania and their future perspectives were considered.

Researchers of the Laboratory were given a great deal of attention during the "Open Days" on 5 May 2011 in LEI. The guests were introduced to the activities carried out in the Laboratory, the available testing equipment and devices planned to purchase in the future, as well as operational principles of solar and wind energy technologies.

In 2011 the researchers of Laboratory published 4 articles in scientific publications, registered in international scientific information databases, 3 reports in international and 4 in national conferences. 3 articles promoting science were published and research results were presented in 2 international and 1 national scientific conference.

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Visitors of the Laboratory are interested in the specificity of RES technologies

ENERGY EFFICIENCY RESEARCH AND INFORMATION CENTER

MAIN RESEARCH AREAS OF THE CENTER:

- in pursuance of scientific research, to compile, analyse 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 LITHUANIA

In 2011 a state funded research project The Development of New Energy Production Technologies in Lithuania and the Research of Energy Consumption Efficiency Increasing Possibilities in Public Buildings was completed. 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 one of the priority directions in the strategy of energy development both in Lithuania and the European Union.

The National Action Plan for Energy Efficiency of Lithuania was approved on 4 December 2008. This document was prepared following the provisions of the European Parliament and Council Directive



Gross inland fuel and energy consumption and their distribution

2006/32/EC on Energy End-Use Efficiency and Energy Services of 5 April 2006.

This document identifies the existing energy saving potential, defines the measures for increasing energy efficiency, determines energy saving rates and presents a strategy for achieving them.

Aiming at more efficient energy use, reduction of CO_2 emissions, increase of renewable energy usage in the European Union, the EU Parliament and Council approved new Directives, namely : 2009/28 EC on the promotion of the use of energy from renewable sources and 2010/31/EC on energy performance of buildings.

In the mentioned documents, the increase of energy use efficiency is based on up-to-date technologies and innovations that enable using local, renewable and waste energy sources more effectively. 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.



Distribution of indigenous and renewable energy sources in gross inland consumption for year 2010



Distribution of industry final energy (heat, electricity, natural gas, liquid fuel, firewood and wood waste, and coal) in accordance with the activities in 2010

The abovementioned Lithuanian and EU documents indicate a necessity to increase 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 stimulation for the change of the behaviour of principal future energy consumers.

The completed research presents the data on industry sector development of Lithuania in 2006–2010, fuel and energy consumption and the greatest industrial energy consumers. The data of 2010 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 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.

It was determined that only after the National Audit Office of Lithuania carried out an audit in 2009 and the report *Use of Renewable Energy Sources Potential in Lithuania* with critical conclusions and recommendations was submitted on 15 January 2010, the National Renewable Energy Strategy, its Action Plan for 2010-2015 and the *Law on Renewable Energy Sources of the Republic of Lithuania were approved.*

The material on the technical-economic assessment of the recent activity of small capacity bio-cogeneration plants (up to 2 MW_e), already functioning in foreign countries, was presented. Moreover, a technical-economic assessment of the possible construction of bio-cogeneration plant and heat-pump compressor in the centralized heat supply systems of Ažupiečiai and Agricultural schools in Anykščiai, and a technical-economic justification of heatpump installation in the boiler room of PI Rokiškis Mental Hospital were carried out.

It was demonstrated 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. In addition, the results of this work were used for compiling a data base of bio-cogeneration power plants and heat-pumps.

Students' knowledge about energetic, 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 specific energy consumption of the schools for the same period of time was presented and the analysis of the received data was performed.

PARTICIPATION IN INTERNATIONAL PROJECTS





Environmental protection expenditure of industrial enterprises, mio LtL

In 2011 the international project *Product and Process Design for Ambient Intelligence Supported Energy Efficient Manufacturing Installations (DEMI)* was continued. It is partially financed by the EU 7th Framework Programme for Research, Technological Development and Demonstration Activities. The period for the implementation of the project is 2010–2013.

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 making decisions about the designed and installed processes. At the same time they would contribute to minimization/ optimization of the environmental impact of technological processes and manufacturing installations during their lifetime.

Produces have invested quite a considerable amount into their products and services in order to make them energy efficient. However, there is still a lack of systems developed on the basis of *Informa*- *tion and Communication* Technologies (ICT). Such systems could improve the product and process design by taking into account energy efficiency.

One of the main issues in optimizing the technological processes energy input (during design) is to define and improve the characteristics of energy consumption of these processes. This may be achieved by using industrial processes based on ambience intelligence (intelligent ICT), which would also allow energy efficiency control function of the processes.

Having completed the project, a general methodology and the following ICT components, compatible with the existing design systems, are going to be developed:

> Energy Dependency Selector for pre-design analysis which enables selecting equipment (device), matching both industrial an energy efficiency requirements during the whole life-cycle of the designed process or product. For this purpose, TRIZ method (Russ. acronym, translated as "the theory of inventive problem solv

ing") and eco-design principles will be applied.

- Energy Monitoring Setup for designing and selecting ambient intelligence-based technologies and other measurement systems ensuring the energy efficiency of the installed industrial process.
- Energy Analyser for the energy efficiency optimization of industrial process and equipment.
- Energy Simulator for modelling design alternatives of industrial processes and equipment and assessing their energy consumption.

During the implementation of the project, currently functioning industrial processes and product design systems are going to be updated with the mentioned ICT components. In 2011, the design solutions obtained using the updated systems were verified using the data of actual industrial processes. Such solutions are expected reduce the energy consumption at least by 15%.



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

In 2011, 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) continued the implementation of the 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.

As has been planned, technical projects for several public buildings renovation in the region of INPP were prepared, which enabled assessing energy saving potential and laid a firm basis for building renovation. While implementing the project, the municipalities mounted solar collectors on several public buildings, which became the first (pilot) investment of alternative solar energy into the public sector of the region. The investments realised during the project gave an excellent example of using the alternative energy potential in the region.

In pursuance of the aims of the project, solar collector system, mounted on the roof of a boiler room in Dūkštas town, Ignalina

district, was publicly presented on 15 June 2011. The presentation of the investment project was visited by the Mayor of Ignalina district Bronis Ropė, Deputy Mayor Henrikas Šiaudinis, representatives of administration and project implementers, contractors who carried out the design and installation work, project partners from the Ignalina NPP Regional Development Agency, Lithuanian Energy Institute, Visaginas and Zarasai district municipalities as well as the representatives of JSC Ignalinos šilumos tinklai. The aim of the project was to provide the citizens of Dūkštas town with hot water every day since before its implementation, hot water was supply via central system was used, but only at the weekends and during the holidays. The project worth LTL 348 000 was financed by the European Union funds.

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

The task of LEI in the preparation of the regional strategy was to arrange a study of the present situation assessment which would demonstrate regional problems, as well as week and strong sides of the possibilities of regional development, and also to consult the partners about en-

Baltijos jūros regiono 2007 – 2013 m. programos projektas "Viešosios energetikos alternatyvos. Saulės kolektorių sistemos įrengimas Dūkšto katilinėje"







Participants of international PEA project and results of their activities in implementing solar collectors in INPP region (Dūkštas and Visaginas)

ergy 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 2011. 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 2011, 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. Moreover, the application of sustainability criteria to the development of bioenergy was evaluated and proposals for biofuel development in the Lithuanian energy sector were presented.

According to the topics of the research carried out in 2011, 3 seminars were arranged, the results of the studies were introduced in 3 scientific articles and 3 scientific papers were read in scientific conferences.

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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 and optimisation research of ICT-based control systems of power systems.

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

- mathematical modelling of power systems (PS), analysis and assessment of their parameters;
- investigation of PS control issues and development of respective algorithms for frequency regulation, active and reactive power control, evaluation of static and dynamic stability, loss reduction, electric power quality, emergency prevention, considerations of electricity market;
- investigation of advanced PS control methods and application of new automatic control devices and information and communication technologies (ICT);
- analysis 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;
- research on the integration of renewable energy sources (wind, solar and other power plants) and distributed generation into PS;
- EES legal regulation of PS control and use of electricity ;
- EES economic efficiency analysis of PS control, development and use of electricity.

With rapid development of ICT, the increasing amount of automatic control and protection equipment, including intelligent electronic devices, is introduced into power systems (PS). Therefore the PS control algorithms are getting more complex as they must enable a coordinated operation of all those devices to run the PS with respect to the entire integrated system and without breaking the parameter boundaries. The complexity is increased by the introduction of GPS-based wide area protection systems and flexible alternating current transmission systems (FACTS). It results in the on-going trend to process more real time information (telemetering data, telesignals) from different PS points in order to:

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

Another general target is to achieve optimal ratio of the centralised and decentralised control of PS by increasing the latter. The FACTS as emerging transmission technology is a power electronic controller capable to increase the transfer capability of the network and improve PS stability. The enhanced controllability increases the cost-effectiveness of PS operation, reduces emergency risk, enables the isolation of the disturbances inside the national system and avoiding of their spread across the interconnected system. Taking into account the mentioned aspects of PS development, the researchers of the Laboratory undertake the up-to-date approaches and new methods in their research.

In 2011, the Laboratory carried out scientific research under the contracts with 2 economic entities of the Republic of Lithuania.

Reliability Study of 10 kV Overhead Lines in Utena Region, Molėtai Territorial Division, carried out under the contract of *SC LESTO*, aimed at increasing the reliability of distribution network in Utena region, Molėtai territorial division by optimal means. The study was implemented together with the Laboratory of Nuclear Installation Safety and JSC Energetikos tinklų institutas.

A statistical analysis of electricity supply interruptions in 10 kV distribution networks of Molétai division that occurred in 2005–2009 was carried out on the basis of interruption registration data. Its main goal was to identify the important factors influencing the reliability of the networks. The statistical data was analysed for different periods of time (years, months), different triggering events and type affected/ damaged network equipment. The frequency of faults and reliability indices of 10 kV lines, local and distribution substations were found and a list of most faulty lines was composed.

In order to be provided with automated procedures of reliability evaluation, optimal development or reconstruction of distribution networks up to the desirable reliability targets and calculation of the respective investment cost, a novel mathematical model and related software program ETPA (Electricity Network Reliability and Renovation), encompassing the options of Microsoft Office Excel 2007 and Microsoft Visual Basic, were developed. This program was employed to simulate the renovation scenario of 10 kV distribution network in Moletai division, 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 ter-



Active power variation of wind power plant generators (1 r.u. = 1000 MW) after a three-phase short circuit on the side of 30/330 kV wind power park 330 kV distribution substation

ritory, the impact of the park on the operation of the Lithuanian PS has to be evaluated.

The study analysed the static and dynamic stability, voltage levels and variations of the Lithuanian PS. The calculation results were employed for determining the voltage stability margins and the additional compensation of reactive power, required for voltage control, after connecting the wind park to the 330 kV electricity transmission line Mūša–Telšiai. SWT-2.3-101type wind power plant models, produced by SIEMENS, were applied for the calculations; the next-stage research is going to be based on **SL3000-113**-type power plants (SINOVEL). The technical task of the study and its results were agreed with SC Litgrid.



In the scope of the national programme *Energy for the Future*, the project Research and Assessment Methodology of Energy Systems Reliability and its Impact on Energy Security was implemented (together with the Laboratory of Nuclear Installation Safety). The aim of the project is to develop a general 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 researchers implemented the following three tasks of the project:

Task 1. Development and validation of methodology and models of reliability for electricity networks, electricity supply reliability and risk assessment; **Task 2.** Development and validation of methodology and models of reliability for heat networks reliability assessment;

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

In 2010-2011, the researchers worked on **Task 1**. The development of the general methodology of electricity network reliability assessment was aimed at improving the special methods and developing preliminary methodologies intended for:

- reliability assessment of individual equipment of a PS (network);
- reliability assessment of the whole PS;
- modelling of PS operational modes;
- assessment of major characteristics of electricity supply.

The developed methodology is based on classical reliability theory and approaches as well as parametric and nonparametric methods for probabilistic and statistic assessment, currently under development. The innovative PS network reliability and risk assessment methodology is intended for assessing the separate units of the network and its integral reliability characteristics, analysing possible accidents and determining their consequences. The methodology and respective software tools were validated by means of test calculations.

In cooperation with the Laboratory of Nuclear Installation Safety and Laboratory of Energy Systems Research, the researchers completed a three-year statefunded project *Lithuanian Energy Security Research*. Its main objective was to develop an energy security assessment methodology and system of indicators on purpose to estimate energy security level of Lithuania till 2025. On its basis, the scenarios of the Lithuanian energy development and its security level were compared to the energy security levels of several other EU countries.

The project report discusses the principles of energy system security assessment and the developed methodology for the energy security analysis. It also describes the threats to energy security and a detailed investigation of disturbances. The model of disturbances spread and energy system modelling by econometric and probabilistic approaches were presented as well as the algorithm developed to carry out the indicator-based assessment of energy supply security level. The researchers of the Laboratory drew up the list of PS indicators and selected the values of their importance coefficients; they also carried out the research of system operation modes by evaluating static and dynamic processes.



The Laboratory has been carrying out the EU 7FP project Product and Process Design for Ambient Intelligence Supported Energy Efficient Manufacturing Installations (code name DEMI) for two years, together with Energy Efficiency Research and Information Center and Laboratory of Nuclear Installation Safety. Apart from LEI, this ICT-directed research project is implemented by 8 partners from 4 EU countries. The project is innovative because it aims at highlighting the usefulness of energy input assessment software, which is going to be developed by the project partners, for industrial products and processes design. The researchers are going to demonstrate the software possibilities in reducing energy input into the manufacture of products by changing their construction or operation of processes by modifying their structure. Demo technologies in the scope of the project include compressed air supply system (reduced electricity input), plastic casting cooling system (reduced electricity input for circular cooling system), and thermal annealing process of metallurgical products (reduced gas input).

The system of the *DEMI* project is developed as an automated information system consisting of the mentioned software and database which interact through interface based on the *SOA* (*service-oriented architecture*).

In 2011 the Laboratory cooperated in revising the conception of the *DEMI* project and defining the project software specifications (the main technical requirements). As the majority of innovative ICT projects, DEMI was included into project risk group and was subjected to verification by the European Commission in Brussels. The representative of the Laboratory presented the interim results of the project together with other representatives of LEI and the EC officials and experts approved the continuation of the project.



After the Lithuanian Energy Institute became a member of Smart Technologies Association on 28 June 2011, the researchers of the Laboratory started active participation in its activity aiming at the creation of smart network conception and its implementation in Lithuania.

The results of research carried out in 2011 were presented in 2 international conferences; 3 articles were submitted to the reviewed scientific publications.

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LABORATORY of HYDROLOGY

MAIN RESEARCH AREAS OF THE LABORATORY:

- analysis of climate change and river run-off variation;
- research of power plants impact on water bodies;
- collection and analysis of data of the 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 activities (energy production and navigation). Therefore, the assessment of the state of water bodies is one of the most important tasks of research.

Applying the information collected in the hydrographic and hydrometeorological database and the up-to-date digital modelling systems, the Laboratory solves the following tasks:

- impact of climate change on water bodies;
- analysis of river flood variation;
- environmental impact assessment of anthropogenic activities on water bodies and justification of environmental protection measures;

- environmental impact of new sea ports and the ports under reconstruction;
- exploitation of sea harbours and waterways, ensuring the nautical depth;
- investigation of quays interaction with water flow and selection of optimal constructions;
- assessment of environmental conditions using water bodies for different objectives;
- estimation of mixing and dispersion of sewage under critical conditions in water bodies;
- sensitivity and uncertainty analysis of hydrologic and hydrodynamic processes.

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 in the Laboratory of Hydrology during long time period, and innovative modelling software (system MIKE 21, developed by Danish Hydraulic Institute, for the modelling of waves, hydrodynamic and silt movement processes, and pollution dispersion, hydraulic process model HBV, developed by *Swedish Meteorological and Hydrological Institute, as well as geographical information systems ArcGIS.* 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 research related to the assessment of the impact of climate change on water resources. Since 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)** has been under implementation. 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 inflow into the Lagoon, hydrological regime and the changed permeability of the Klaipeda Strait due to the dredging of Klaipeda port. In order to expand the Port, 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, the long-term water balance of the Curonian Lagoon of 1961-2007 was estimated.

To assess possible changes in the water balance of the Curonian Lagoon in the 21st century, it is crucial problemto forecast water balance elements (the changes of total river inflow precipitation, evaporation and water exchange in the Klaipeda Strait). The Nemunas inflow is the main component of the water balance income of



Fig. 1. Comparison of the Nemunas inflow into the Curonian Lagoon, following two climate change models and three emission scenarios during the period of 2011–2100, with the inflow of the climate norm (period of 1961–1990)

the Lagoon, thus, a hydrological model of the Nemunas river up to the mouth was developed using HBV code and daily data of the period from 1961–1990, gathered in 10 water gauging and 14 meteorological stations.

According to the A2, A1B and B1 emission scenarios, output data of Echam5 and



Fig. 2. Participants of the international conference **The importance of Smalininkai water measuring station in the history of the country** next to the Smalininkai water measuring station on 24 September 2011

HadCM3 global circulation models (hereinafter GCM) were applied to the Lithuanian territory by recalculating them and changing from the monthly to daily step. Using the developed run-off model and data of climate change, the Nemunas inflow into the Curonian Lagoon was modelled for the period of 2011–2100 by following two models of climate change and three emission scenarios (Fig. 1). According to all 6 climate scenarios, the average annual run-off of the Nemunas will reach 517 m³/s during the period of 2071–2100, i.e. 178 m³/s or 25.6% less than the run-off during the reference period. The forecasts revealed that the variation of the inflow during different periods is determined not only by emission scenarios, but also by the selected global climate model.

In 2010, the researchers of the Laboratory, together with the Laboratory of Nuclear Installation Safety and Laboratory of Energy Systems Research, initiated a scientific research project *Analysis of Processes in Complex Technical, Natural and Social Systems Applying Best Estimate Methodology* (supervisor Dr. Habil. A. Kaliatka), financed by state subsidies. In 2011 uncertainty analysis of water balance in the Curonian Lagoon was carried out by applying the best estimate methodology.

RESEARCH OF RIVER INFLOW VARIATION

The Laboratory was implementing the work related to the assessment of river run-off variation by applying statistical analysis methods, while hydrological modelling and climate change scenarios were used to estimate future variation. Such assessment would be impossible without the data of water measuring stations. In 2010, the European hydrologists celebrated the 200th anniversary of hydrological research. The Lithuanian gauging station that operates the longest continous period of measured discharges is located in Smalininkai near the Nemunas; its data series encompasses the period of 1811–2011.

The 200th anniversary of this station was celebrated last year and the Lithuanian hydrologists organized an international conference *The importance of Smalininkai water measuring station in the history of the country* in Smalininkai to mark this occasion (Fig. 2.).The hydrologists of LEI, M. Lasinskas, J. Jablonskis, B. Gailiušis and others have been investigated 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

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. The European researchers presented the results of COST activity in the international EGU Leonardo 2001 conference Floods in 3D: Processes, Patterns, Predictions and the researchers of the Laboratory J. Kriaučiūnienė and D. Šarauskienė introduced the report Analysis of spring flood frequency in the Lithuanian rivers (Fig. 3).



Fig. 3. Distribution of maximal run-off in the Nemunas according to 3 probability distribution



European Network of Freshwater

Research Organisations

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 Framework Programme projects;
- To form consortiums with EurAqua scientific institutions by preparing joint proposals for FP projects;

laws

- 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 XXXVI meeting of EurAqua members took place on 21-22 October 2011. The participants discussed the political aspects and further use of European water resources, and established topical issues of the new scientific research and innovation programme *Horizon* related to the most relevant aspects of freshwater use and protection.

COOPERATION WITH STATE AND SCIENTIFIC INSTITUTIONS

The Laboratory of Hydrology has cooperated closely with the Institute of Envi-



ronmental Engineering of Kaunas University of Technology and has published 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-todate 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), concerning Lithuanian sea sector development, is to unite institutions and departments of maritime science. The initiators for establishing the Valley are Klaipėda University, Nature Research Centre, Lithuanian University of Health Sciences, 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 works on environmental and prepares hydrotechnical construction projects



The old Šventoji Seaport

according to agreements with enterprises and organizations:

- Under the agreement with Klaipeda State Seaport Authority, preparatory works for harbour navigation channel dredging, i.e. environmental impact assessment, technical projects for dredging and reports on engineering geological research are being prepared;
- Under the agreement with Klaipeda State Seaport Authority, environmental impact assessment report (EIA) of the Šventoji State Seaport reconstruction is being prepared;
- Under the agreement with JSC Lietuvos energija, the operating instructions of Kaunas Hydroelectric Power Plant reservoir were revised;

 Under the agreement with Klaipėda University, modelling of the conditions of soil dumping sites in the Baltic Sea was carried out.

MIKE 21 modelling system was applied for the evaluation of navigation conditions and the environmental impact of Klaipėda and Šventoji Seaports development. The most important tasks are the navigation channel dredging, 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 the bed and shore erosion at extreme hydro-meteorological conditions.

Following the 06-11-2003 meeting minute No. 19 of the Governmental Strategic Planning Committee of the Republic of Lithuania, the priority activities in the Šventoji Seaport are the following: service of entertainment and sport ships, small cruise and Ro-Ro passenger ships, small fishing boats; service of auxiliary ships of Butinge Oil Terminal; service of specialized rescue ships of State Boarder Guard Service. However, reconstruction of the Šventoji Seaport is crucial for the implementation the mentioned activities. The researchers of the Laboratory together with the scientists of Klaipėda University and Nature Research Centre carried out the environmental impact assessment of the Šventoji State Seaport reconstruction. The following main reconstruction alternatives were analysed:

- "0" zero alternative, i.e. present state of the seaport;
- "1" short, 400 m long breakwaters, 6 m deep harbour and 7 m deep entrance channel;



Fig. 4. Flow structure in the Šventoji Seaport water territory at western 20 m/s wind: a) – "1" alternative; b) – "2" alternative



Fig. 5. Spread of pollution from "1" damping region at south-west 15 m/s wind (relative initial concentration is 500): a) - 6 h after the moment of soil dumping; b) - 12 h; c) - 24 h (dumping of soil takes places every 8 h)

- "2" long breakwaters (800 m), 6 m deep harbour and 7 m deep entrance channel;
- "3" long breakwaters (800 m), 8 m deep harbour and 9 m deep entrance channel.

Modelling of hydrodynamic and sediment transport processes demonstrated that the "1" alternative of the seaport reconstruction meets minimal requirements and has the least impact on the litodynamic processes of the coast. "2" alternative would result in erosion of the shores in both southern and northern sides of the port gates (see Fig. 4). Finally, dredging from the port ("3" alternative) up to 8 m would increase the impact on the sediment transport processes.

While dredging the water territory 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, spawning sites and places of recreation. The assimilation capacity of the site in the Baltic Sea where the soil has been dumped since 1998 is almost running out. In order to select a new dumping site, the researchers of the Laboratory carried out a study Modelling of conditions of soil dumping sites in the Baltic Sea. The spread of pollutants from three possible sites in the Baltic Sea was modelled at different climate conditions and concentrations of pollutants in the sites (Fig. 5). The site with the least spread of pollutants during dumping and most negligible environmental impact was determined.

The possibilities of MIKE 21 modelling system application for port development projects are considerable. Modelling results are especially useful for assessing the impact of port development, harbour construction and dredging of waterway on the ecosystem of the Curonian Lagoon and the Baltic Sea.

In 2011, the researchers of the Laboratory participated in 7 international conferences and published 1 article in the ISI WoS database, 3 in the reviewed scientific journals and 4 in science promotion journals.

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YOUNG SCIENTISTS ASSOCIATION

The Young Scientists Association (YSA) of the Lithuanian Energy Institute (LEI) has been actively working on its activity since 2002. The mission of the Association is to develop the research activity of the young scientists at the Institute and the resources necessary for its implementation in order to achieve new results and their acknowledgement. In 2011 the YSA organized the following events:

- International conference CYSENI 2011 Conference of Young Scientists on ENergy Issues;
- Open Day at LEI 2011;
- KTU Career Days 2011;
- Researchers' Night 2011.

CYSENI 2011

On 26 May 2011, the Institute was bustling with young people: a two-day international conference of doctoral students and young scientists, *Jaunoji energetika* 2011 (CYSENI 2011), began. The conference, which has been organized for eight years in a row by YSA, this year has attracted a great number of speakers from the Lithuanian scientific and research institutions (Vytautas Magnus University, Lithuanian Institute of Agriculture, Kaunas University of Technology, Vilnius Gediminas Technical University, Vilnius Univer-



sity, Center for Physical Sciences and Technology and Aleksandras Stulginskis University). The organizers aim at turning this conference into the foremost annual event for the young scientists, working in the energy field, in the Baltic Sea region. Thus, many young scientists arrived to the conference from the scientific and research institutions of the neighbouring countries, such as Tallinn University of Technology (Estonia), University of Latvia (Latvia), Institute of Physical Energetics (Latvia), Riga Technical University (Latvia), Institute of Silicate Materials (Latvia), Institute of Nuclear Chemistry and Technology (Poland), and A. V. Lykov Institute of Heat and Mass Transfer (Belarus). The conference was also joined by the participants from A. N. Podgorny Institute for Mechanical Engineering Problems (Ukraine), Taras Shevchenko National University of Kyiv (Ukraine), University of Pisa (Italy), Wuppertal Institute for Climate, Environment and Energy (Germany), Braunschweig Institute of Technology (Germany), University of Bergen (Norway), and Federal University of Technology (Nigeria). The great number of conference guests was welcomed by the Director of LEI, Prof. Dr. Habil. Eugenijus Ušpuras, and LEI YSA board member, Dr. Diana Meilutytė-Barauskienė.

The main energy-related topics covered in the conference (67 young scientists from different Lithuanian and foreign institutions presented their scientific papers):

- 1. Hydrogen and fuel elements;
- 2. Renewable energy sources and their use;
- 3. Smart energy networks;

making;

- Energy efficiency and saving;
 Knowledge for energy policy
- 6. Research in the fields of thermal physics, fluid and gas mechanics and metrology;
- Nanosciences and nanotechnologies; research on multifunctional materials;
- Research on combustion and plasma processes;
- 9. Global change and ecosystems;
- 10. Fusion energy;
- 11. Nuclear fission and radiation protection.

86 annotations were submitted to the conference of 2011 and 75 of them were accepted for presentation. Experienced reviewers selected 68 scientific publications suitable for issuing in the conference material from the submitted ones. The majority of presentations of research results were made in the field of nuclear fission and radiation protection (10 papers); 9 reports were delivered in each the topic on renewable energy sources and their use, as well as global change and ecosystems.

The work of the conference took place in three parallel sections in which the reviewers of the articles, experts of the technological sciences, were also present. They were provided a possibility to overview the submitted papers of the young scientists and researchers before the conference; thus, during the event, they asked questions, commented on the work of the young scientists and lead the discussions. 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 was commented on by 2 reviewers and the presenters themselves) and their presentation to the scientific society. The articles and their annotations submitted by the participants of the conference were published in the conference material issued in the electronic media (a CD), which will be available at the main Lithuanian and some foreign science centres and libraries. The participation in the conference provided the scientists with great possibilities not only to hear the reviews of their papers, but also to learn to review and as-



Moment from the conference CYSENI 2011





Dances of conference participant with the folk dance group Rasa

sess the articles of their colleagues, the relevance of the discussed topics and importance of the obtained results.

This year, as always, the authors of the best papers were announced after assessing the relevance of the raised scientific issues, the suggested methods of solution, the importance of the obtained results and effectiveness of public speaking skills. Considering the scientific research experience and skills of the participants, the assessment was carried out in two groups. The points were accumulated from the official, anonymous, the young and presentation reviewers; thereby the authors of the best article and report were announced. In the group of postgraduate students and the first and second year doctoral students:

- 1. Li Ya-Chieh (Feng Chia University, Taiwan);
- 2. Tadas Kaliatka (Lithuanian Energy Institute, Lithuania);
- 3. Paulius Danilevičius (Vilnius University, Lithuania).

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

- 1. Mantas Marčiukaitis (Lithuanian Energy Institute, Lithuania);
- 2. Vladimir Leschevich (A A. V. Lykov Institute of Heat and Mass Transfer, Belarus);



Fig. 1. Variation in the number of conference participants

3. Roman Voronov (Lithuanian Energy Institute, Lithuania).

Apart from the official part, the event included various cultural activities. At the end of the first day of the conference, the guests were invited to have dinner and enjoy a folk dance group *Rasa* performance, which guaranteed the good mood of the evening. At the end of the conference, the organizers offered a thematic tour to Kaunas Hydroelectric Power Plant and a possibility to admire Kaunas Pažaislis Monastery and its surroundings.

The conference was first organized back in 2002 in pursuance to provide a possibility for the young scientists of the Institute to present the results of their research and become acquainted with the work done by their colleagues, discuss the relevant energy-related issues and promote scientific cooperation. This annual conference became more and more popular: in 2007 guests from neighbouring countries joined the conference and their number is growing every year (Fig. 1).

Since 2007, the scope of the conference rapidly increases and its name, **CYSENI**, is already known by the young scientists and researchers from 15 countries. The summarised information about the 2008-2011 distribution of the participants according to countries is presented below (Fig. 2).



Fig. 2. 2007–2011 distribution of the conference participants according to countries

The organizers of the conference are the Board of LEI Young Scientists Association, supervised and assisted by the Director of LEI, *Prof. Dr. Habil.* Eugenijus Ušpuras, Head of the Information Department, Dr. Rolandas Urbonas and Studies Administrator Jolanta Kazakevičienė.

The conference and its material are prepared in English, which not only promotes the dissemination of research results obtained by the young Lithuanian researchers and their foreign colleagues, but also provides favourable conditions for further cooperation. The conference organizers received many positive responses from the research associates and young scientists who participated in it: this clearly demonstrates the relevance and need for such event. The support of the LEI authorities and positive feedback of the conference participants motivate the LEI Young Scientists Association to nourish and develop the idea of the conference as the annual event for meeting of young researchers working on energy issues, exchange of ideas and experience as well as



The board of LEI YSA and Studies administrator Jolanta Kazakevičienė

development of skills. Since 2006, the material of the conference **CYSENI** has been enrolled into the INSPEC database, which widened the international spread of the work presented in the conference.

OPEN DAY AT LEI

The LEI Open Day, organized on 5 May 2011, provided a possibility for everyone who is interested to become acquainted with the Institute, researchers of the scientific departments, doctoral students and young scientists as well as to observe real experiments. The Lithuanian Energy Institute, widely known as one of the most advanced scientific centres of the country, takes active participation in international research programmes, carries out scientific investigations necessary for the Lithuanian and foreign clients, and closely cooperates with business, scientific and educational institutions. The Institute also gives a great deal of attention to the presentation and promotion of research in the society, organization of public events, such as **Researchers' Night** for the promotion of science, conference for doctoral students and young scientists CYSENI seminars for relevant energy-related issues, etc. The Open Day at LEI was organized for the second time in order to motivate the best students of the Lithuanian and foreign universities to associate their future with the Institute and the research performed here. Although the Open Day is in principle targeted towards students as potential employees, everyone interested was welcomed to participate: the event attracted visitors from the energy associations and scientific institutions carrying out related research.

During *the Open Day*, the visitors were provided information about the possibilities of employment, placement and doctoral studies in the Institute. The representatives of all departments of the Institute introduced themselves and presented their Laboratories. As stated by the Deputy Director of LEI, Dr. Rimantas Levinskas, a



Moments from the Open Day

considerable amount of job vacancies are going to be created in the Institute, participating in the activity of Santaka valley, for this reason the Open Days provide many possibilities to start a scientific activity in Lithuania. "Every educational institution requires constant refreshment, thus LEI seeks to attract young people educated in different fields and determined to pursue a career in science. In order to prepare specialists who could substitute the experienced scientists, every year doctoral students are accepted and favourable conditions for young people to work and practice in the Institute are created. By organizing this event, we want to show that the resources of the European Union Structural Funds are properly used: new equipment was purchased and is successfully used for scientific research, whereas the National Open Access Scientific Centre for Future Energy Technologies, currently under development, will provide equally good conditions for young people to work towards innovative results as in the research centres well-known worldwide" — said R. Levinskas.

An excursion in LEI was also organized: the participants could evaluate work conditions, observe real experiments and become acquainted with everyday work of the researchers. The stands of all Laboratories attracted attention of the visitors who had many questions initiating discussions. They were taken to Laboratory of Heat Equipment Research and Testing, Laboratory of Combustion Processes, Laboratory of Nuclear Engineering, Plasma Processing Laboratory, Laboratory of Material Research and Testing, and Center for Hydrogen Energy Technologies, where they could see brand-new equipment based on the most advanced technologies.

In the program, some time was also devoted for informal communication: the guests of the Institute could talk to the representatives of the Institute and ask all relevant questions about the posters of the Laboratories. The young people working in the Institute confirmed that it provides excellent conditions for those who are really motivated to become researchers and realize themselves through research important to the society rather than simply seek for a degree and "a life of ease".

In the end of the event, the Head of Center for Hydrogen Energy Technologies, Dr. Darius Milčius, gave a lecture to the guests of the Institute about hydrogen energy technologies which are seen as the future energy by many.









KTU CAREER DAYS 2011

On 16 March 2011, an already traditional event KTU Career Days 2011 took place in Kaunas University of Technology and the representative of LEI also participated in it. For seven years KTU Career Centre and Student Association have been organizing the event which attracts many students from thirteen different faculties of the University, the representatives of the largest Lithuanian enterprises and foreign visitors. Every year the vent receives considerable attention from students, professors and the representatives of companies; over several thousands of students and high-school graduates come to the event which is referred to as the market of companies and students. The main objective of the market is to directly clarify the needs of both parties and exchange the contacts.

This year, LEI YSA members and the Studies Administrator, J. Kazakevičienė, participated in the event in order to present the Institute and provide information about the scientific career possibilities to the students. The stand of the Institute mainly attracted the students studying electrical power engineering and technologies, applied physics, applied mathematics, electronics 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 7 worked for practice. As a result of the effort made by LEI YSA Board and J. Kazakevičienė to interest as many young people as possible, 9 curricula vitae were received in 2011.

RESEARCHERS NIGHT 2011

At 6 p.m. on 23 September 2011, the Institute welcomed the society and offered a possibility to explore the scientific world filled with innovations for the second time.

The events of the evening are intended to provide information for people of various ages about the most advanced research carried out in the Institute and to make children and young people interested in science. "This event has been organized



Our stand attracted considerable attention

for the second time in a row in the Institute; thus, the experience of the previous year has shown that the citizens of Kaunas very clearly understand the relevance of energy issues. For this reason, the interest in the research performed in the Institute has markedly grown. We try to involve all visitors into the activities rather than leave them as passive observers. Energy issues are not the only ones discussed: the events are aimed at people of various ages and interests so that everyone can 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," ---said Dr. Diana Meilutytė-Barauskienė.

The visitors were offered a great deal to see during the 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 also offered a European Researcher's Passport with their thermovisual photographs. From 6 p.m., excursions to the Laboratories of the Institute, during which the researchers showed real experiments, were organized. The exhibition World of Science offered the visitors many interesting sights: developed models, surprises, exploration of micro and macro world demonstrating huge and very tiny objects. The participants could also travel around the world together with the researchers and to find out about their usual and extraordinary hobbies in a "live exhibition".

Considerable attention and entertainment were provided to children who came to the Institute: a drawing and sculpture competition *Scientists through the Eyes of Children* and a children's quiz were organized, they could test their skills in educational free-access computer games, presenting analysed scientific phenomena in a captivating way, as well. Moreover, exciting statistics was prepared and the visitors could find out more about themselves,



Researchers' Night 2011

their friends or neighbours, whereas films and cartoons about real science were shown in the science film centre.

The lectures, which took place in LEI hall, encompassed a very wide range of interesting and serious topics. 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*; the visitors of the Institute did their best to prove that they are cleverer than the scientists. The questions required intelligence rather than knowledge of bare facts, thus the question whether the scientists.



At Lithuanian Television broadcast Leaders



tists are really so clever remained intriguing. In the end, the team of scientists won the quiz, but only by a single point.

Young Scientists Association of the Lithuanian Energy Institute

http://jms.lei.lt, www.cyseni.com

LEI soccer team

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;
- Funds 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)

	2007	2008	2009	2010	2011
Income:					
State Budget Subsidies	7902.1	9917.2	9152.5	7896.0	8335.0
Contracts	9439.1	8370.0	9646.4	9356.0	6071.0
SF Support	1048.0	8467.0	772.9	5403.6	10992.1
Other Income	1356.2	1136.9	1155.3	99.7	95.5
Total:	19745.6	27891.1	20727.1	22755.3	25493.6
Expenses:					
Salaries (soc. ins. incl.)	112919.9	15650.0	13722.0	13843.0	14273.0
Operating Expenses	4881.8	5059.0	3749.0	2432.3	3435.0
Capital Funds	2010.4	9757.3	392.0	6122.0	10863.0
Total:	19812.1	30466.3	17863.0	22397.3	28571.0
Long-term Projects Assets	4678.1	2102.9	4967.0	5325.0	2247.6



on **http://www.lei.lt** (About LEI: Financial Reports).

Financial Reports may be found





- LMT Research Council of Lithuania;
- MITA Agency for Science, Innovation and Technology;
- ŠMM Ministry of Education and Science of the Republic of Lithuania;
- VMT State Metrology Service.

The structure of finances obtained from the contractors of LEI for year 2011



Dynamics of assets devoted for equipment purchase, thous. LTL

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THE MAIN EVENTS IN 2011

Participation at KTU career days 2011

e institutas

16 March.

25 March.

18 January.

The signs of Honour of association LINPRA were granted to LEI representa-



1 February.

The cooperation agreement signed between LEI and SC Kauno energija



2 February.

Visit of the representatives from Agency for Science, Innovation and Technology (MITA)



LAS award for scientific works of young

researchers granted to award winner dr.

D. Meilutytė-Barauskienė

12 April.

Meeting of association EURATOM-LEI committee



20 April.

Meeting of the Energy Committee of the Confederation of Lithuanian Industrialists



5 May.

The open days at LEI



26–27 May. 8th International conference of Young Scientists on Energy Issues CYSENI 2011



15 June.

Seminar Relevant issues of Heat sector development



17 June.

Dr. Mario Guarrancino (National Research Council of Italy) visit to LEI



16 September.

Visit paid by the representatives from the Energy Security Centre under the Ministry of Foreign affairs of the Republic of Lithuania



23 September. Researchers' Night 2011





17 October.

Meeting of participants for 7th FP project Product and Process Design for Aml Supported Energy Efficient Manufacturing Installations (DEMI)



17 October.

Valley Monitoring Group experts paid visit to LEI



19 October.

Meeting of the organizational committee for project *B25, Near Surface Repository for Low and Intermediate Level Short-lived Radioactive Waste*



27 October.

Visit by NASA experts at LEI



16 December.

LEI was awarded the golden medal at competition *Lithuanian product of the year 2011* organized by the Lithuanian Confederation of Industrialists

4 November.

The activities of the national academy of students at LEI Center for Hydrogen Energy Technologies



18 November.

Visit by Prof. Witold Brostow from the University of North Texas Dept. of Materials Science & Engineering



30 November. Defense of final state budget financed project reports









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