



**LITHUANIAN  
ENERGY  
INSTITUTE**



**2009**

**ANNUAL  
REPORT**

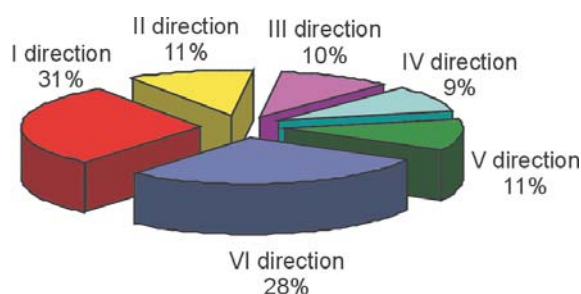
# Lithuanian Energy Institute in 2009

## Scientific Research Activity of the Institute is carried out according to six research directions:

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

*Lithuanian Energy Institute is a state scientific research organization, established for Lithuanian energy and long-term scientific research of international significance and experimental development.*

*The Institute carries out research of hydro and gas dynamics, heat transfer, fundamental and applied research of materials science and nano technologies, which are needed to develop the most advanced and future energy technologies, to justify their safety and reliability, and estimate their impact on the environment. The Institute is also the highest qualification expert in the field of energy economy, metrology and energy system management.*



*Distribution of researchers according research directions*

In 2009 researchers of Lithuanian Energy Institute carried out 15 research projects funded by the Ministry of Education and Science of the Republic of Lithuania, five of which were successfully completed and defended, whereas the remaining 10 projects will be continued in the period of 2010-2011. State funded research projects attract particular attention at the Institute, their implementation and achieved results are discussed in the expert commission of scientific works, whereas annual and final scientific research reports are approved at the Institute Council. Information concerning projects funded by the Ministry of Education and Science of the Republic of Lithuania is presented in this Annual Report as well. It is expedient to note that state funded fundamental and applied works, such as application of best estimate methodology for various systems, meteorological parameter analysis of meters, radiation impact analysis during radioactive waste management, security and reliability assessment of energy supply, new hydrogen technologies, fuel elements and environmental issues, are especially important to Lithuania.

***Analysis of Liquid and Gas Flow Characteristics Impact on Metrological Parameters of Volume and Rate Meters*** (project leader – Dr. Habil. Antanas Pedišius).

The aim of the project is to analyse the dependability of inaccuracies of gas and liquid amount meters, mostly used in

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practice, on flow pulsations aroused by consumption instability, improper operation of control equipment, hydrodynamic disturbances and changes of physical properties. Doppler anemometers were used for the research, while dimension analysis methods and Navier-Stokes equations were applied for carrying out the analysis.

This project is relevant for Lithuania where limited energy resources exist and imported resources become more expensive and should be used efficiently and economically. Accuracy in consumption accounting is one of the main methods of saving.

The accomplished project has extended knowledge on liquid and gas flow characteristics under various disturbances and changes of physical properties in action. This enables determining generalized dependencies of volume and flow measuring inaccuracies on consistent patterns of flow pulsations, and reasonably analyse and assess measuring uncertainty of small air velocities.

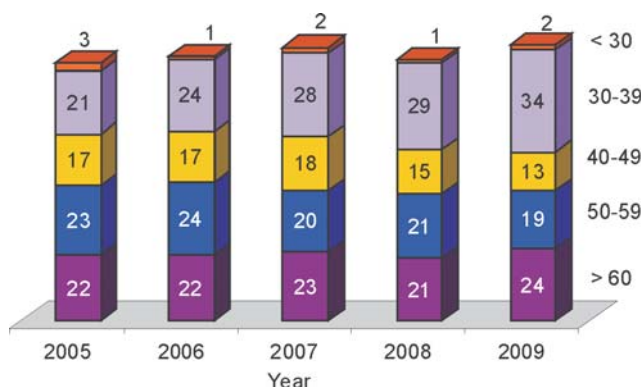
The results of the research will enable developing a method for predicting inaccuracies of liquid and gas volume meters during exploitation, estimating and determining calibration conditions for small velocity meters and assured uncertainty.

**Best Estimate Methodology for Simulating Processes in Technical, Environmental and Social Systems.** Project leader – Dr. Habil. A. Kaliaška.

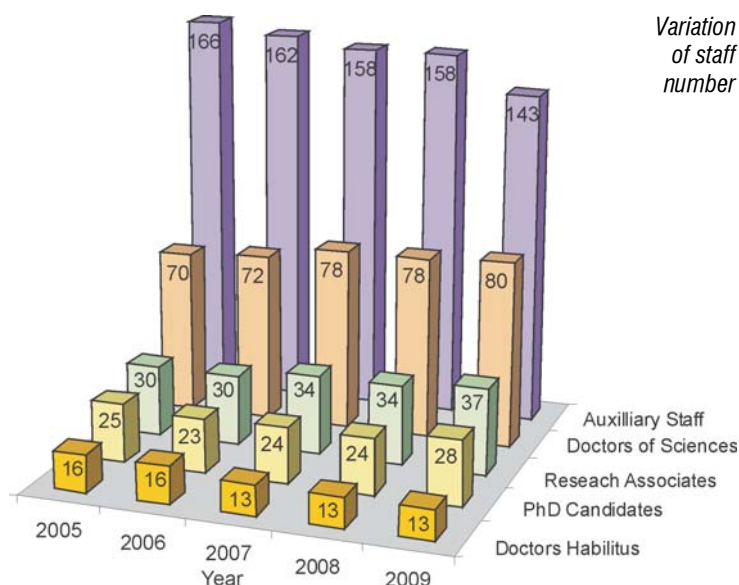
The aim of the project is consolidation of the best estimate methodology for modelling technical, environmental and social systems, and analysis of thermal-hydraulic processes taking place in pressurised water reactors (and other types except RBMK) during accidents. The work is relevant for solving energy economy and hydrology issues in order to obtain reliable modeling results.

During the implementation of the project, a model of pressurised water reactor (PWR) was designed, a selected accident was analysed applying the best estimate method, and FEMAXI software package was adjusted to the needs of RBMK-1500 reactor.

Consolidation of the best estimate methodology in physical and social sciences is a new step in applying this advanced methodology. Selected accident analysis applying best estimate methodology in PWR reactors will enable improving knowledge in the field of thermal-hydraulic process analysis in other than channel-type nuclear power reactors. This is relevant for preparation of the new power plant construction in Lithuania.



Dynamic of age of scientists



The obtained results are going to be used for renewing National Energy Strategy and preparing work related to Kaunas hydro-energy system exploitation and safety.

**Radioactive Impact Analysis and Optimisation Performing NPP Equipment Dismantling and Managing Radioactive Waste.**

Project leader – Prof. Dr. Habil. Povilas Poškas.

The aim of the project is to analyse and optimize the predicted radiation effect while performing Ignalina NPP Unit 1 facilities dismantling and managing radioactive waste.

State-of-the-art methods of modelling which are more accurate in assessing radiation effect during both exploitation termination of contaminated facilities and managing radioactive waste were applied for the research.

The work is important for solving safety issues arising during the shutdown of Ignalina NPP and managing radioactive waste.

Determined consistent patterns and collected information on radiation effect will be used in planning of Ignalina NPP dismantling, its safety assessment, designing surface repositories and analysing possibilities of constructing geological repository in Lithuania.

**Synthesis of Nanocrystalline Metal Hydrides, Designed for Hydrogen Storage, Applying Ion-plasma Methods.** Project leader – Dr. Darius Milčius.

The aim of the project is to detect unexplored metastable conditions of magnesium/ aluminium nanocrystalline alloy hydrides when the material actively absorbs/ desorbs hydrogen. Non-balance physics technologies were applied in this research and materials of distinctive structure were obtained; they are characterised by absorption/ desorption properties that enable developing new generation hydride storage equipment.

The main problems limiting the use of metal alloys for hydrogen storage are related to hydriding/ dehydriding process. For this reason, the project aimed at reducing the pressure of hydriding and temperature of dehydriding processes up to 80-200 °C, having applied metal alloys for hydrogen storage in transport. An intensive search for new chemical compounds and technologies was carried out in order to increase the efficiency of metal alloys and improve work parameters.

Work results are going to be applied in providing industrial recommendations and developing new generation hydride storage equipment.

**Impact of Climate Change on the Condition of Lithuanian Water Resources and Hydroenergy Sector.** Project leader – Dr. Habil. Brunonas Gailiusis).

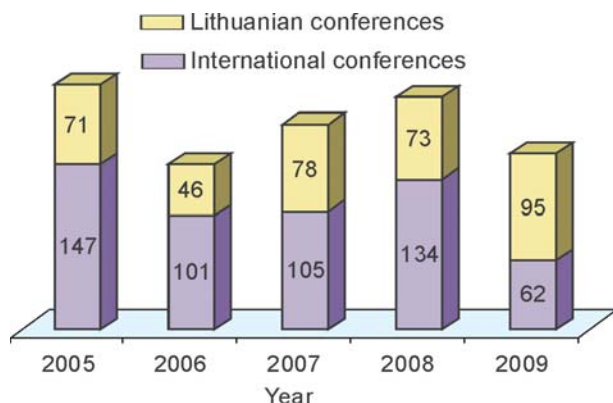
The aim of the research is to assess the impact of Lithuanian rivers run-off in hydroenergetic resources considering climate change.

While planning the operation of large hydropower plants, the knowledge on river water resource changes in the 21<sup>st</sup> century is especially relevant. Therefore, the operation of Kaunas hydropower plant under predicted run-off conditions was analysed for the first time in Lithuania, regarding the safety of system operation under extreme conditions. The performed risk analysis of the energy system will enable a proper assessment of system condition in respect of climate change.

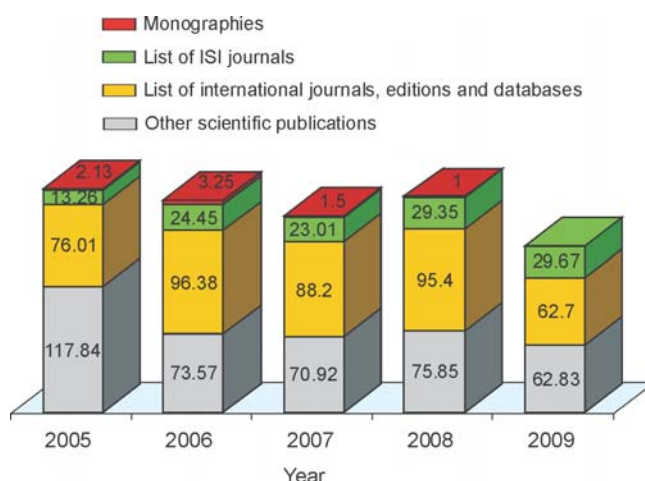
Applying methods of statistical analysis, the tendencies of meteorological and hydrologic parameter changes in Lithuania were determined and the results were compared to the trend parameters of the Baltic and Nordic countries. The Nemunas run-off formation model was developed using modern software HBV created by Swedish scientists. Additionally, the forecast of Nemunas run-off considering various scenarios of climate change was carried out and the operation of Kaunas hydropower plant was analysed, estimating the forecast of Nemunas run-off. The results of this project were applied in the project *Climate and Energy Systems* (2007-2010) initiated by the Nordic countries (Nordic Energy Research).

The following state funded projects have been continued:

- **Experimental and Numerical Modelling Research of Biofuel and Calorific Waste Aiming at Improving Energy Production Technologies.** Project leader – Dr. A. Džiugys;
- **Heat Transfer and Flow Hydrodynamics Research in Transitional Flow Zone at Mixed Convection and Interaction of Stable and Unstable Air Density Stratification.** Project leader – Dr. R. Poškas;
- **Planning Principles and Implementation Possibilities of Sustainable Energy Development.** Project leader – Dr. V. Kveselis;



Number of papers in scientific conferences



Variation of publication number (authors' contribution evaluated)

- **Experimental Investigation of Dissociation Patterns of Zirconium-Base Alloys Designed for Production of Thermal Element Coatings and Pressure Pipes.** Project leader – Dr. A. Grybėnas;
- **Lithuanian Energy Security Research.** Project leader – Prof. Dr. Habil. J. Augutis;
- **Experimental Numerical Research of Condensing Two-phase Flow.** Project leader – Dr. M. Šeporaitis;
- **The Research of Wind Energy Prediction and the Developmental Possibilities of Biomass Resources Use in Energetic.** Project leader – Prof. Dr. Habil. V. Katinas;
- **The Development of New Energy Production Technologies in Lithuania and the Study of Increasing Energy Consumption Efficiency Possibilities in Public Buildings.** Project leader – Dr. R. Škėma;
- **Development of Multicriteria Decision Making Methods and their Application in Energy and Environmental Policy.** Project leader – Prof. D. Štreimikienė;
- **Identification and Assessment of Prevailing Factors Determining the Synthesis of Inorganic Material Oxides Fibre in Plasma Ambient.** Project leader – Dr. V. Valinčius.

The actual results of the Lithuanian Energy Institute activity in 2009 comply with the planned goals, whereas the contractual income compensated the budgetary subsidy decrease. Having made use of EU Structural Funds support and considerably expanded the basis of research in 2008, much less expenses arose in 2009: only new hardware and software, and some experimental equipment were obtained.

Researchers of the Institute actively participated in European Union programmes projects: in 3 FP6 projects, 7 FP7 projects, 9 *Intelligent Energy – Europe* projects, 4 International Atomic Energy Agency projects, 5 COST programme projects, 1 EUREKA projects, 2 *Nordic Energy Research Programme* projects and 1 *Baltic Sea Region Programme 2007-2013* project.

In 2009 the following Seventh Framework Programme projects were under implementation:

- **Security of Energy Considering Its Uncertainty, Risk and Economic Implications, SECURE** (LEI representative – Prof. Dr. Habil. J. Augutis). The aim of the project is to develop an energy safety assessment methodology, covering all issues related to energy supply safety problems, including geopolitical changes, price formation, development of energy markets inside and outside the EU, terrorism threats, etc.;
- **Energy Technological Foresight and Scenario Development, PLANETS** (LEI representative – Prof. D. Štreimikienė). The aim of the project is to determine the most perspective technology development scenarios for the EU countries till 2050 that would correspond to the goals of the EU energy policy priorities and substantial development;
- **Integrated European Network for Biomass and Waste Reutilisation for Bioproducts, AQUATERRE** (LEI representative – Prof. Dr. Habil. V. Katinas). The aim of the project is to inventory the European biomass resources and determine the potential of biofuel production and value; applying Geographic Information System, to compose maps of European biomass resources use and determine the schemes of economic factors and environmental impact by optimal Life Cycle Assessment (LCA) scenarios;
- **Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste, CARBOWASTE** (LEI representative – Prof. Dr. Habil. P. Poškas). The main object of research is irradiated graphite used in Russia and its characteristics and experimental research. The first phase of the research included the integral analysis of Russian radioactive waste (graphite) management and the research report was prepared. Nuclear objects, such as nuclear power plants, reactors used for experiments and industrial reactors used for plutonium production, in different parts of Russia were analysed in the report. Detailed information on exploitation of the mentioned objects and planned new nuclear objects was presented. The report includes a comprehensive analysis of graphite characteristics used in Russia, experimental and numerical research of this field, presentation of ionising radiation measurement analysis of graphite in specific nuclear objects, and also technologies for this waste recycling, applied and planned in Russia.
- **Fate of Repository Gases, FORGE** (LEI representative – Prof. Dr. Habil. P. Poškas). The project is devoted for gas generation and spread in PBK/RA repositories for broadening understanding and process research;
- **European Fusion Development Agreement** (LEI representative – Prof. Dr. Habil. E. Ušpuras). The aim of the project is to perform safety assessment of fusion experimental equipment W7-X of stelator type being built in Max-Plank-





Institut für Plasmaphysik, in co-operation with the mentioned Institute;

- **Network of Excellence for a Sustainable Integration of European Research on Severe Accident Phenomenology, SARNET2** (LEI representative – Dr. Habil. A. Kaliatka). This project is for integration of severe accident phenomena and operation research in Europe. 41 educational and business institutions of the EU countries participate in this project together with LEI.

No trend in employees' variation was observed in the Institute: only the number of technical personnel was reduced. Dealing with inevitable ageing issues of employees, LEI gives a considerable attention on training and education of young generation, thus, a certain number of PhD Candidates are constantly studying at the Institute.



Successful activity of the Lithuanian Energy Institute is evidenced by the nomination **Successfully Operating Company 2009** in the group of large enterprises, established and granted by Lithuanian Confederation of Industrialists. This shows that it is possible to achieve ones aims successfully and socially responsibly, although the economic situation is difficult.

LEI researchers actively participate in the activities of the following technology platforms:

- *Future manufacture;*
- *Hydrogen and Fuel Cells(H2/FC);*
- *National Thermal Energy;*
- *National Biomass and Biofuel Production and Use;*
- *Lithuanian National Biofuel.*



The Institute has actively participated in the preparatory work of *Valley Santaka*. Together with Kaunas University of Medicine and LEI, Kaunas University of Technology initiated the establishment of integrated science, studies and business center *Valley Santaka* in the end of 2006. It aims at focusing scientific research, studies and knowledge-receptive business potential, developing common use infrastructure and purposeful implementation of scientific research

and experimental development relevant for Lithuanian economy including energy sector. The following largest Lithuanian business subject groups contribute to the establishment of *Valley Santaka*: JSC concern *Achemos grupė*, SC *Kauno tiltai* (AB *Tiltra Group*) and JSC *MG Baltic Investment*. Having expanded the activity of the Valley, a greater co-operation is planned with other interested economy subjects.



In December 2009, Lithuanian Energy Institute joined the European Technical Support Organization Network (**ETSON**), which was established in 2006. Presently the members of the organization are IRSN (France), GRS (Germany), Bel V (Belgium), SJV (the Czech Republic), VTT (Finland) and LEI (Lithuania). **ETSON** is one of the principal organizations that arranged Strategic Research Agenda (SRA) for nuclear energy. The main aim of participating in the activity of **ETSON** is to influence European research in the field of nuclear energy and to take active participation in it.

In 2009, **ETSON** partners decided to establish training and consulting organization that would encompass the needs of newly accepted nuclear energy specialists. This was the primary stimulus to found European Nuclear Safety Training and Tutoring Institute (**ENSTTI**). In December 2009, ETSON partners (IRSN, GRS, UJV, LEI) signed a memorandum on ENSTTI foundation. The aim of ENSTTI is to organize and implement training and consulting programmes in pursuance of increasing qualification of the future experts in the nuclear energy sector.

In 2009, a project **Foundation of Hydrogen Energy Technology Center** funded by EU Structural Funds was implemented; it offers conditions for the development of dynamically integrated fundamental and technological research in the strategic field of scientific research and experimental development of the EU.

Retrospecting the activities carried out in 2009 and considering recognition shown to the Institute researchers, the Institute team with great enthusiasm and energy looks forward to scientific, creative and technical challenges in the future.

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# Activity of Institute's Young Researchers

Since 2003 Lithuanian Energy Institute has a joint PhD studies programme with Kaunas University of Technology in the following research directions:

- Economics (04S);
- Environmental engineering (04T);
- Energy and power engineering (06T).

In the period of 1992–2009, 64 PhD Candidates completed the PhD studies, 37 defended the theses and 28 studied at the Institute.

In 2009 Kaunas University of Technology together with Lithuanian Energy Institute granted the Doctor of Science degree to the following researchers of the Institute:

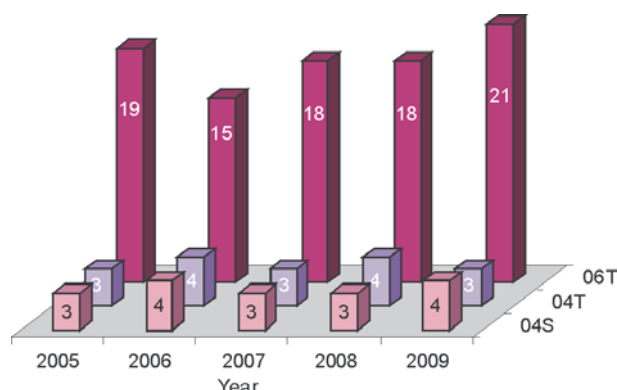
- 30 April. Mantas MARČIUKAITIS for technologic sciences: energy and power engineering work (06T) **Investigation, Modeling and Prediction of Wind Energy;**
- 5 June. Asta MIKALAUSKIENĖ for social sciences: economics (04S) work **Assessment of Market Based Climate Change Mitigation Tools in Lithuanian Energy Sector;**
- 29 June. Nerijus STRIUGAS for technologic sciences: energy and power engineering (06T) work **Investigation of Hydrogen Rich Gas Production by Thermal Glycerol Fraction Decomposition;**
- 30 June. Diana MEILUTYTĖ-BARAUSKIENĖ for technologic sciences: environmental engineering (04T) work **Impact of Climate Change on Runoff of the Lithuanian Rivers;**
- 27 November. Darius TARVYDAS for social sciences: economics (04S) work **Economic Assessment of Energy Security Enhancement Measures;**
- 17 December. Ernestas NARKŪNAS for technologic sciences: energy and power engineering (06T) work **Investigations of the Change of Nuclides' Content in the RBMK-1500 Reactor Structural Components.**

On 22 December 2009, Vytautas Magnus University granted the Doctor of Science degree to the researcher of the Laboratory of Nuclear Installation Safety Gediminas STANKŪNAS for physical sciences: physics work (02P) **Experimental Fission Reaction Studies: from Fission Product Yields and Their Release Properties to Delayed Neutron Emission.**

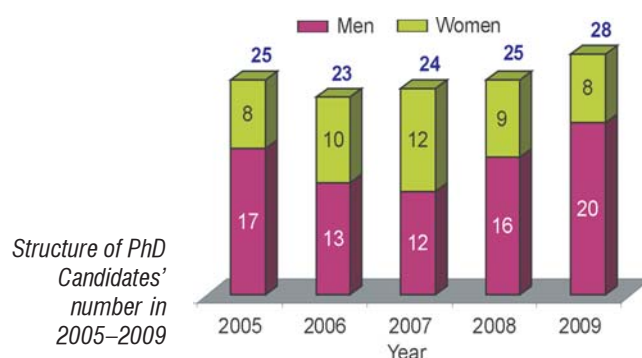


Young Scientists' Association (YSA) actively operates at the Institute. On 18 March 2009, YSA representatives participated in the traditional event organized by Kaunas University of Technology, **KTU Career Days 2009.**

LEI stand was constantly surrounded by students, especially interested in PhD studies, practice and employment possibilities, and experiments carried out in the Institute. The most attention was received from students of chemistry and environmental engineering. Face to face conversations, advantageous to both sides, took place from the beginning to the end of the event. LEI participated in this event for the



Arrangement of PhD Candidates according to science directions in 2005–2009



Structure of PhD Candidates' number in 2005–2009

fourth time, which demonstrates its importance in searching for perspective young employees as well as benefit for students looking for studies and career opportunities.





In 2009, YSA initiated the sixth international conference *Youth Energy 2009 (CYSENI 2009)* for PhD Candidates and young researchers. Its main aim is to encourage PhD Candidates and young researchers' active scientific work, cooperation and development of skills in presenting scientific research results. Young researchers are given an opportunity to meet the colleagues, familiarize with their scientific activity, exchange ideas and contacts that may be useful in developing common projects and expanding scientific research in progress.

54 young researchers from various Lithuanian and foreign institutions presented their papers in the conference; PhD articles reviewers, known experts in the field of technological sciences took part in it.

A great number of young researchers from scientific and educational institutions of neighboring countries participated in the conference; they are the following: A. V. Lykov Heat and Mass Transfer Institute (Belarus), A. M. Pidgorny Institute for Mechan-

ical Engineering Problems of the National Academy of Sciences of Ukraine, Institute of Solid State Physics of University of Latvia, Riga Technical University (Latvia), Institute of Silicate Materials (Latvia), Tallinn University of Technology (Estonia), Wuppertal Institute for Climate, Environment and Energy (Germany).

Authorities of the Institute favored the YSA initiative to arrange the annual event and provided financial and technical support. The support for the conference was also provided by Lithuanian State Science and Studies Foundation, COST and Lithuanian District Heating Association.

Organizers (e-mail [info@cyseni.com](mailto:info@cyseni.com)) seek that this conference would become the best known annual event for young researchers working in the energy sector. Therefore, they search for famous and well-experienced scientists who perform experiments under the themes of the conference and would make a contribution in training young researchers; these people are welcomed to become members of editorial college of the conference.



*The Chairman of Scientific Council of Lithuanian Energy Institute Prof. J. Vilemas and the Board President of Young Scientists' Association of LEI D. Meilutytė-Barauskienė congratulate the best author of article in the section of masters and first and second year PhD Candidates M. Lelis (LEI), and V. Leschevich (A. V. Lykov Institute of Heat and Mass Transfer, Belarus) in the section of third and fourth year PhD Candidates*

*Moments from the conference  
CYSENI 2009*



# Laboratory of Heat-Equipment Research and Testing

## Main research areas and applied work of the Laboratory:

- Scientific research of the influence of liquid and air (gas) physical properties and flow structure on the measuring of velocity, volume and flow rate accuracy and reliability. Research reorientation to the studies and measuring of flow structure and transfer processes in microsystems and joining the projects of European Metrology Research Programme;
- Provision of metrological support to the Lithuanian energy sector in the field of liquid and gas flow measurements, uncertainty studies of reproducible reference values and ensuring measurement traceability to National Measuring Institutes in Europe and Lithuanian laboratories;
- Research of efficiency and emission of small and medium capacity heat-equipment burning the solid biomass, its mixtures and recovered fuel as well as the implementation of innovative technologies;
- 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 the gaseous, liquid and solid fuel (including biofuel).

## Accredited fields of applied activity in the Laboratory against LST EN ISO/IEC 17025 and 17020 standards:

- Calibration, testing and conformity assessment of liquid and gas flow measuring instruments and facilities designed for their calibration/verification. In the field of water and heat meters the Laboratory is notified, identification No 1621;
- Testing and conformity assessment of gas appliances and hot water boilers burning gaseous, liquid and solid fuel, including biofuel. In the field of gas appliances the Laboratory is notified, identification No 1621;
- For testing and conformity assessments of hot water boilers the Laboratory meets the requirements of LST EN 305-1:2000.

Calibration and measurement capabilities approved and declared by International Bureau of Weights and Measures (BIPM) and accredited by Lithuanian National Accreditation Bureau are presented in the corresponding websites

<http://www.bipm.org/en/db/>  
and  
<http://www.lei.lt/>.

## The main results of scientific work and experimental development of 2009

In 2009 the Laboratory completed and defended a state subsidy funded research project *Study of the Influence of Liquid and Gas Flow Characteristics on Metrological Parameters of Volume and Flow Rate Meters* that took 3 years; its main conclusions can be described as follows:

- A universal method for evaluation of the dynamic response of meters to flow pulsations, which change according to different consistency patterns, and of their influence on the errors of measurement was created. The method was applied for the evaluation and prognosis of dynamic errors of turbine gas meters in pulsating



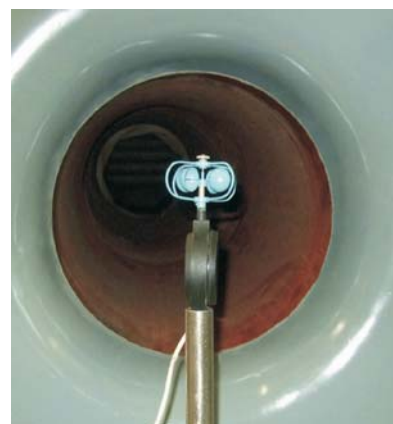
Measurement channel of aerodynamic facility, which is applied for measuring velocity in the entrance region of channel and free stream inflowing to the protective chamber, was reconstructed in 2009; 1 – measurement channel; 2 – protective chamber; 3 – object under test - wind speed meter

flow, considering the variations in meter rotation frequency. The study suggested that analogous dynamic errors have to be assessed by measuring wind speed using mechanical anemometers and water or heat consumption using mechanical meters. In such cases analysis should be based on the method created;

- Consistent patterns of velocity distribution under the transitional flow regime in the entrance region of channel were determined. Asymptotic values of axial and mean velocity ratio in the beginning and end of transitional flow were identified using *numerical methods*. These values, which are approved by experimental measurement applying laser and ultrasound anemometers, enable to reproduce velocity values up to 0.05 m/s with reliably defined uncertainty;
- The reasons of air velocity measurement results dispersion were explored by the experiments and international comparison and also means and conditions for harmonized air velocity value reproduction in National European laboratories were suggested;
- The influence of water meter installation, inlet flow conditions and interrelated hydrodynamic disturbances on the accuracy of measurement water and heat flow was examined;
- The effect of oil product viscosity on positive displacement meter errors was examined and compared with the measurements carried out in the National Measurement Institute of the Netherlands. The results of the study were generalized following the theoretical assumptions. Analogous study results in the compressed gas flow were presented and the importance to develop the universal measuring method, which is based on (Coriolis) mass meters and is independent on fluid physical properties, was grounded;

- International comparisons in all measurement areas were carried out; their results suggest that the Laboratory study results are reliable and their level is closely related to the results indicated by National European Institutes.

In the process of research, experimental equipment and research methods were constantly being improved in order not only to solve the budgetary work tasks but also to direct the research to the further efficient use of energy resources including biofuel, reduction of pollution and the development of innovative technologies for energy production. Aerodynamic facilities for measuring air flow, including wind, velocity and volume at 0.005–16 m<sup>3</sup>/h were thoroughly reconstructed, whereas the construction of critical nozzle facility and gathering the microflow measuring instruments is still in progress.



*The wind speed meter installed in the free stream inflowing to the protective chamber of aerodynamic facility*

The accomplished researches and international comparisons enabled the recalculation of flow measurement capabilities and their noticeable improvement in the areas of air velocity and fluid (water and oil products) volume and flow rate measuring.

<b>Fluid, value</b>	<b>Accredited measurement range/ uncertainty</b>	<b>Measurement range/uncertainty achieved</b>
Volume of oil products and biofuel	(1–135) m <sup>3</sup> /h, ±0.12 %	(1–150*) m <sup>3</sup> /h, ± (0.04–0.08) %, considering the method of measuring
Volume of water	(0.01–100) m <sup>3</sup> /h, ± 0.08 %	(0.01–100) m <sup>3</sup> /h, ± (0.06–0.08) %, considering flow rate values
Air velocity	(0.05–0.2–60) m/s, ±(50–7–1)%	(0.05–0.2–60) m/s, ±(15–3.5–0.5) % applying laser anemometer

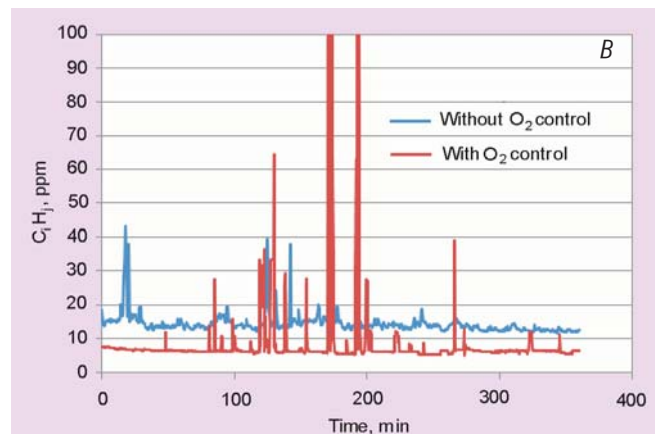
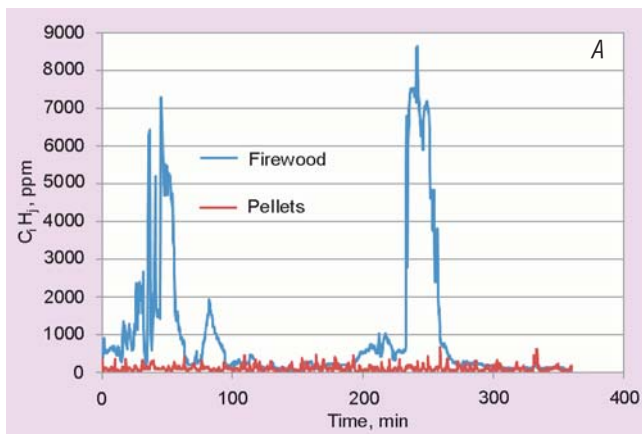
\* – new values are marked in red in the table

## The perspectives of scientific research in 2010–2012

In 2010–2012 two scientific research directions are planned; firstly, the studies are going to be accomplished in order to summarize the effects of non-stationary liquid and gas flow structures on flow velocity, volume and flow rate meters operating under the principle of tachometer and having different response to the influencing factors. Another aim is to present practical recommendations for evaluation of meter dynamic errors and, clarifying and removing the reasons for the imbalance of gas, water and heat supply/consumption. This area will grant a great deal of attention to the new research methods of momentum and heat transfer, especially applying particle visualization technique in macro- and microsystems.

The second research direction is the analysis of the effectiveness and emission of small and medium capacity heat equipment that is fired with biofuel or its mixtures. The analysis is carried out considering the construction of the equipment, the type of fuel used, the means and technology applied to improve its quality, the distribution of air flow in combustion chamber and temperature in burning zone, the draught and other factors. Considerable experience, experimental equipment and measuring instruments have already been collected in this field; however, the possibilities will enlarge after becoming a part of open access scientific Renewable and Alternative Energy Centre and cooperating with other competence centres.





The variation of  $CH_4$  concentration while burning wood pellets and firewood (A) and wood pellets when the burner is provided with oxygen sensor and without it (B)



A PhD Candidate I. Briliūtė and dr. A. Stankevičius in the international conference in Krakow (Poland)

## The young researchers' contribution

The young researchers' contribution to the scientific and applied works of the Laboratory is notably enlarging: in 2009 even 4 researchers (A. Bertašienė, I. Briliūtė, E. Maslauskas ir A. Tonkonogovas) worked under preparation of dissertations and actively participated in scientific conferences and public activity.

During the development of the researches in the fields of micro-flows, the use of renewable energy sources and other fields of innovative technology, even a greater number of perspective young employees streaming for a scientist career are expected to take part in them.

## International cooperation

### Activity in EURAMET and COOMET technical committees

Implementing national standard laboratory functions, the Laboratory participated in the activity of technical committees *Flows* of international organizations EURAMET and COOMET in 2009. In the annual EURAMET meeting in Copenhagen, a report on the conditions for harmonizing velocity unit reproduction conditions was presented. A representative of the Institute was involved into the group of experts that assesses measuring capabilities of COOMET national member Institutes. 3 proposals to participate in joint projects in the fields of wind speed measuring and the enhancement of energy equipment efficiency, under the call *ENERGETICS* of European Metrology Research programme were made.

Active participation was taken in international measurement comparisons that approved that the level of Laboratory measurement meets the level of the best Euro-



A PhD Candidate A. Bertašienė in the international conference in Moscow (Russia)

## Characteristics of international comparisons in 2009

<b>Project No, status</b>	<b>Reference laboratory</b>	<b>Fluid, value</b>	<b>Measuring range</b>	<b>Number of countries/ laboratories</b>
<i>EURAMET 1046, completed</i>	<i>CMI, Czech Republic</i>	<i>Water, volume</i>	<i>1–10 m³/h</i>	<i>12/13</i>
<i>EURAMET 877, completed</i>	<i>SP, Sweden</i>	<i>Water, volume 50 °C</i>	<i>0.006–0.025 m³/h</i>	<i>6/6</i>
<i>EURAMET 1006, completed</i>	<i>CMI, Czech Republic</i>	<i>Air, volume</i>	<i>1000–10 000 m³/h</i>	<i>14/16</i>
<i>COOMET 412/UA/07 Measuring carried out in LEI</i>	<i>SE „Ivano-Frankovsk SM“, Ukraine</i>	<i>Air, volume</i>	<i>4–160 m³/h</i>	<i>4/4</i>
<i>EURAMET 1050 Measuring carried out in LEI</i>	<i>INRIM, Italy</i>	<i>Air, velocity</i>	<i>2–50 m/s</i>	<i>9/11</i>
<i>COOMET 412/UA/07 Prepared for comparison</i>	<i>PTB, Germany</i>	<i>Water, volume</i>	<i>0.01–100 m³/h</i>	<i>7/7</i>

pean Institutes. It means that the measurements carried out in Lithuanian economics and scientific researches is related to the measurements of other countries, which is essential for international exchange.

It was prepared to re-evaluation of the Laboratory activity, as the part of national measurement organization, of 2004-2010. The re-evaluation will be carried by EURAMET technical committee QUALITY 23-25 February 2010 in Brussels. A written report and an oral presentation were prepared.

### **Baltic Sea Region Neighbourhood Programme**

In 2009 the Laboratory was working on an international Baltic Sea Region Bioenergy Promotion project, which is partially funded by the EU and is a part of Baltic Sea Region Neighbourhood Programme. The aim of the project is to strengthen a stable, competitive and territorially integrated development of Baltic Sea region in the field of stable bioenergy usage. Partners of various scientific institutions from 36 countries take part in the projects, which is to be fulfilled during 2009-2011. While carrying out the project, a seminar ***Production and Consumption of Bioenergy in Lithuania: Present Situation and Future Perspectives*** was conducted on 17 December 2009 and a paper *Solid Biomass* on the

use and perspectives of solid biomass in Lithuania was published.

## Conclusions

Results of scientific and applied works of 2009 may be generalized in the following way:

- 6 articles were published in peer-reviewed journals and 4 in the proceedings of international conferences; 8 papers were presented on international conferences, while 11 on national.
- Researchers Dr. Habil. A. Pedišius, Dr. J. Tonkonogij, Dr. G. Zygmantas ir Dr. N. Pedišius were granted the titles of Lithuanian science awards laureates of 2008 for a work *National Standards and Experimental Equipment Complex for Reproduction of Liquid, Gas and Heat Values and Research and Testing Their Measurement Instruments*;
- Over 350 calibration and 3000 verifications, tests, conformity assessments and technical expertises were carried out in main areas of activity, among them foreign countries – Latvian, Danish and Estonian contractors;
- Activities were carried in accordance with the following most important agreements: with State metrology service – to maintain, improve and investigate level of national standards; with SC *Lietuvos dujos*, *Axis Industries*, *Astra*, *Kalvis* and *Panevėžio energija* – to investigated manufactured products, estimate their conformity to the requirements, prepare normative documents and solve technical problems. Income from various applied works comprised 1.4 mln. LTL;
- 4 certificates of water meter type examination and 89 certificates of conformity assessment for meters produced by SC *Axis Industries* were issued. It granted the chance to sell the production to foreign customers.



The seminar "Production and Consumption of Bioenergy in Lithuania"

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# Laboratory of Combustion Processes

## Main research areas of the Laboratory:

- Efficiency increase of combustion processes;
- Reduction of waste emission to the atmosphere;
- Development and improvement of burners and fuel injection equipment;
- Research of hydrogen separation from organic fuel;
- Research of solid high-calorie waste thermal decomposition and gasification;
- Numerical modelling of granular media and multi-particle systems;
- Assessment of the impact on environment.

In 2009, the state subsidy funded research project *Investigations of Combustion and Plasma Processes in the Fields of Fuel Saving, Reduction of Environmental Pollution and Thermal Decontamination of Materials* was carried out in the Laboratory. The scope of this project is related to practical applications, providing scientific and technical consultations to Lithuanian companies and cooperation with Lithuanian scientific institutions and foreign scientists.

## Gasification research of different types of fuel

Gasification specifics of different types of fuel and high-calorie waste was theoretically and experimentally researched by examining the types of waste, which could be potentially used for fuel; they are the following: tyres, wood, peat and textile waste (cotton, wool, viscose and mixtures). Gasification tests of high-calorie waste were performed in the Laboratory of Experimental Research of Gasification Processes of Lithuanian Energy Institute, using the gasification reactor. Time of emission of volatile compounds from the heated samples as well as the amount of resulting tars and carbon residues were measured experimentally and these data were applied for determining content of volatile compounds in the respective fuel sorts.

As the volatile content of textile material was known, theoretical calculations of gasification process were carried out yielding all the required parameters in detail: the required amount of air, the gas yield, the thermal fuel balance for pyrolysis, the expected chemical composition of gas, methods for enhancing the gasification process, etc.

It is reasonable to distinguish two cases of the gasification process for two

types of fuel, namely:

- high-calorie fuel (tyres, plastic);
- low-calorie fuel (wood, peat, waste, other types of fuel).

In the first case, lower amount of air is required to reach the temperature of 1100 °C and to evaporate more volatiles, producing high-calorie gas: 5000-7000 kJ/Nm<sup>3</sup>. In the second case, the fuel contains more oxygen and an extensive carbon backbone, thus, it is more difficult to heat, it decomposes slower and therefore higher temperature is necessary. For this reason, light gases CO, H<sub>2</sub>, CH<sub>4</sub>, C<sub>2</sub>H<sub>4</sub> are produced and the caloric value only amounts to 3000-4000 kJ/Nm<sup>3</sup>. The case of textile gasification has exemplified a characteristic feature of gasification when the oxygen content of fuel has a special importance: as the heated fuel starts to decompose during auto-pyrolysis, many species of hydrocarbon compounds form and the oxygen contained in the fuel begins to interact yielding high amounts of CO, CO<sub>2</sub> and unbound H<sub>2</sub> besides H<sub>2</sub>O. This is the novelty related to the gasification process, which has not been published yet.

An experimental research of chemically-derived coke fuel combustion was carried out last year: the strength of solid particles of principal gas waste CO, NO<sub>x</sub>, SO<sub>2</sub> was determined by experimental method and the chromatographic analysis of oxides was performed and compared to the composition of fuel oil. Gases produced during the combustion were analysed quantitatively and qualitatively by the gas chromatograph VARIAN GC-3800, the mass spectrometric-detector Saturn 2000 and the gas analyser TESTO 350 XL. It was determined that the composition of combustion products from chemically-derived coke

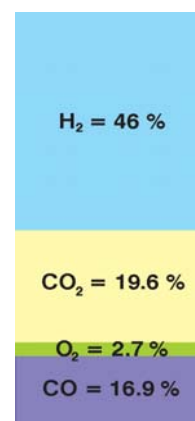
fuel similar to that of the fuel oil combustion.

## Thermal glycerol fraction breakdown for hydrogen extraction

The analysis of thermal glycerol breakdown was carried out, an investigation stand was completed and the experiments were performed. The results suggest that the most effective hydrogen production technologies that employ thermal method to breakdown glycerol are its partial oxidation or autothermal conversion. Additionally, the dependence of gas reaction product yield from autothermal glycerol conversion on the ratio of water vapour and carbon in the glycerol was examined.

## The formation of catalytic covers by plasma technologies and their activity research in the biofuel conversion process

Catalytic covers were developed applying plasma pyrolysis method and the conditions for their composition as well as their effect on glycerol gasification and hydrogen amount extracted were examined.



Composition and amounts of gas mixture produced during fuel conversion applying nickel catalyst

## Biogas production modelling by chemical thermodynamic balance calculation method

Recently, non-nutritive biomass and waste gasification is perceived as one of the possible energy resources that could reduce the dependence on fossil fuel since gasification is a simple and reliable method for high-calorie fuel production. However, gasification systems have to match technical and environmental requirements because undesirable by-products, such as tars, solid particles, alkalis, sulphur and ammonia may be formed during the gasification. Therefore, this section is devoted to the analysis of solid particles and tar influence on the gas produced.

The models of gas phase hydrocarbon chemical kinetics generally may be grouped into three types, namely: empirical, molecular and mechanistic. The disadvantage of empirical research is high computational costs and instrumental inaccuracies, whereas molecular models yield quick and reliable results in some cases. Although only mechanistic models are appropriate for a rather accurate reproduction of realistic chemical reactions, their development for high-molecular-mass hydrocarbons is complicated and requires extensive experimental work, considering the extent and types of compounds analysed. Thus, the facilities in the Laboratory enable the analysis of molecular model which aims at determining thermodynamic balance of gas phase

hydrocarbon, nitrogen and tarry mixtures and their dependence on the temperature.

The model selected was appropriate for anticipating the composition of the gases produced and analysing thermal breakdown, vapour reforming and partial oxidation.

### Particle combustion model

Numeric simulation programme for solid fuel combustion processes was applied last year. Since solid fuel combustion is a complicated process, the engineering of equipment that uses solid fuel is also intricate. Moreover, respective requirements have to be taken into consideration; they are the following:

- thermal efficiency requirements;
- exploitation requirements;
- waste limit values.

Process models that are accurate enough are required in order to match the requirements mentioned. Due to the complexity of the process, the analysed system is divided into subsystems by creating an individual model for each, while the operation of the whole system is described by the interaction of separate constituent processes.

Since the solid fuel combustion system analysed contains two principle phases (solid and gas), its division into the collection of solid particles and ambient gas is natural. The latter is composed of turbulent reacting flows, whereas the particle combustion is described by their material (fuel) conversion, which depends on the

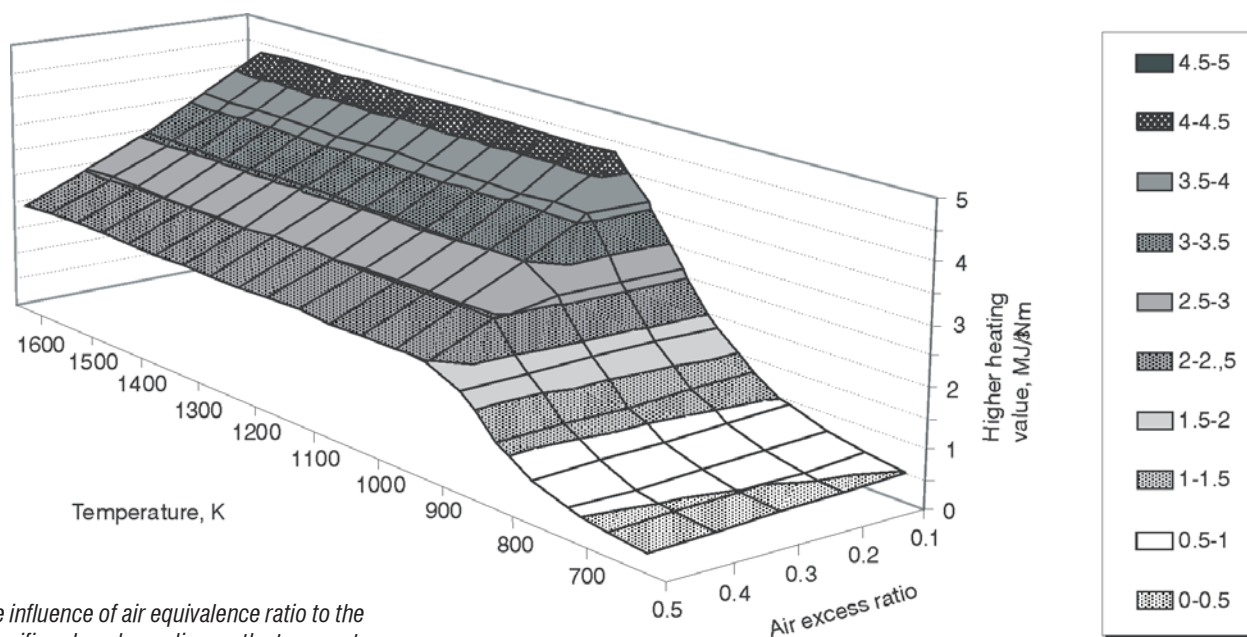
amount of air, thermal emission and solid particle movement.

In order to approximate the process mentioned, it is assumed that the particles consist of water, fuel (reactive material of the particle), carbon residues (the product of pyrolysis) and ash (inert material). Mass fraction may change due to various conversion reactions, taking place inside the particle. The most relevant processes are the following:

- drying;
- pyrolysis;
- gasification.

Each of these processes is characterized by different rates. For simplicity, the spatial dependence of the variables is not considered.

To maintain the combustion of the solid particles in a packed bed, air is supplied that spreads in the void spaces among the particles. The void distribution among the particles depends on their arrangement, size, decrease due to the combustion and their movement on the fire-grate or rotary kiln; due to the movement of the particles, void distribution also depends on the time. This type of distribution of the void and particles may be perceived as a porous medium with porosity changing in space and time. The gaseous environment above the particle beds can also be described as porous in a limit case; the porosity of this environment is treated as negligible. Applying mass and energy conservation equation, local time and space depending parameters are elicited, such as tempera-



The influence of air equivalence ratio to the calorific value, depending on the temperature



ture, flow velocity, phase distribution in the flow. Since the position of the particles is known, it is possible to accurately describe the interchange of heat and mass and flow conditions in the vicinity of a particle. Due to thermal conversion, such as evaporation of volatile compounds and pyrolysis, compounds are emitted from the particles into the gas environment; combustible components of these compounds burn above the particle bed in the homogenous medium and its composition depends on the mixing. However, the oxygen for heterogeneous solid particle combustion is brought by the air flow during mass exchange. These conditions determine the whole process of particle conversion, whereas the process of each particle is described by a model that determines one-dimensional and varying distribution of temperature and phase in the particle. In this way the change of particle properties during the conversion is determined; this model is applied to each particle. Due to the movement of both the fire-grate and rotary kiln, the par-

ticle positions change, therefore, they are exposed to different ambient conditions in the locally varying flow field.

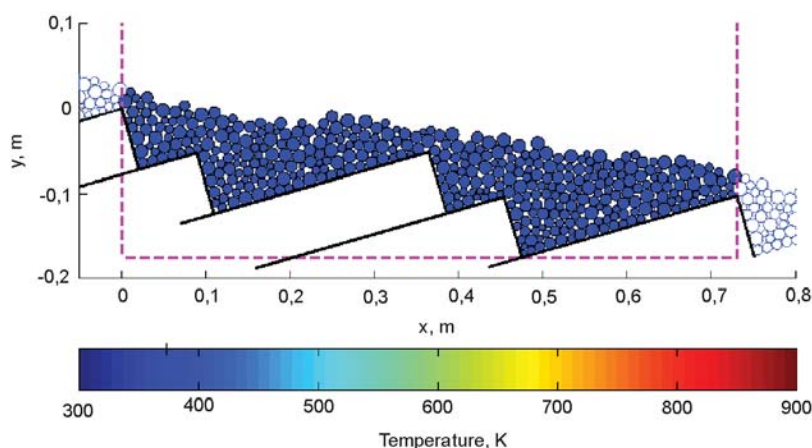
Since the species concentrations and temperatures in the particle evolve differently, the results of an accurate modelling of these processes are more realistic assuming simultaneous warming up, water evaporation and the pyrolysis and heterogeneous combustion of a particle, than outright choosing the model of reacting or shrinking nucleus. Application of the three-dimensional model for each particle is too computationally costly, whereas varying one-dimensional model enables to model sufficient number of spherical particles in a sufficiently short time and achieve adequate agreement between the modelling and experimental results. Although realistic particles appear in different shapes, the relevant parameters for combustion process modelling are Thiele module and efficiency number; their interrelation is weakly influenced by the real shape of the particle.

## Applied works for industrial subjects

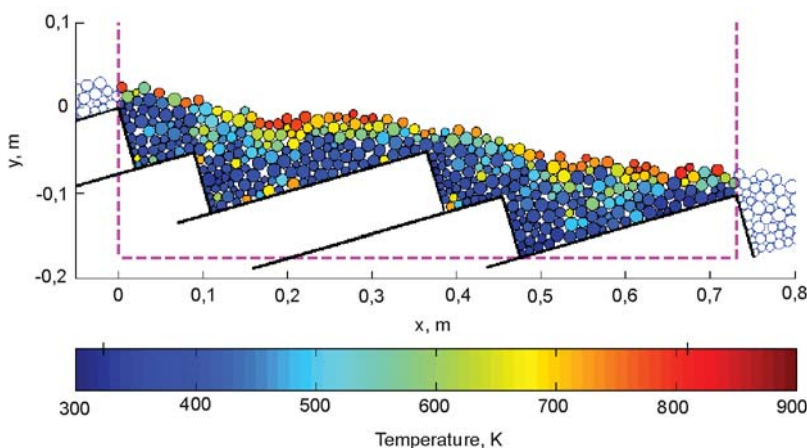
The method of furnace air and fuel flow conformity and flame formation for the optimum combustion and minor pollution. Following the multiplex measuring of boiler combustion process, a thorough boiler conformity method for gas and liquid fuel was prepared. It encompasses the control of air movement process, fuel dispersion and flame torch unfolding in the furnace in order to receive the optimum result in terms of economic and environmental approach. Additionally, primary characteristics of fuel pyrolysis and their variation due to  $\text{CH}_3$ , OH, H, NO and O were detected.

In 2009, the Laboratory was cooperating with and received orders from major Lithuanian energy and industrial companies, such as *Mažeikių nafta*, *Klaipėdos nafta*, *Lietuvos elektrinė*, *Vilniaus energija* and other.

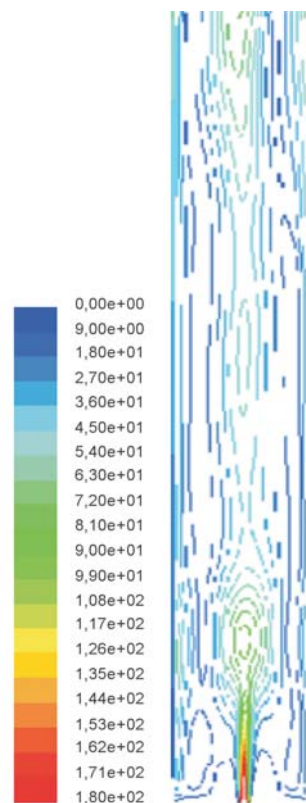
Building on extensive experience in upgrading boiler equipment gained throughout the years, the goal to reduce emissions by 15% for nitrogen oxides and by up to 20% for solid particles was successfully achieved, which favored reduction in fuel consumption as well.



Distribution of particle temperature on the grate after 1 s of combustion time obtained from the numerical modelling. Particles of different temperature are marked in different colours

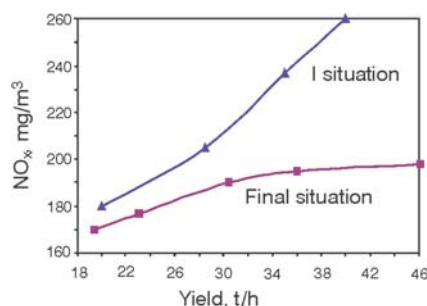


Distribution of particle temperature on the grate after 200 s of combustion



The development of the current, representing velocity in isolines and vectors

The works were implemented by combining the theoretical modelling by means of software package FLUENT with experimental burner adjustment.

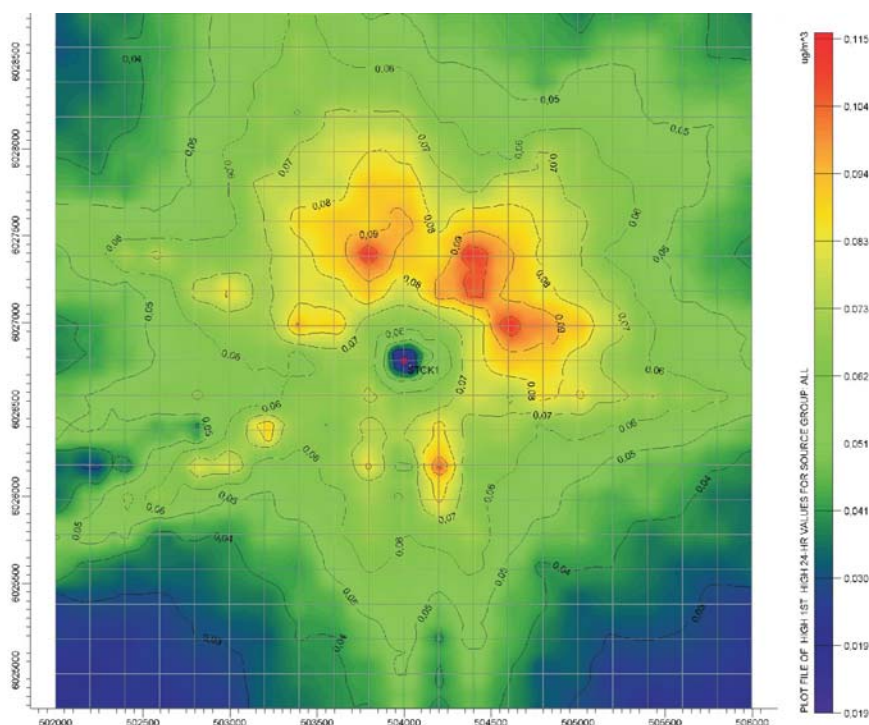


*The level of nitrogen oxide emissions during the operation of steam boiler GM-50*

The spatial mesh for simulation was composed of nonuniform size tetrahedral cells. To reduce the computational expenses, a symmetric case for half the firebox with two burners was solved. Certain elements of the firebox were represented by tetrahedral cells with edge length of 2 mm, and those at the top of the firebox – with the edge length of 20 mm. For this purpose, the surfaces are identified, they are meshed by the triangular cells, and then the separate volumes are created with smooth transitions from one space to another. Using this approach, by T-grid method, all the components of the firebox were approximated, from the small size gas supply openings, with their usual diameters of 6–8 mm, to the upper space of the firebox with the size of 2×5 mm. Elaboration of burner gas jets enabled their control, by opening or closing them in groups. The characteristic feature of this work is increasing the flame turbulence throughout the entire firebox. For this purpose, formation of the burner jet and its control by means of nozzle geometry is applied. By using the obtained results, an improved burner has been designed. The combustion process is controlled by adjusting the burner vane angle and adjusting the gas nozzle openings according to the gas supply pressure. Moreover, the metals for burner production were selected and after the production, their characteristics were calibrated and burner nozzles designed.

### **Assessment of environmental effect**

The Laboratory of Combustion Processes has gained considerable experience in filling the assessment reports for environmental and weather impact of economic activity for different economic subjects of



*The result of pollution spread modelling*

energy sector and approving them with relevant institutions. New software, operating under a world wide acknowledged model, has been obtained; it enables modelling pollution propagation and determining the concentrations near the ground under the applicable norms of the EU.

### **Research of utilization of glycerol extracted from biodiesel production**

The analysis of thermal glycerol breakdown was carried out, an experimental setup was implemented and experiments were performed. The results demonstrate that the most efficient glycerol production technologies by thermal breakdown of glycerol are the partial oxidation or autothermal conversion. Furthermore, the dependence of the output of gas reaction products of autothermal glycerol conversion on the ratio of water vapour and carbon, present in the glycerol, was examined.

Thermodynamic analysis of chemical reactions taking place during glycerol oxidation, performed as a part of earlier research, determined that the principal end products of the partial oxidation reaction is hydrogen ( $H_2$ ), carbon monoxide (CO), carbon dioxide ( $CO_2$ ), methane ( $CH_4$ ), acety-

lene ( $C_2H_2$ ) and unreacted initial reacting substances. It was determined that the optimum temperature of the autothermal conversion maximizing the hydrogen yield was 1000 K.

As seen from the thermodynamic analysis, the process did not proceed to the end when the amount of extracted hydrogen increased, that is, CO concentration increased with the increasing amount of hydrogen. In order to achieve the optimal autothermal reaction, it was decided to use catalysts for intensifying CO conversion by water vapour in the future.

In 2009, 1 article published in the ISI indexed journal, 2 contributions were made in international conferences and 3 in Lithuanian conferences.

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# Laboratory of Materials Research and Testing

## Main research areas of the Laboratory:

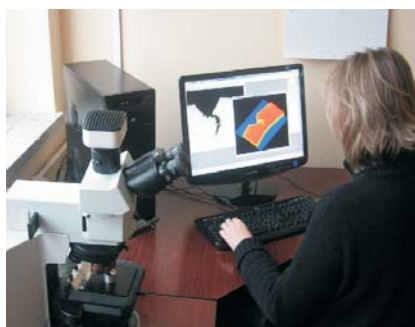
- Research of metal ageing processes and properties degradation under the impact of operational factors;
- Research of hydrogen and hydride influence on the mechanical and physical properties of zirconium alloys;
- Assessment of reliability of power plant facilities;
- Development of materials and composites of novel multifunctional and structural properties;
- Testing of materials, assessment and analysis of their qualitative indicators.

In 2009, a new state subsidy funded research project **Experimental Modelling and Investigation of Zirconium Alloys Degradation and Temperature Induced Structural and Phase Changes of Heat-resistant Carbon Steels** was initiated. During its implementation, the most attention was given to experimental research and theoretical substantiation of processes that influence hydride cracking in zirconium alloys. Additionally, the impact of temperature and time on heat-resistant steel carbide phase structure and the consistent patterns of crystallographic parameter changes were investigated using numerical and experimental methods.

## Assessment of reliability and operational life-time of power plant facilities

The Laboratory continued the research on hydrogen and hydride induced degradation of zirconium alloys used in nuclear power plants fuel channels and fuel cladding. The Laboratory has completed the work under the International Atomic Energy Agency (IAEA) coordinated research project **Delayed Hydride Cracking of Zirconium Alloy Fuel Cladding**. Applying special test equipment, experimental procedures were established for assessing the velocity of delayed hydride cracking in zirconium alloy fuel cladding tubes. Moreover, the conditions inducing fuel cladding degradation were determined.

Obtained experimental data may be used in developing and validating predictive models of hydrogen induced cracking in zirconium-based alloys, estimating hydrogen influence on physical and mechanical properties of alloys. These issues are important in dealing with problems of en-



*The analysis of crack formation and hydride orientation in the wall of zirconium alloy fuel cladding (image analysis system)*

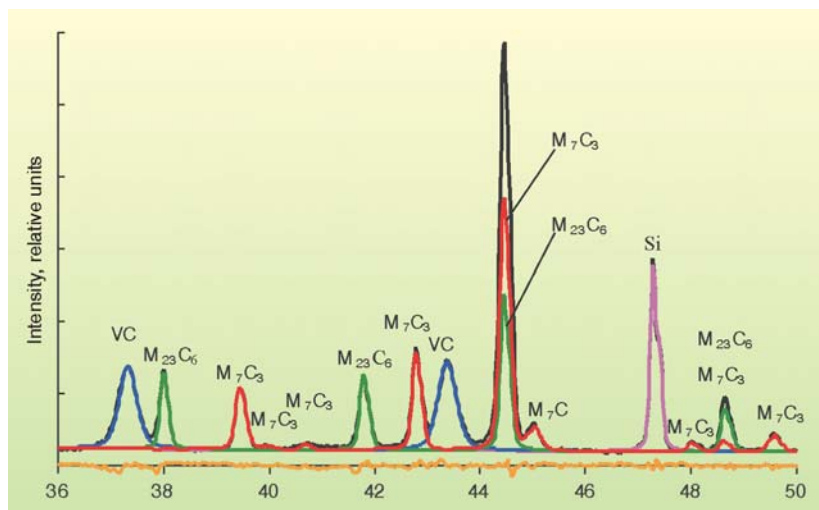
sureing safe operation of nuclear power plants; they are also relevant in storing spent nuclear fuel assemblies.

Under the funding of the Lithuanian State Science and Studies Foundation, in 2009 a project **Analysis of Spent Nuclear Fuel Cladding Resistance to Hydride**

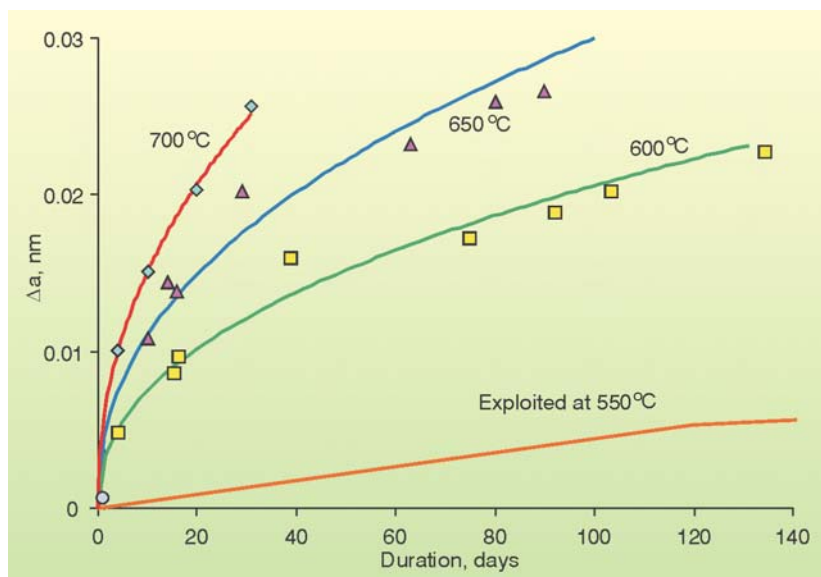
**Cracking During Long-term Storage** was implemented. The project included the investigation of hydride cracking in the fuel cladding of different types of reactors, the analysis of their post-operational condition and examination of the influence of various factors on the cladding structural integrity during the long-term dry storage period.

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

In 2009, a considerable amount of work was carried out to investigate the processes of ageing of metal alloys that are



*X-ray diffraction patterns of carbides after the Rietveld refinement*



The change of carbide  $M_{23}C_6$  crystal lattice parameter  $a$  after the thermal treatment

used as the constructional elements of power plants, and to solve of their longevity and aging control issues. Applying the X-ray Diffraction (XRD) analysis as well as optic and scanning electronic microscopy, structural changes (carbide phase composition, sequence and crystallographic parameters) of used and laboratory-aged steel were examined. Using modern numerical methodologies for processing and analysing X-ray diffraction profiles, experimental data were obtained, describing the structural changes steel that determine its physical properties. Implementation of this work focused attention on the investigation of fundamental physical phenomena in steel structures.

Obtained experimental data provides an opportunity to perform qualitative and quantitative phase analysis of the com-

pounds and to accurately determine the changes of carbide crystal lattice parameters. These parameters may be used for assessing condition of steel and predict remnant service life.

Under the agreement with JSC GEOTERMA, a new project **Analysis and Optimisation of Absorption Heat Pumps Working Parameters** was started in 2009. The aim of this project is to carry out the analysis of geothermal power plant heat pumps operational and monitoring data, evaluate the efficiency of the inhibitors in LiBr solution environment, assess influence of operating conditions and other factors that affect the corrosion process. After the completion of this project, the recommendations for minimising the intensity of corrosion process and optimization of LiBr solution are going to be provided.

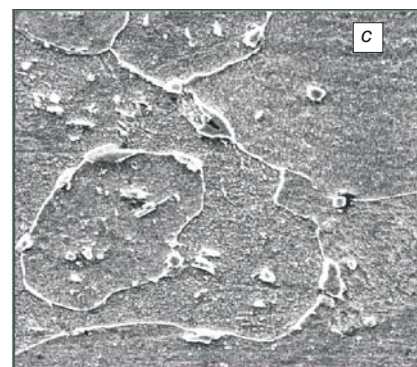
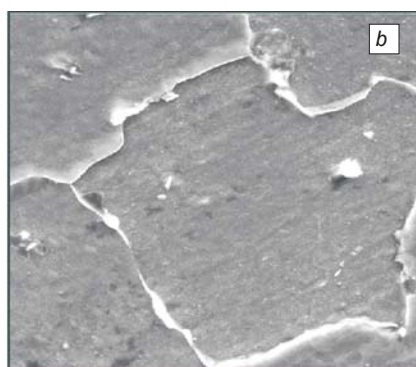
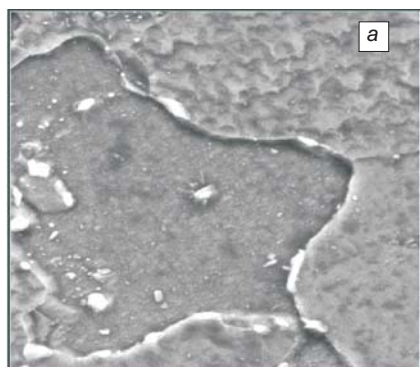
## Development of multifunctional materials and composites with novel structural properties

In 2009 researchers of the Laboratory successfully continued the project **Peculiarities of Nano-structures Formation in the Cementitious Building Materials: Research and Technological Development**. The objective of the project is the development of novel cementitious building materials, the properties of which are conditioned by nano-structures, developed in their structure.

Research is carried out by analysing the principles of nano-structure formation of cementitious composite materials with nanomodifiers and the impact of these structures on the product properties. Production of microfiber as nanomodifier in plasma-chemical reactor from waste catalyst of oil refinery industry and analysis of its properties was performed in collaboration with Laboratory of Plasma Processing.

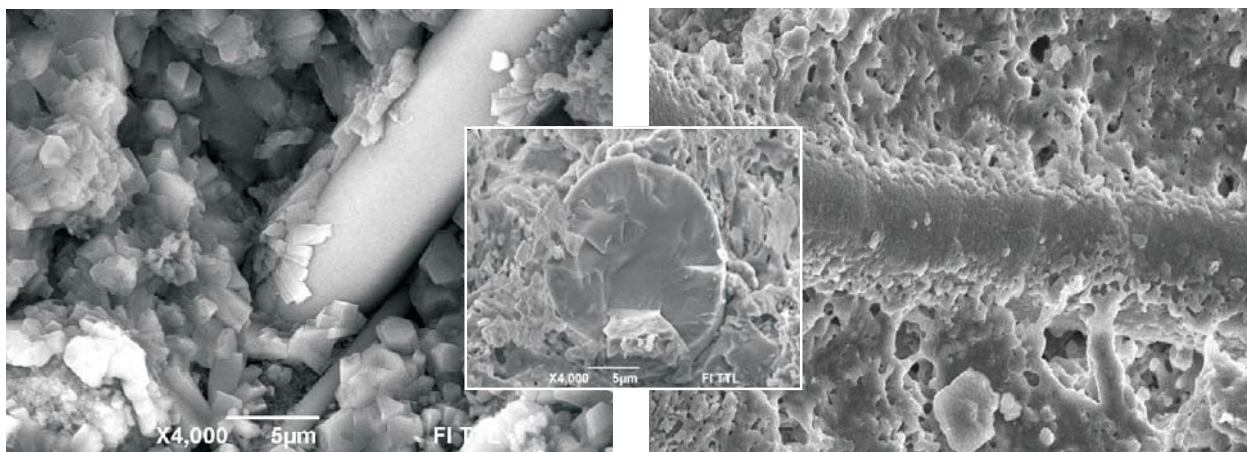
The main task of this research is to investigate the interaction of cementitious complex binder components and modifying additives with zeolite microfiber produced by atmospheric plasma spray method at normal conditions and at elevated temperatures.

It was determined that modifying additives influence the morphological changes of crystal hydrates and the formation of nano-structures within the composition as well as on the fibre surface. The analysis of mortars for thin refractory coatings production showed that microfiber produced from zeolites by plasma spray method is compatible with cementitious binder and is suitable for creation of complex refractory castables.



Microstructural change of steel 12X1MΦ during the process of thermal ageing: 240 h at 650 °C (a); 600 h at 650 °C (b); exploited 227000 h (c)



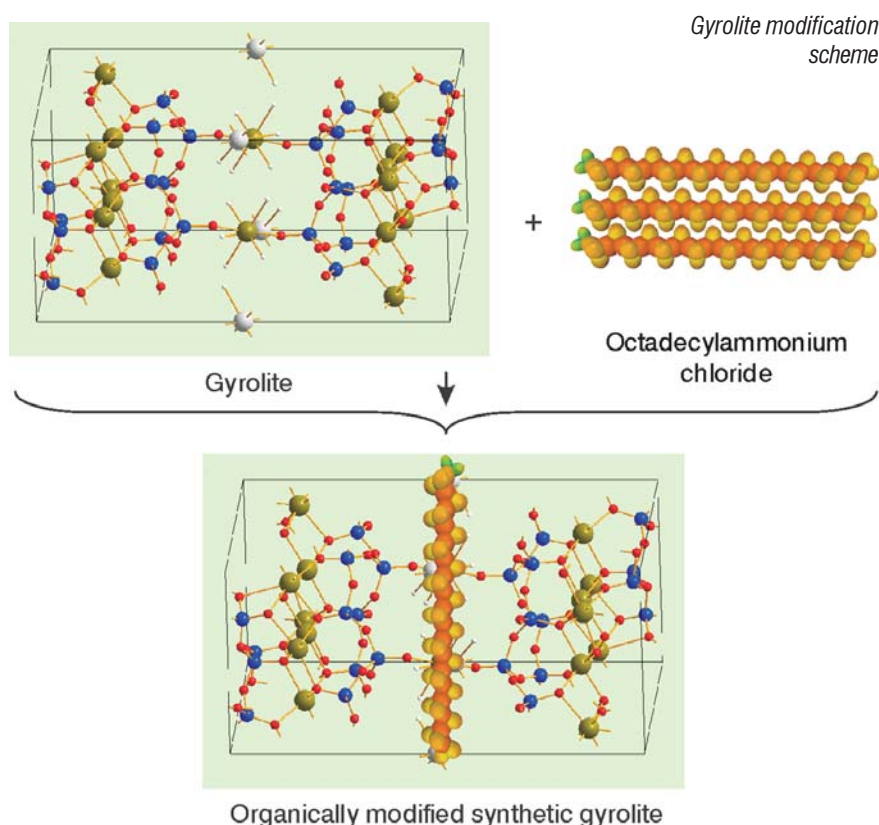


*Cementitious complex binder with microfiber*

This research is relevant from both ecological and economical point of view since it can help solve the problems of industrial catalyst waste utilization. The project under High Technologies Development Program is carried out together with scientific and educational institutions of Lithuania, such as Vilnius Gediminas Technical University, Institute of Thermal Isolation, Kaunas University of Technology, Institute of Physical Electronics of Kaunas University of Technology and industrial companies JSC *Betoneta* and JSC *Statizola*.

Researchers of the Laboratory are taking part in activity **COST MP0701 Composites with Novel Functional and Structural Properties by Nanoscale Materials**, as 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 hardener and compatibility with filler) on intercalation/exfoliation of mineral filler in polymer matrix. In 2009, pure synthetic nonsized filler gyrolite and also sodium substituted gyrolite were organically modified by octadecylammonium chloride (surface characteristics of the filler were changed) seeking compatibility with polymer matrix (epoxy resin). Participating in COST MP0701 activity, the Laboratory researchers cooperate with researchers from Kaunas University of Technology, Faculty of Chemical Technology, Department of Silicate Technology.



**COST action 533 activity Materials for Improved Wear Resistance of Total Artificial Joints** has been implemented together with Laboratory of Plasma Processing. The main objective of the action was to analyse the problems of artificial joint wear resistance, investigate the processes of degradation in the artificial joints and to search for alternative durable materials that would improve the durability of the implants and their wear resistance. Scientists from 19 European countries participated in solving these issues. The research of structure and tribological characteristics of promising wear-resistant ceramic coatings produced by plasma technologies was carried out. Although the programme activity was completed in March 2009, Virtual Tribology Institute and also European Tribology network ENIWEPP (European Network for Industrial Wear Prevention) were established to extend tribological research. While participating in COST 533 activity, Laboratory researchers cooperated with the researchers from Lithuanian University of Agriculture, Faculty of Agri-



cultural Engineering, and Department of Mechanical Engineering.

## Testing of materials and assessment of their quality

Researchers of the Laboratory provide accredited services, perform material testing and assessment of their quality. The Laboratory is accredited for LST EN ISO/IEC 17025 standard and tests for plastic pipes, pre-insulated heat-supply pipes, building mortars, adhesives for tiles, putties and refractory materials and products. As a result of successful collaboration with commercial enterprises, the Laboratory carries out research, performs various tests and gives advices on guarantee of quality of products for energy industry and buildings.



In 2009 researchers of the laboratory published 14 scientific articles: 10 of them in the publications on the ISI list and 4 in reviewed conference proceedings.

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# Centre for Hydrogen Energy Technologies

## Main research areas of the Centre:

- 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 2009, a state subsidy funded project **Synthesis of Nanocrystalline Metal Hydrides, Designed for Hydrogen Storage, Applying Ion-plasma Methods** was completed. During its implementation, systems composed of Mg/Ni/Al/Ti-H were examined; in 2007 the most attention was given to the studying of Mg-Al-H systems, whereas in 2008, Mg-Ni-H systems and the influence of surface barrier layer on the works of hydrogenation kinetics were concentrated on. In 2009 the work was related to Mg-Al-Ti-H, Mg-Ni-Ti-H and Mg-Ni-Al-H thin films systems and applied Mg-Ni-H flake type systems. Specific working systems were selected considering tentative research results yield, following the analysis of theoretical sources and estimating the discussions of International Energy Agency Hydrogen Implementation Agreement Task 22 and the seminars of Nordic Energy Research project.

The practical importance of this work is mainly related to the Mg-Ni-H systems analysed since the impact of surface layer on hydrogenation kinetics was examined and also new generation hydrogen storage in Mg-Ni-H flakes were created in cooperation with the scientists from EC JRC Institute for Energy (hereinafter JRC). In 2008-2009, these storage systems were synthesised in LEI Centre for Hydrogen Energy Technologies and successfully examined applying SEM and XRD methods before and after the hydrogenation. An interim agreement between LEI and JRC scientists was reached that systems created by LEI will be repeatedly examined by JRC applying SEM, XRD and SIMS methods (this examination is presently in progress). Additionally, thorough examination will be

carried out applying NERDA method in order to determine one of the principal parameters of hydrogen storage systems namely, hydrogen distribution profile.

Following the tripartite agreement No. VP2-1.1-ŠMM-02-V-01-005 concluded 22 June 2008 among the Ministry of Education and Science of the Republic of Lithuania, public institution *Central Project Management Agency* and Lithuanian Energy Institute, the Institute is implementing a project *Centre for Hydrogen Energy Technologies*. It is carried out under the measure VP2-1.1-ŠMM-02-V, *Development of High-Level Research Centres and Competence Centres*, of the task VP2-1.1, *Strengthening of Public and Private Research and Technological Development*, priority VP2-1, *Research and Development for Competitiveness and Growth of Business*, of the Lithuanian VP2 Operational Programme for Economic Growth of 2007-2013.

During the implementation of this project, **Centre for Hydrogen Energy Technologies** was established in Lithuanian Energy Institute. The activity of the Centre is in principle related to the synthesis and property analysis of materials for hydrogen production, storage and fuel cells. State-of-the-art technologies of DC, RF, impulse DC and electronic beam evaporation may be applied for material synthesis. The surface topography and morphology of the materials yield are examined employing optical, scanning and atomic-power microscopes and also modern 3D profilometer. A modern BRUKER D8 ADVANCE X-ray diffraction equipment is used for material structure examination and

analysis; their results enable to assess the fundamental properties of the materials and their appropriateness for specific devices of hydrogen energy technologies. In order to study the suitability of individual materials for practical application, the Centre uses a Sievert-type device (PCT Pro 2000) for the analysis of technological properties (reversability, durability, etc.) of hydrogen storage materials. For investigating the suitability of specific oxide in the synthesis of hydrogen separation membranes and fuel cells electrolytes, a modern device ProboSTAT for ion-electric conduction analysis is applied.

In co-operation with lecturers and students at Department of Physics of Vytautas Magnus University and Department of Physics of Kaunas University of Technology, the Hydrogen Energy Centre 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 high-qualified specialists (including all study cycles) and develop competitive research. It is equally important that LEI is in a position to become a powerful centre of attraction for young researchers.

Collaboration with partners from Nordic countries is continued within the work in the project of The Nordic Energy Research Programme **Nordic Center of Ex-**



*Bruker D8 Discover (Germany) X-ray diffractometer with accessories that enables carrying out the crystal structure analysis in the form of synthesized materials, thin coatings or nanopowder*

#### **cellence for Hydrogen Storage Materials**

in 2009. This fundamental research attempts at synthesis of magnesium and aluminium hydrides, containing a small amount of aluminium and magnesium additives, by using non-equilibrium technologies. It is expected that due to experimental magnetron sputtering technologies it will be possible to escape intermixture limits of materials (magnesium and aluminium), developed by traditional equilibrium methods. Moreover, the synthesis of these materials in conformation of thin layer is expected to allow a particular “immobili-

sation” of this unstable structure and to protect it from disintegration and/or oxidation.



In 2009, the researchers of the Centre actively participated in International Energy Agency Hydrogen Implementation Agreement (IEA HIA) Task 22, **Fundamental and Applied Hydrogen Storage Materials Development actions**. In this activity, chemical destabilisation of metals and their alloy hydrides was carried out by introducing new elements into materials, which form intermediate derivatives during hydride decomposition and, thus not allowing the system to get fully relaxed to the lowest energy state, or form a destabilized hydride during hydrogenation.

In 2009, the researchers of the Centre published 11 articles on investigation results in ISI indexed journals, 2 papers in Lithuanian conference and 1 in science-promotion article.

Researchers of the Centre for Hydrogen Energy Technologies actively participated in **COST programme**: the investigation of the activity **542 Efficient Energy Storage for Mobile and Stationary Equipment** carried out in 2009 exposed the following:

- The capacity of electrode supercapacitors, made of absorbent carbon extracted by precipitation method from plasma torch in working gas  $\text{Ar} + \text{C}_2\text{H}_2$ , depends on  $\text{Ar}/\text{C}_2\text{H}_2$  ratio during precipitation. The capacity sharply decreases in the  $\text{Ar}/\text{C}_2\text{H}_2$  ratio value interval 15-30, whereas capacity reliance on working gas composition is minor when ratio values are greater. The result of the study was applied in pursuance of creating a technology of electrodes with recurrent parameters. It was concluded that stability voltage decreases when  $\text{Ar}/\text{C}_2\text{H}_2$  ratio exceeds 40;
- Electric capacity of absorbent carbon electrode supercapacitors increases up to two times after the exposition in oxygen plasma, while short-term absorbent carbon exposition in plasma stabilises the microstructure and relief of the cover;
- Optimal electric characteristics of supercapacitor are achieved following certain technological parameters, namely: (i) absorbent carbon electrodes are precipitated out from plasma torch in  $\text{Ar}$  and  $\text{C}_2\text{H}_2$  gas mixture maintaining their flow ratio – 40, (ii) outright after the precipitation, electrodes are put into 1 min. oxygen plasma maintaining the pressure 1.3 Pa.

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# Laboratory of Plasma Processing

## Main research areas of the Laboratory:

- Development and research of DC plasma sources for wide range of applications;
- Research of processes and phenomena taking place in reaction arc zone and exhaust plasma jets and flows;
- Research of high-temperature gas flow dynamics and heat-mass transfer processes in atmospheric and reduced pressure plasma environments;
- 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 when reacting combustion products outflow the catalytic surface;
- Formation and modification of constructional material surfaces in plasma;
- Synthesis on micro and nano dispersed granules and mineral fiber from hardly alloyed materials and investigation of properties;
- Generation of water vapour plasma and its application for fuel conversion and neutralization of hazardous waste.

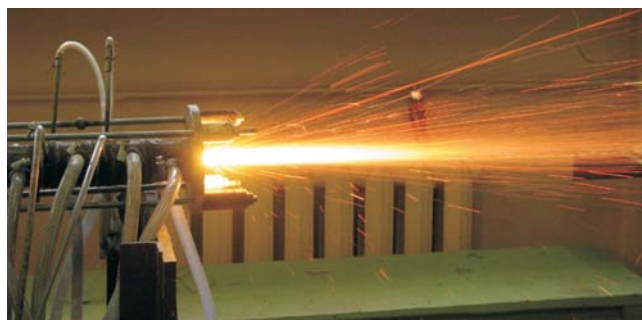
Researchers of Laboratory of Plasma Processing have over 40 years experience working in different fields of development, scientific research and application of low-temperature plasma technologies and are able successfully simulate new plasma technologies, using plasma equipment, produced in the Laboratory. 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 transfer.

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

## Development of plasma sources and research of plasma flows

Recently Laboratory of Plasma Processing has been developed novel plasma generators with capacity 150 kW. According to the construction of linear plasma generator, and variety of processes occurring in the reactive discharge chamber the thermal and operational characteristics are analyzed. The similarity theory for generalization of voltage-current and thermal characteristics of plasmatrons has been applied. This allows to select suitable operating regime and options of gas supply for various purposes. The obtained results are compared to the results of numerical calculation and with results of other authors' works.

The Laboratory carries out investigations on heat transfer in plasmatron reactive arc zone, electric arc strength variation in laminar and turbulent arc, its impact on characteristics of plasma flows and jets, impact of thermal 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.



*Operating linear DC arc plasma generator*

## Diagnostics of plasma and high-temperature jets

Formation of high-temperature and plasma jet, its dynamics and heat transfer 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 package *Fluent*. The *Fluent* software has been used to solve full Navier–Stokes and energy equation based on the dynamic  $k-\epsilon$  model for the fluid jet. However, the numerical research become especially complicated when the solid particles are injected into the jet. This is because of specific plasma properties; therefore, numerical research of multiphase plasma jets are performed applying software package *Jets & Poudres*, which was developed under the basis of GENeral MIXing (*Genmix*), improved and adjusted to model plasma jets. Yet, if the task is not considerably simplified, numerical research methods become impossible to use for multiphase plasma jets; thus, the experimental method is given the priority in the Laboratory.

Recently, non-contact method has been widely applied for plasma diagnostics in the Laboratory. One of them is optical spectroscopy method; its main analytical device is an optical spectrometer AOS-4 with an installed detector and optic acoustic chan-

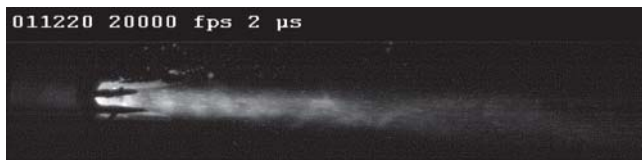
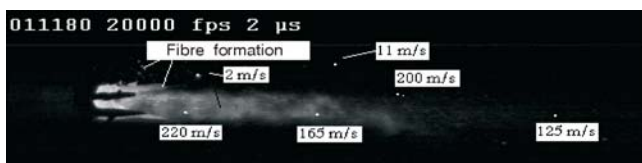




*The measurement of plasma flow characteristics by optical spectroscopy method*

nel filter of inner stabilisation. It is a rapid optic measurement system that may be used for the investigation of gas radiation characteristics in wave stretch of 250–800 nm. The system is used for the examination of plasma element composition, the temperature of electrons and heavy particles.

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



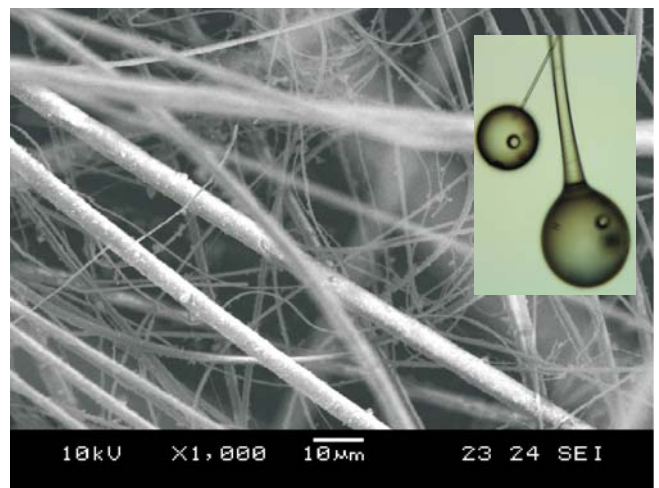
*Behaviour of melted granules of zeolites in supersonic air plasma jet observed by high-speed video camera*



## Research on interaction of plasma jet and materials

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

The plasma processing efficiency depends on many factors, such as the nature of chemical reactions, the value of plasma ambient temperature and velocity, the time of presence of material in high temperature zone, etc. Coatings formed employing plasma method are obtained by laminating many dispersed particles, which before collision with the solid surface must be partly melted and plastic. Thus their shape and structure in the coating is very different. The interaction of particles and substrate during contact is defined by flow, deformation, and cooling processes, whereas particle interaction with the variety of fundamental results 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 kind are very different in the cross-section of coated substrate. In real-



*Catalytic mineral fibre (left) and the process of its formation (right)*

ity, 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 as unisotropic. These processes describe the structure and features of the produced final product.

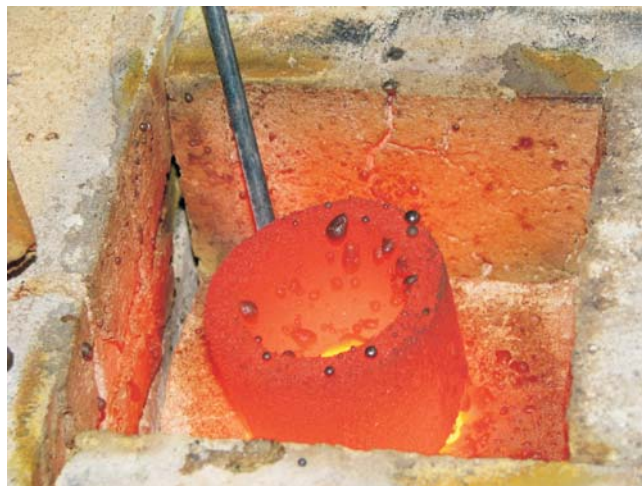
### Melting of ceramic materials and synthesis of high-temperature mineral fibre

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

Plasma technology is the only alternative to obtain a high quality high-temperature fibre. Melting and stringing ceramic materials and forming mineral fibre, an experimental plasma device with 70–90 kW capacity plasma generator has been developed at the Plasma Processing Laboratory. It enables to form a fibre from dispersed particles, using air as plasma forming gas and auxiliary (Ar, N<sub>2</sub>, propane-butane) gas mixtures.

about 6 times greater than air enthalpy. This suggests that heating water vapour requires 6 times greater capacity than the same amount of air mass jets; therefore, the produced energy of the jet is much greater than of other gas plasma energies used up to now. Another reason why the material processed in water vapour plasma may receive much more energy in the same time is that its thermal conduction coefficient is much greater than of other gas plasma. The comparison of water vapour and air volume enthalpies shows that they are rather similar. On the whole, in order to compare the properties of water vapour and air plasma, they have to be compared on the basis of equal mass volume, but not 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 relevant to explore the impact of water vapour plasma



*Melting of materials in plasma-chemical reactor (left) and in high-temperature crucible (right)*

### Other technologies developed at the Laboratory

The synthesis process of micro- and nano-dispersal particles and granules for the production of micro- and nano-structural catalysts is implemented in the Laboratory. New generation CO oxidising CuO, Cr<sub>2</sub>O<sub>3</sub>, Al<sub>2</sub>O<sub>3</sub> and zeolite catalysts, which could substitute for expensive metal catalysts of platinum group, were produced. Presently, new catalysts for neutralisation of SO<sub>x</sub> and NO<sub>x</sub>, which will be beneficial for environmental protection, are being developed.

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



*Water vapour plasma jet, flowing from 95 kW capacity plasma generator*



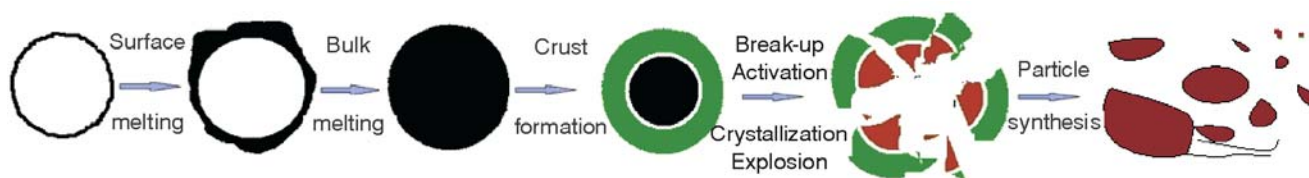
parameters on physical and chemical characteristics of the final product and the formation processes of nano-dispersal structures, microgranules and vapour phase. Further research will be aimed at proper investigation of the interaction mechanism of water vapour plasma jet with dispersal particles and jet elements.

In 2009 a new state subsidy funded research project **Identification and Assessment of Prevailing Factors Determining the Synthesis of Inorganic Material Oxides Fibre in Plasma Ambient** was initiated. Its main objective is to examine the consistent patterns of various 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 world wide scientific and technical sources and an experimental dynamic gas device with a plasma generator for special purpose was designed and produced. Following the similarity theory, the performance parameters of plasma generator were studied and generalized as well as the dynamic and thermal characteristics of gas flows outflowing from the generator.

In the experimental equipment of the Laboratory, the process of plasma spray pyrolysis was implemented and its initial consistency patterns were analysed. It was determined that the interaction of plasma flow and dispersal particles takes about 1 ms and the most rapid particle phase change begins at  $x/d = (3-8)$  from the outflow of the exhaust nozzle. The mechanism of plasma pyrolysis process has recently been explored and its impact on the formation process of micro- and nano-dispersal particles has been determined.

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

- European research, development and cooperation programme *Eureka* was carried out until the end of 2009. The researches of the Laboratory has initiated and are coordinating the *Eureka* project **E13539 PLAZMINFIB** entitled **Novel Methods to Produce Mineral Fibre from Local Raw Materials and Waste**. It is suggested to realise the synthesis of mineral fibre and granules in atmospheric pressure air plasma jet reactor, in which high temperature and high concentration of active ions are achieved. An experimental plasma-chemical facility, designed for the research of Si, Mg, Ca and Al oxides and their compounds melting, stringing melts and granule formation processes, has been developed. The fibre of 0.5–2  $\mu\text{m}$  diameter is obtained in plasma reactor, with DC plasma generator, creating a high-temperature air flow kinetic energy, which is employed for the formation of fiber filaments. The cooperation proceeds with researchers from University of Catania (Italy) and JSC *Termotechnika* (Lithuania);
- A project **Dissemination and Fortering of Plasma Based Technological Innovation for Environment in BSR** of *Baltic Sea Region Programme 2007-2013*. The main objectives of this project are to develop and use plasma technologies for solving environmental problems. It is also important to develop equivalents that prove the possibility to practically improve air and water quality and to introduce of plasma technologies in the field of environmental protection.



The formation mechanism of micro- and nano-dispersal particles during the process of plasma spray pyrolysis

Researchers of the Laboratory participate in the following international programmes and projects:

- **COST CM0903** activity **Utilisation of Biomass for Sustainable Fuels and Chemicals** (UBIOCHEM) until 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 increased amount of hydrogen. Not only different waste, but also hazardous materials will be processed using water vapour plasma technology. Scientists from 18 European countries participate in this activity;
- **COST D41** activity **Inorganic Oxides: Surfaces and Interfaces** until 2010. This activity is related to the investigation of synthesis processes of metal oxide coatings, their surfaces and inner structure. Its main objective is to improve scientific knowledge and understanding about the

A new application for Baltic Sea Region Programme 2007-2013 is on preparation. The project **South Baltic Plasma Training Network** is going to be presented in 2010, whereas the application for the project **Development of Water Vapour Plasma Device for Biomass Conversion and Hazardous Waste Utilization** (EU-REKA) is also going to be submitted in 2010.

In 2009, scientific and technological production of the Laboratory was presented in 7 international and 4 national conferences, 9 articles were published in ISI indexed journals and 7 articles in other peer-reviewed publications.

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# Laboratory of Nuclear Engineering

## Main research areas of the Laboratory:

- Experimental investigation of heat transfer and turbulent transport patterns in single-phase flows: forced and mixed convection, turbulent and transition flow regimes, influence of channel geometry, variable physical properties, roughness, centrifugal forces and transients effect;
- Numerical modelling of heat interchange and transfer in single-phase flows in various channels and geological structures;
- Management of spent nuclear fuel: modelling of fuel characteristics, safety and environmental impact assessment of storage and disposal facilities, normative and legislative base;
- Management of radioactive waste: strategy, safety and environmental impact assessments of treatment technologies and storage and disposal facilities, normative and legislative base;
- Evaluation of different factors related to decommissioning of nuclear power plants: planning and cost of decommissioning and dismantling, radiological assessment of buildings, systems and facilities, safety and environmental impact assessment, normative and legislative base;
- Fire hazard analysis of nuclear power plants and other large facilities;
- Research related to construction of new nuclear power plant in Lithuania.

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

Since the foundation of the Laboratory, research of heat interchange and hydrodynamics has been carried out in energy equipment for different purposes (in the elements of nuclear reactor, various air heaters, etc.). Due to the analysis of spent nuclear fuel (hereinafter SNF) disposal possibilities, such investigation have been initiated in geological structures in recent years. It has been observed that in the case of laminar and turbulent flows, the effect of thermogravitational forces on heat interchange is manifested in many energy facilities. Under certain conditions the impact evoked by thermogravitational forces on heat interchange usually becomes a reason for accidents in different facilities. For this reason, mixed convection scientific research has been begun in pipes, later in flat channels as well.

In 2008-2009, experimental and numerical research of mixed convection of opposing flows heat interchange and flow structure were carried out in transitional flow zone of flat leaning channels (tilting angle 30° and 60°) financed by the state budget grant. Additionally, numerical research was performed in a vertical channel, subject to mixed convection for single-sided flows. Numerical modelling under different cases of mixed convection was carried out applying FLUENT (USA) software. Various models of the laminar, transition and turbulent transfer were used. Due to obtained heat interchange and flow hydrodynamics results, the understanding about the laminar flow transition to the turbulent under the impact of thermogravi-

tational forces changes and expands. Moreover, influence of stable and unstable stratification of the air density to the heat transfer in case of the mixed convection in the transition flow area was shown up.

## Management of spent nuclear fuel

After the decision to use dry storage facility for 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 of normal and extended capacity under normal operational and accident conditions, variation of radioactive nuclides activity during the storage period, ra-



*The Deputy Director Dr. R. Levinskas is greeting participants in the meeting of scientific research project "Numerical Model Application Performing Location Characterization and Safety Assessment of Geological Repository" coordinated by IAEA (Kaunas, 13/09/2009)*

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

Implementing 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 crystal 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 possibilities of SNF disposal in Lithuania, the costs assessment of geological repository installation was carried out and generic repository safety assessment was initiated.

The research was carried out in the following projects: the study *Analysis and Optimisation of Radiation Effect During the Implementation of NNP Facilities Dismantling and Managing Radioactive Waste* (2007-2009) financed by the state subsidy grant, the project *Manner of Gases in Geological SNF/RA Repositories (FORGE)* (2009-2012) financed by the Seventh Framework Programme of the EU, and the scientific research project *Safety Assessment and Geologic Repository Site Characterization Applying Numerical Modelling* (2005-2010) coordinated by IAEA.

The research related to the radionuclide migration and the processes affecting it in the far-field of the repository (geosphere) were carried out aiming at more optimally evaluating the impact of geosphere on the safety of SNF repository. The data of Veresnia (Ukraine) was employed. Evaluating different flow conditions of underground water in different geological formations, the geofiltration nature of underground water under respective conditions was determined. The input data on the analysed radionuclide flow to the far-field environment of the repository were collected after carrying out the probabilistic assessment of radionuclide migration in the near-field environment following KBS-3H conception of disposal. The results of numerical evaluation revealed that when the region underground water flow is absent in the geologic layers, the unsorbed long-lived iodine isotope  $^{129}\text{I}$  dispersed from the near-field environment of repository would reach the river water. If the regional flow were present in the system, a greater amount of radionuclides would reach the river,

whereas the delay in the geologic structures would be much shorter. In both cases, the flow to the river would be lesser than the flow via the engineering barriers from the near-field environment of the repository.

The investigation of the influence of gas spread processes on radionuclide migration and integrated studies of the influence of heat spread and mechanic processes in geologic and engineering structures undersaturated with water were begun.

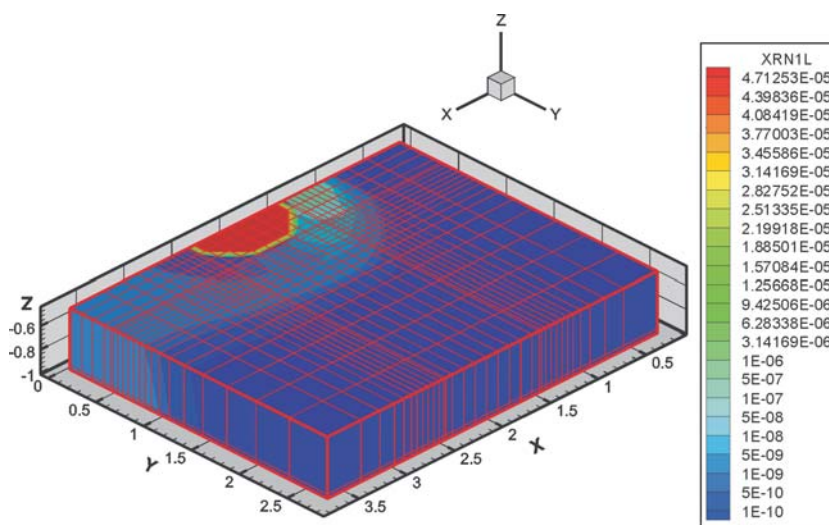
Software AMBER (the United Kingdom), TOUGH2 (USA), COMPULINK, CHAN3D, PREBAT-BATEMAN (Sweden) were applied for the assessment of radionuclide migration.

In 2009, the Laboratory, as a partner of consortium GNS – NUKEM Technologies GmbH (Germany), continued a extensive project *Design and Installation of the Interim Storage Facility for RBMK Spent Nuclear Fuel Assemblies from Ignalina NPP Units 1 and 2* (2005-2009). This project comprises all activities for the design, construction, installation, commissioning, operation and decommissioning of the new SNF storage facility and 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 foreseen to store approximately 200 CONSTOR type 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.

## 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 evaluation of existing 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) carried out the environmental impact and safety assessments for Ignalina NPP cement solidification facility and a temporary solidified radioactive waste storage facility. Additionally, the Laboratory constantly participates in the research programmes coordinated by IAEA.



The migration of  $^{129}\text{I}$  from RBMK-1500 SNF disposal casks and its distribution in the near-field environment of the geological repository



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 radionuclides 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 near-surface repository and prepared the implementation programme. The impact of *heterogeneous* waste activity distribution on radionuclides migration from model near-surface repository was investigated. Software packages DUST, GENII, GWSCREEN (USA) and AMBER were applied for the research.

During 2006-2008, 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. ISAM safety analysis method and software AMBER and DUST were used in the assessment. The documents were prepared and submitted to regulatory institutions in 2007; in 2008 they were coordinated, whereas in 2009 the final report was prepared after a review of Lithuanian and foreign experts.

In 2009 the Laboratory together with NUKEM GmbH (Germany) continued the project **New Ignalina NPP Solid Waste Management and Storage Facility (2006-2011)**. This facility is intended for solid radioactive waste retrieval, sorting, transportation, treatment (using envisaged technologies), packaging, characterisation and storage. The facility comprises the solid waste retrieval facility located near the existing INPP solid waste storage buildings, the new solid waste treatment facility, the new short-lived radioactive waste storage facility and the new long-lived radioactive waste long-term storage facility.

The Laboratory prepares environmental impact and safety analysis reports for this complex. In 2008 *Environmental Impact Assessment Report* was approved by the Ministry of Environment, whereas two Preliminary Safety Analysis Reports: *New solid waste treatment and storage facilities at Ignalina NPP* and *New solid waste retrieval facility at Ignalina NPP* were submitted to regulatory institutions for assessment. The former was approved and VATESI has issued the licence for the construction of the treatment and storage facilities. In 2009 Preliminary Safety Analysis Report *New solid waste retrieval facility for 1 and 2-3 modules at Ignalina NPP* was newly prepared.

In 2009 the Laboratory in the composition of Lithuanian consortium (JSC *Specialus montażas-NTP*, LEI, *PramProjektas*, JSC *Vilstata*) continued implementing the project **Installation of Very**



*The participants of the 10<sup>th</sup> waste management group meeting of the European atomicenergy association (Kaunas, 11-12/05/2009)*

**Low Level Radioactive Waste Repository (Landfill)** (2008-2010). *Landfill* repository is intended for disposal of very low level radioactive waste generated during Ignalina NPP operation and decommissioning. *Landfill* facility will be comprised of three repository modules and buffer storage where waste will be stored till their disposal.

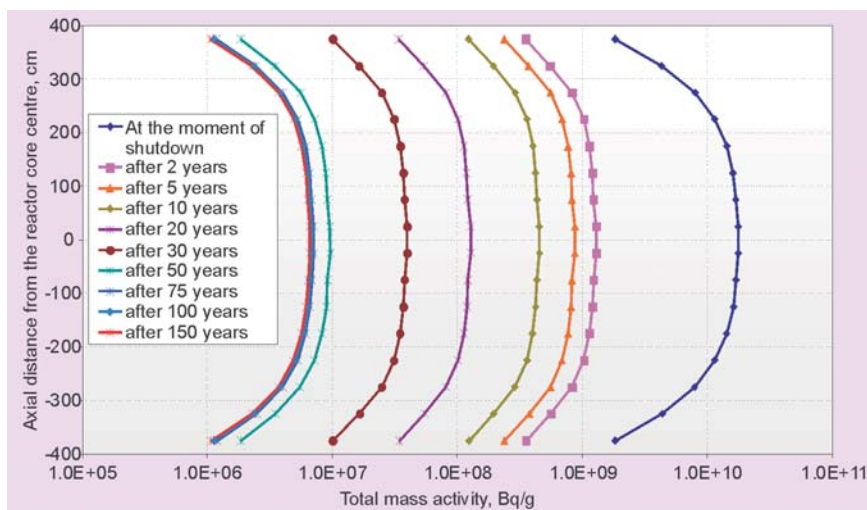
In 2008, the Laboratory prepared *Environmental Impact Assessment Report* for the planned economic activity; it was coordinated and approved by the Ministry of Environment in 2009. Furthermore, two Preliminary Safety Analysis Reports were elaborated: *The buffer storage of the Landfill repository* (approved by VATESI in 2009) and *The disposal modules of the Landfill repository* (submitted for review to regulatory institutions).

## **Evaluation of different factors related to decommissioning of nuclear power plants**

In 1998 the Laboratory researches started new studies related to the planning of decommissioning of Ignalina NPP. The experts of the Laboratory participated in PHARE project preparing *Preliminary Ignalina NPP Decommissioning Plan*. In the course of preparing *Final Ignalina NPP Decommissioning Plan*, the Laboratory analysed the data on radiological pollution of Ignalina NPP systems. In 2004 the Laboratory specialists prepared the drafts on *The Ignalina NPP Decommissioning Programme* and the *Plan of Means of its Implementation for the period 2005-2009* for the Ministry of Economy.

Together with Institute of Physics the Laboratory implemented the project **Development of Radiological Characterization Programme for Equipment and Installations at Ignalina NPP**. This project included the analysis of the international situation, on the basis of which *General Programme of Radiological Survey* was prepared. Having collected and analysed the data on INPP site, *Historical Assessment Report of Radiological Situation at INPP* and *Programmes of detail radiological characterizations* and de-





A model of the total mass activity distribution in axial direction of central part of fuel channels at Ignalina NPP 1<sup>st</sup> unit RBMK-1500 reactor and its variation in 150 years after the final reactor shutdown

tailed radiological research programmes for the equipment of V1, G1 units and 117/1 building of INPP were also prepared. Later, detailed radiological research programmes for the equipment of B1, D0, D1 units and 119 building of INPP were formulated. An electronic Microsoft Access database was created which stores all the necessary data for equipment description and drawings showing the sites of radioactivity measuring and sampling. The programmes created and the collected and analysed data on the radiological situation of INPP are vital for pursuing the decommissioning of INPP.

Since 2002, the Laboratory has been performed fire hazard assessments in the nuclear power plants and other important facilities. In consultation with Swedish experts, the Laboratory specialists assessed the fire hazard of the 1<sup>st</sup> and 2<sup>nd</sup> units of INPP. Fire hazard assessment of some renewed INPP premises for displaced purposes and newly designed INPP SNF and radioactive waste storage facility was carried out as well. An external fire effect on the new INPP complex for solid waste processing and storage was assessed and the risk analysis of the most dangerous areas in the case of an internal fire hazard was performed. In 2008-2009, the impact of fire hazard during the implementation of Ignalina 117/1 building dismantling and decontamination was evaluated similarly as the fire hazard of newly designed buffer storages and disposal modules of *Landfill* repository.

The research related to the neutron activation of constructional reactor material was carried out in the frame of the state funded programme **Analysis and Optimisation of Radiation Impact During Dismantling of NPP Equipment and Radioactive Waste Management** (2007-2009) and the project of Seventh Framework Programme of the EU **Treatment and Disposal of Irradiated Graphite and Other Carbowaste** (2008-2012).

This research was implemented by describing the irradiated graphite in the reactor and its constructional elements, located further from graphite flooring boundary. This analysis enabled collecting and systemising information on radiological situation at RBMK type reactors, assessing the possible methods of dismantling and disposing graphite blocks and rings from the reactor, considering mechanic, radiological and other properties

of the graphite. For this purpose, the model, created in the Laboratory in 2008, was applied since it enables to statistically evaluate neutron flows and their distribution in axial direction in the analysed constructions of the reactor. In 2009, applying modelled neutron flows by software MCNP-5 (USA), the neutron activation of the fundamental constructional elements (graphite blocks rings/ hubs, metal constructions, serpentine fillings), located in the central part of the RBMK-1500 reactor, was evaluated (using software ORIGEN-S (USA)).

In 2007-2009, Lithuanian Energy Institute, as a partner of consortium VT Nuclear Services Ltd (UK) – LEI – NUKEM (Germany), participated in the implementation of the project **Ignalina NPP Building 117/1 Equipment Decontamination and Dismantling**. Researchers of the Labora-

tory participated in preparing environmental impact assessment and safety justification reports, technical and detailed projects and developing overall data base. Using CORA/CALCOM (Germany) software package, the equipment of building No 117/1, waste amounts and their characteristics were analysed and economic assessment of the planned decontamination and dismantling activities was carried out. Personnel radiation doses were simulated after estimating surface contamination of facilities by VISIPLAN 3D ALARA software (Belgium). In 2009 *Environmental Impact Assessment Report, Safety Justification Report and Overall Data Base* were prepared and submitted to the contractor.

In 2009, Lithuanian Energy Institute, as a partner of consortium VT Nuclear Services Ltd (UK) – LEI – NUKEM (Germany) – Ansaldo Nucleare (Italy), began the implementation of a new project **Ignalina NPP Building V1 Equipment Decontamination and Dismantling** (2009-2011). Specialists of the Laboratory participate in preparing environmental impact assessment and safety justification reports and developing shared data collection. In 2009, a software package DECRAD was created for assessing the amounts of dismantled equipment, radioactive and free release waste, transportation and disposal packages, personnel demand, the radiation doses received during the dismantling of radioactive equipment, expenses of decontamination and dismantling. The software also provides schedule for the implementation of the works.

In 2009, the specialists of the Laboratory together with Laboratory of Nuclear Installation Safety and JSC *Specialus montażas – NTP*, were carrying out a project **Environmental Impact Assessment and Safety Justification Reports of the Unit 2 Decommissioning**. This project encompasses the decommissioning of the reactor in INPP Unit 2, discharge of fuel from the reactor and storage pools and its transfer to a intermediate SNF storage facility. Additionally, isolation and modification of systems and waste management during the defuelling phase are also included into this project. The specialists of the Laboratory have prepared *Environmental Impact Assessment Report* and presented it to the competent authorities; they also participated in the preparation of *Safety Analysis Report for the INPP Unit 2 Decommissioning Project for the Final Shutdown and Defuelling Phase*.



The defence of E. Narkūnas' (right) doctoral thesis in the Board Meeting on 17 May 2009

## Research related to the construction of a new nuclear power plant in Lithuania

In 2007-2009 the researchers of the Laboratory were carrying out investigation related to the implementation of a new nuclear power plant in Lithuania. In 2007, in accordance with the order of SC *Lietuvos energija*, consortium Pöyry Energy Oy (Finland) – LEI (Lithuania) were implementing a project **Preparation of Environmental Impact Assessment Programme for New Nuclear Power Plant**, where the scope of the new NPP environmental impact assessment report was determined. *Environmental Impact Assessment Programme* was prepared by the consortium specialists and approved by the Ministry of Environment.

Continuing the investigation in 2008-2009, the consortium Pöyry Energy Oy – LEI started a new project **Preparation of Environmental Impact Assessment Report for New Nuclear Power Plant**. The specialists of the Laboratory participated in the preparation of the *EIA Report*, which was submitted to the competent authorities. In the *EIA Report*, possible environmental impacts of the construction and operation of new NPP were assessed in cooperation with other Finnish and Lithuanian institutions (Institute

of Botany, Institute of Ecology and National Public Health Surveillance Laboratory). The possible effect of the planned economic activity on the components of the environment, such as water, air, soil, biodiversity, landscape, cultural heritage objects, social and economic environment and public health, was analysed. A great deal of attention was devoted to numerical simulations of Drūkšiai lake water temperature and the spread of radionuclides emitted during an emergency, and to estimations of the impact on lake ecosystem and radiological impact on public health during normal operation as well as during design basis and severe accident. The possible international impact of the new NPP in Lithuania to the Republics of Latvia and Belarus was also assessed. According to the *EIA Report* of 2009, positive evaluations of the competent authorities were made concerning the planned economic activity and, therefore, following this *EIA Report*, Ministry of Environment has made the motivated decision that the construction and operation of new nuclear power plant with respect to the environmental impact is allowed in the selected area.

## Main results

In 2009 the Laboratory (28 researchers) continued 2 (completed 1) state subsidy funded research projects, carried out 12 applied research projects. In Laboratory one PhD thesis *Investigations of the Change of Nuclides' Content in the RBMK-1500 Reactor Structural Components* was defended (E. Narkūnas). Currently there are 4 PhD Candidates in the Laboratory. Researchers of the Laboratory actively participated in different training programmes, coordinating meetings, presented 7 papers at international conferences (the United Kingdom, Germany, Poland and Lithuania) and published 13 scientific articles in Lithuanian and international peer-reviewed journals.



The Drūkšiai lake

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# Laboratory of Nuclear Installation Safety

## Main research areas of the Laboratory:

- Safety assessment of nuclear power plants;
- Thermal-hydraulic analysis of accident and transient processes;
- Assessment of thermal-hydraulic parameters in NPP containments;
- Simulation of radionuclides and aerosols transport in the compartments;
- Assessment of nuclear reactor core modifications and analysis of postulated reactivity accidents;
- Safety analysis of thermonuclear fusion reactors;
- Analysis of new generation nuclear power plants;
- Reliability estimation and control of energy systems;
- Level 1 and Level 2 probabilistic safety assessment of NPPs;
- Strength analysis of constructions, piping and components in complex technical systems;
- Single failure analysis and engineering assessment for complex technical systems;
- Risk and hazard assessment of industrial objects;
- Assessment of security of energy supply;
- Probabilistic modeling and analysis of unusual events;
- Sensitivity and uncertainty analysis of modelling results;
- Fundamental research in thermal physics.

In 2009, the researchers of the Laboratory, together with other national and foreign subjects, were implementing the following 29 projects: 3 state subsidy funded scientific research projects; 14 international projects (5 projects of EU 6<sup>th</sup> and 7<sup>th</sup> Framework Programmes (FP) and 4 international scientific research programmes without external funding); 12 projects funded by Lithuanian economy subjects.

## Preparing for construction and operation of new nuclear power plant in Lithuania

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

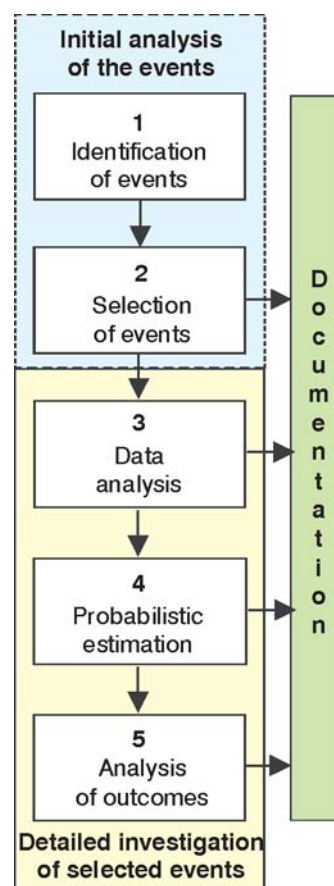
These projects are important in strengthening Lithuanian competence in the nuclear energy field which is necessary for every country owning nuclear power objects.

### Preliminary work for Visaginas NPP

In 2009, under the agreement **Assessment of Potential Visaginas NPP Construction Sites in Respect of External Events** between JSC Visaginas NPP and LEI, the tasks on external factors (such as human-induced events, meteorological phenomena, site flooding) assessment were performed. The main objective of this completed project was to evaluate the suitability of potential sites for

Visaginas NPP construction, following the requirements of International Atomic Energy Agency (IAEA).

In accordance with the technical task and project management plan all information and activities were divided into three separate topics. Performing research under the first topic *Accidentally human-induced phenomena and events*, the most attention was devoted to those sources of hazards and events, which are related to the aircraft crash, gas pipeline explosion and forest fire. Performing research under the second topic *Meteorological extreme phenomena and events*, the focus was on probabilistic assessment of extreme winds, temperatures and precipitation and description of their probable outcomes. Moreover, performing research under the third theme *Flooding induced hazard, phenomena and events*, various factors, conditioning the water-level of Drūkšiai lake and flooding outcome were analysed in more detail.



Scheme of external event analysis



man-induced events, meteorological phenomena, site flooding) assessment were performed. The main objective of this completed project was to evaluate the suitability of potential sites for



Probabilistic estimates of aircraft crash, gas explosion and flooding, which may induce severe outcomes, are relatively small. Events such as forest fire, extreme winds, precipitation and temperature are much more probable; however, their outcomes are not so severe and from the safety point of view they controlled easier. The results of performed research may be important while making a decisions regarding particular construction site and planning management of their risk. Following the recommendations of IAEA, the analysis of external events should be updated if any additional information emerges in the future.

LEI actively participates in the activities of nuclear energy scientific research and increasing specialists' qualification. The researchers of Laboratory of Nuclear Installation Safety not only take part in the Framework Programme projects of EU **Scientific Research and Experimental Development**, but also organize **National and Regional Basic Professional Training Course in Nuclear Safety** in cooperation with IAEA. On 19-30 October 2009, *Basic professional training course in nuclear safety* were organized in Vilnius by IAEA and LEI. The representatives from 16 countries (Albania, Armenia, Azerbaijan, Belarus, Bulgaria, Georgia, Hungary, Kazakhstan, Montenegro, Poland, Romania, Russia, Slovakia, Slovenia and Ukraine) participated in nuclear safety training courses, which took place for the second time. Additionally, the representatives from JSC *Visaginas NPP*, State Nuclear Power Safety Inspectorate (VATESI), Vilnius University and State Institute of Information technology also participated in these courses.

During the training course, the participants became acquainted with basic principles of nuclear and environmental safety, as well as the peculiarities of ensuring and assessing nuclear power plant safety. Practical tasks were carried out at Ignalina NPP training centre, where the participants were taught to control the reactor in cases of emergency by using the full-scope NPP simulator. The experts from IAEA, Kaunas University of Technology, LEI, Institute of Physics and Ignalina NPP lectured and shared their knowledge.

In 2009, the researchers of the Laboratory participated in the implementation of the *Transition Facility Projects*. One of its objectives is to increase the qualification of local specialists in order to ensure Ignalina NPP safety maintenance and assessment, including the phase after the final shut down of the reactor. The scope of the implemented project **Enhancement of VATESI and its Technical Support Organizations Specialists Knowledge through Seminars and Internships** matched the three following objectives:

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



*Participants of Basic Professional Training Course in Nuclear Safety*

- Prepare recommendations for programmes of inspections in the field of structural integrity.

During the implementation of this project, the Nuclear Research Group from the University of Pisa (Italy) was the partner of LEI. By common efforts, 7 training seminars (23 days in Lithuania), 8 working seminars (16 days in total, 8 in each Lithuania and Italy, the University of Pisa), and 3 internships (each lasted for one week in Italy, Germany, Slovenia and Croatia) were organised. While performing internships, the participants visited nuclear power plants, spent nuclear fuel storages, organizations developing software, etc. In working seminars, specific recommendations were prepared and submitted to VATESI on the renewal/change or improvement of present national requirements for fuel operations and instrumentation and control systems and equipment. Moreover, the projects of state-of-the-art inspection programmes and (procedure) manual documentation for performing structural integrity inspections of safety-important systems were prepared.



In 2009 according to plans for project **IRIS** (International Reactor Innovative and Secure) and the joint agreement between project IRIS participants and *Westinghouse Electric Company LLC* the new bilateral research contracts were considered. Conceptual IRIS project has already been finished and, at present, work of reactor technical systems testing and preparation of reactor project for licensing are in progress (till year 2010). In this stage researchers of LEI participate in preparing methodologies for new reactors comparisons and in implementing work, related to structural, economical, security and safety analysis of the reactor. In the recent years specialists of the Laboratory have participated in

performing IRIS probabilistic safety and economical efficiency analysis and research, devoted to reduce the risk of different external hazards and the uncertainty of obtained results. As the building of new NPP is planned, scientific research in this field is relevant for the study of new reactors construction in Lithuania. IRIS project and related research will be completed around 2010-2015, i.e. in the time when assessment and licensing issues for new nuclear reactor in Lithuania will be extremely important.

New generation reactor development and analysis, related to IAEA coordinated research programmes, are carried out in the laboratory. One of such programmes is **Economic and Energetic Benefit of Small and Medium Reactors with Reduced Emergency Zone Requirements: the Case of Lithuania**. The research of this programme, implemented in 2007-2008, is devoted for the assessment of evacuation zone and safety measures of nuclear power plants as well as the analysis of perspectives of secure and efficient small and medium capacity reactors. While performing the investigation, the researchers of the Laboratory overviewed the situation of energy safety until 2009. Several scenarios, related to possible interference of energy resources supply, were analysed and the research of the impact of small (IRIS) and big reactor installation on electricity and heat production was carried out.

In 2009, under the order of VATESI, a legal act regulating nuclear safety **General Regulations for Nuclear Power Plant Safety** was prepared. This legal act will substitute the VATESI document VD-B-001-0-97 *General regulations for nuclear power plant safety* approved in 1997. The new regulation document sets the principal objectives, criteria and principles for safety as well as technical and organizational means for ensuring safety of nuclear power plants. The document is going to be one of the most important legal acts that regulate the safety requirements of the planned Visaginas NPP.

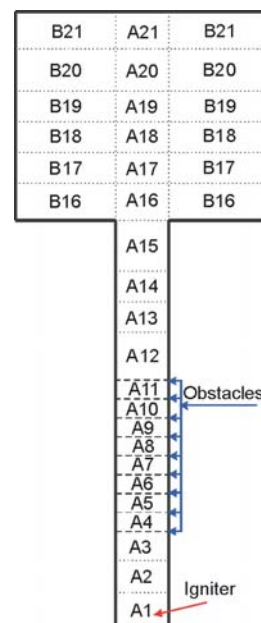
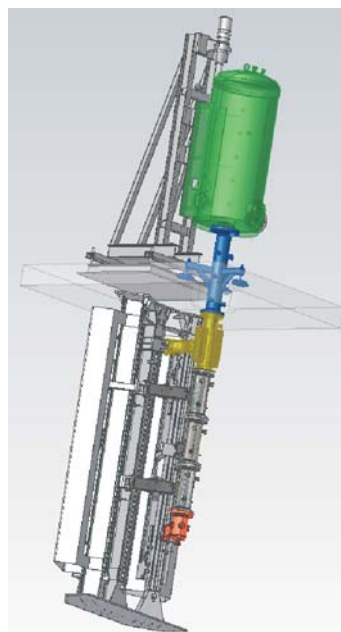


#### **Network of Excellence of Severe Accident Research of Nuclear Power Plants SARNET-2**

In 2009, a new agreement on FP7 project **SARNET-2** was signed; it extends the activity of **SARNET** network of excellence which was carried out for four years. This project aims at the integration of NPP severe accident and operational research in Europe. Including LEI there are 41 Scientific and business institutions from EU countries that participate in this project. The researchers of Laboratory of nuclear installation safety take part in the activity of the three following working groups of the project:

- WP4 ASTEC – adaptation and verification of integrated code ASTEC for modelling severe accidents in NPP;
- WP5 COOL – cooling of melted core and remaining debris;
- WP7 CONT – analysis of processes in containments of NPP.

The kick-off meeting was held on 27-29 April 2009 in Karlsruhe, Germany, where work programmes were discussed.



*An ENACCEF stand of experiments on hydrogen burning research and numerical model for software package ASTEC*

The objective of working group WP-7 CONT is to examine the challenges for NPP containment integrity that arise because of steam explosion and hydrogen deflagration/detonation. The researchers of the Laboratory participate in research related to hydrogen deflagration/detonation. One of the tasks in solving this issue is hydrogen mixing in the containment atmosphere. In this task it is planned that IRSN (France) performs experiments in TOSQAN test facility and the other organisations including LEI performs numerical analysis of the experiments. The other task related to hydrogen deflagration in which our Laboratory is involved – hydrogen burning by the Passive Autocatalytic recombiners. To solve this task our laboratory is going to use ASTEC code. The hydrogen deflagration experiments performed in ENACCEF test facility will also be investigated using ASTEC code.

The Laboratory continued the research in **PHEBUS – FP** programme, which is one of the largest international research programmes for water-cooled nuclear reactor safety and severe accident research. In 1988, IRSN (France) initiated the programme and presently coordinates it. Applying COCOSYS code, the Laboratory performs numerical research of the phenomena in PHEBUS containment. FPT-1 experimental data was used to analyse the impact of nodalization scheme of the model and modelling parameters (aerosol density, border layer thickness and aerosol solubility) on modelling results.

In 2009, continuing the cooperation with GRS mbH (Germany), it was decided to investigate PHEBUS – FP experiments together and develop a common model of the containment, which would enable a detailed analysis of processes during the FPT-2 experiment. On 9 December 2009, a meeting with a GRS mbH expert G. Weber took place in LEI, where details of the model development were discussed and further plans were agreed. The Laboratory is responsible for the part of the model related to the description of thermodynamic processes as well as aerosol and radionuclide transport processes. GRS mbH will supplement this model with information on chemical transformations of iodine.



The model developed by LEI and GRS later could be supplemented by adding the modelling of processes in PHEBUS reactor carried out using ATHLET-CD code.



### **Network of Excellence of Nuclear Plant Life Prediction**

In 2009 LEI together with partners continued activities of FP6 project **NULIFE** (Nuclear Plant Life Prediction) network of excellence. One of the main tasks is to create a single organisation structure in the form of a Virtual Institute, capable of providing harmonised R&D at European level to the nuclear power industry and the related safety authorities in the area of lifetime evaluation and management methods for structural components. This project is also related to the methodology improvement of decision-making, based on risk assessment, and optimization of exploitation control. The researchers of the Laboratory participated in the activity and organized meetings of working groups *Assessment of structural integrity (IA-2-2)* and *Safety, risks and reliability (IA-2-4)*. *IA-2-2* working group prepared a research report on the assessment of RBMK-1500 reactor fuel channel failure and the analysis of acceptable and critical cracks in fuel channels. The assessment of delayed hydride cracking was carried out using the leak before break methodology. *IA-2-4* working group prepared the description of NPP safety, risk and reliability assessment programme and information on estimation methodology of safety coefficients assessment. Participants of the project submitted offer for FP7 projects in the fields of material degradation, decay mechanics and risk assessment. The project will be implemented till 2011.



### **NPP operation reliability characteristics research**

In accordance with agreement between EC JRC Institute for Energy and LEI in 2009 the implementation of research on **Reliability and Data Analysis of Passive Components** was continued and a report was prepared. Activities of the project are related to *Network for Incorporating Ageing Effects into PSA Applications (APSA)* and research of *Probabilistic Safety Assessment for Evaluation of Ageing Effects to the Safety of Energy Facilities*, coordinated by EC JRC IE. **APSA** research network comprises 14 organizations from different countries and is related to NULIFE network of excellence. Taking into account the impact of equipment degradation and change of their reliability characteristics, **APSA** research network is devoted to improve the classical probabilistic safety assessment (PSA). Applying an assumption of constant reliability parameters, sometimes in practice and theory an inadequate safety assessment is carried out applying the classical PSA. In order to perform age dependant PSA, larger amount of data, inspection assessment and more detailed models are essential.

In this research network LEI devoted most of the attention to activities, related to component reliability analysis methods and time dependent reliability characteristics assessment as well as application of such methods and estimates in PSA models. Fur-

thermore, the issues of development and application of reliability database and relevant software (e.g. WinBUGS) were considered. Since 2008 LEI had been coordinated **APSA** research network activity *Ageing data and reliability analysis for passive components*.



### **Inspection and qualification research**

In 2009 LEI, being the member of **ENIQ** (*European Network for Inspection and Qualification*) coordinated by EC JRC Institute of Energy, continued the participation in activities of working group on risk analysis TGR (Task Group on Risk). The researchers of the Laboratory represented and introduced activities for risk-informed inspection programme development and optimisation in Lithuania. ENIQ research network is comprised of 20 different organizations. Activity of this network is related to NULIFE network of excellence and other FP7 projects.

### **International standard No. 49**

In 2009 an OECD project **International Standard No. 49**, which aims at analysing the processes of hydrogen burning in NPP containments, was begun. During the implementation of this project, the tests are performed in two experimental stands, namely ENACCEF (France) and THAI (Germany). The researchers of the Laboratory plan to carry out numerical experimental research using ASTEC code, which includes an up-to-date hydrogen burning model. The first project participants' meeting took place in 2009 where the first results were discussed. The project is due to finish in 2010.

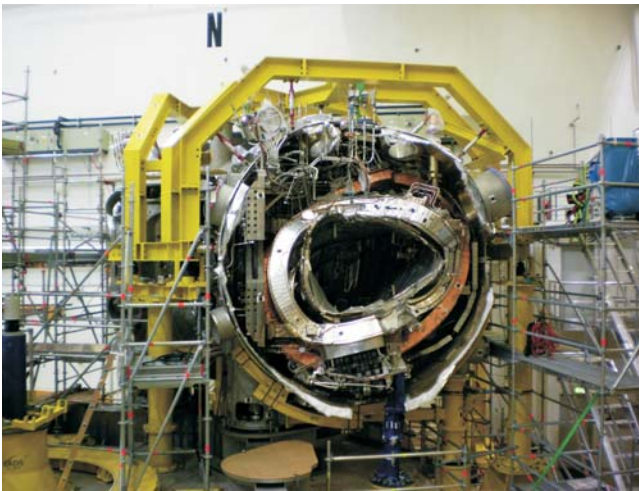
### **Safety analysis of thermonuclear fusion reactors**

Scientific research of thermonuclear fusion energy (FUSION) development is one of the priorities of EU FP7 research. Its main objective is the development of International Thermonuclear Experimental Reactor (ITER). The reactor will display the scientific and technical possibilities of thermonuclear energy use for peaceful purposes and will be the first thermonuclear fusion facility generating 500 MW capacity. The reactor will be built in Cadarache research centre, France (close to Marseilles).



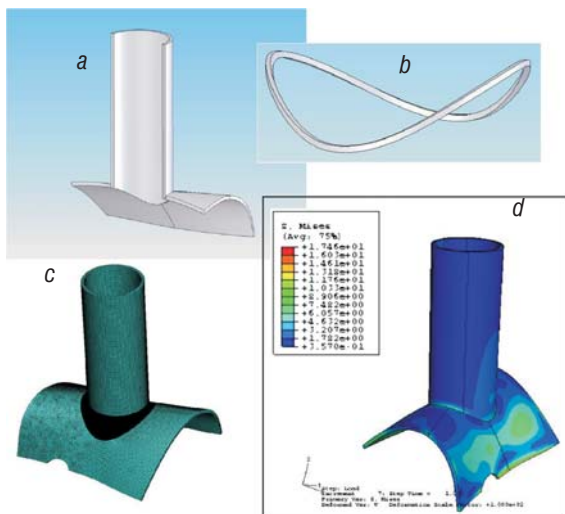
In 2009 the activities were continued in accordance with **Association Agreement Concerning the Cooperation in the Field of Scientific Research of Thermonuclear Fusion** signed between LEI and European Commission. Cooperating with Max-Planck-Institut für Plasmaphysik (Germany), the analysis of stellarator type thermonuclear fusion experimental equipment W7-X, constructed in the institute, and structural analysis of its part was carried out.





W7-X stellarator (Germany)

In 2009 the models of the port welds between the plasma vessel and the ports in W7-X cryostat system was prepared using software's SolidWorks and Brigade/Plus. Software SolidWoks was used for preparing the geometrical models of these port welds. The finite element (FE) models of these port welds were prepared using software Brigade/Plus. The test analysis of these FE models was carried out.



Calculation results and weld seam model of plasma vessel ports AEU30: a, b – geometric model, c – finite element model, d – calculation results

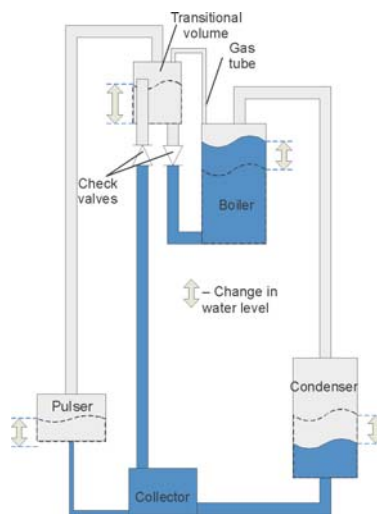
Last year LEI, together with other EURATOM associations: IPP (Max-Plank-Institut für Plasmaphysik, Germany), CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, Spain), KIT (Karlsruhe Institute of Technology, Germany) and CEA (Institut de Recherche sur la Fusion par confinement Magnétique, France), submitted an application for participation in training programme organized by European Fusion Development Agreement (EFDA). It is planned to enroll in the research field related to the engineering of large components: LEI would contribute to the designing of ITER vacuum vessel by performing structural analysis. This programme is beneficent since it offers training for junior researchers and incorporates them into the issues of thermonuclear fusion.



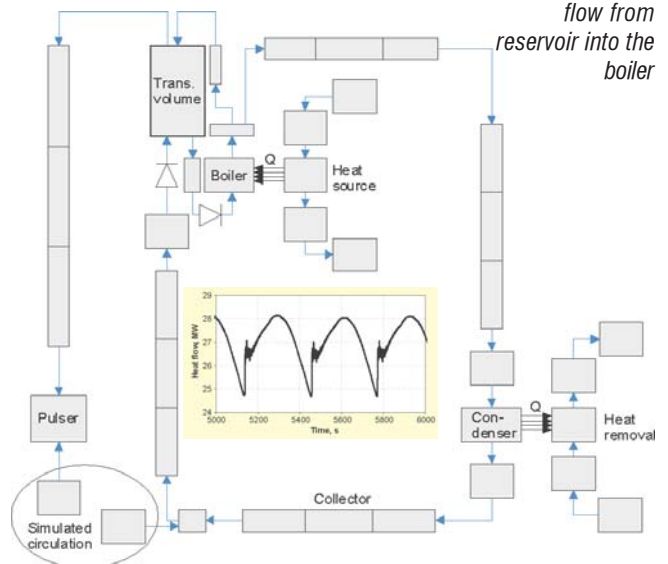
Consultations in Max-Plank-Institut für Plasmaphysik

## Research of condensation implosion

In 2009 a state subsidy funded research project **Numerical and Experimental Research of Condensing Two-phase Flow** was initiated. Its main objective is to examine condensing stratified cocurrent two-phase flow in a closed horizontal channel and to determine the phenomena interrelation during the flow.



Circuit scheme of thermal-hydraulic system; its RELAP5 model and its usage for calculating the change of heat flow from reservoir into the boiler



At the same time, the project aims at developing a numerical model for thermal-hydraulic system, which uses condensation implosions for circulation, and to prepare recommendations for the construction of such system. The model was developed and modeling results demonstrated that the system may operate using condensation implosions for circulation. Continuing numerical and experimental research of two-phase flow, the improvement possibilities of thermodynamic two-phase flow model FLUENT3D (used for interphase friction calculation) were analyzed.

## Application of best estimate methodology

In 2009 a three year state subsidy funded research project **Best Estimate Methodology Application Simulating Processes in Technical, Natural and Social System** was completed. Researchers from the Laboratory of Hydrology and the Laboratory of Energy Systems Research also took part in this study. The aim of the project was the application of uncertainty analysis methodology in the field of engineering and social sciences and performing modeling of hydrological processes.

Carrying out numerical research in technical systems and applying the calculation results made by Kurciatov Institute scientists, the developed numerical model of RBMK-1500 fuel rod was reviewed and the code FEMAXI-6 was improved. Best estimate methodology and the use of sensitivity and uncertainty analysis methods reveal that applying the improved FEMAXI-6 code, a better concurrence with the calculation results made by Kurciatov Institute specialists is achieved. The results of best estimate methodology use in social systems (for energy economy tasks) are presented in great detail in the section on Laboratory of Energy Systems Research.

Solving natural system tasks, hydrological model for the Nemunas River, which may simulate Kaunas HPP inflow under various natural conditions and in accordance with forecasted climate change scenarios, was developed. Using GLUE (Generalized Likelihood Uncertainty Estimation) method, calibration parameter analysis of the Merkys River (belonging to Nemunas

River basin) hydrological model was carried out. This uncertainty analysis enabled reducing the influence of model parameters on the performed run-off forecast. Applying the developed and calibrated model, and using the best estimate methodology, the Merkys River run-off modeling was carried out following the global climate models and scenarios of emission.

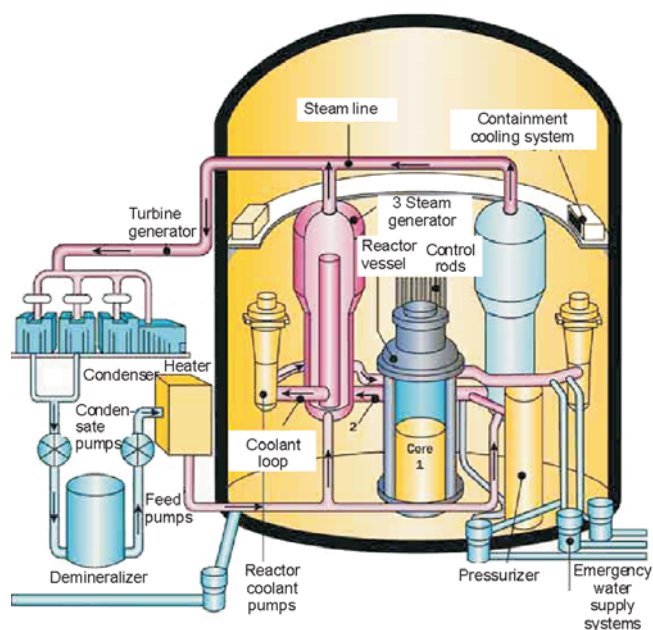
The appendix of the project report includes the material on the origin of uncertainty and the main methods of its evaluation. The report discusses emergency and transitional processes, taking place in light water vessel and channel-type reactors, introduces the prepared model of pressurized water reactor (PWR) core and reactor cooling circuit for thermal-hydraulic analysis, and presents an example of designed PWR accident analysis, applying best estimate methodology.

## Security of energy supply assessment

In 2009 a new state subsidy funded research project **Lithuanian Energy Security Research** was initiated. Its main objective is to estimate energy security level of Lithuania during various periods of time till 2025 and to compare energy security level to several other countries of the EU, applying energy security assessment methodology prepared by the researchers of the Laboratory in advance. In 2009 the indicator system for energy security level of Lithuania was created, the values of indicators were calculated, the weights of indicators, and their pre-critical and critical values were selected.

In 2009, the FP7 project **Security of Energy Considering its Uncertainty, Risk and Economic Implications (SECURE)** was continued; 15 partners from 11 countries of the EU and European economy zone take part in it. The aim of the project is to develop an energy security methodology, considering the issues of energy supply, assessing geopolitical changes, price formation, market development in and outside the EU, the threat of terrorism, etc. In 2009, a energy security level assessment methodology for nuclear energy sector was developed, and the scenarios of nuclear energy development were created. In the future, geopolitical, technical, economic, and national political influence of the EU on the secure of nuclear energy supply will be estimated. An additional means for evaluating the whole possible impact of nuclear energy security of supply will be developed and tested, regarding technical problems, any disturbances and political uncertainties. The sensitivity and uncertainty analysis for developing and testing models will also be performed. The project, coordinated by Observatoire Méditerranéen de l'Energie (France), is significant and timely in respect of EU energy security.

In 2009, works were performed following an agreement **Strength Analysis of Heat Supply Network Pipe via Kleboniškis Bridge** signed with SC Kauno energija. This project analysed the technical condition of Kaunas heat supply network pipe via Kleboniškis bridge after the accident. The finite element model was developed of this pipe and the strength analysis was carried out using software PepS v2.0 (a conservative strength analysis of the pipe) and BRIGADE/Plus (a detailed strength analysis of the pipe). PepS is a combined software, consisting of PIPESTRESS and EditPipe modules; it is applied for analysing pipes, used in chemical industry, thermal power plants and other objects. PepS is useful for analysing the changes in pipe configuration and stress condition at influence of internal and external load. However, it

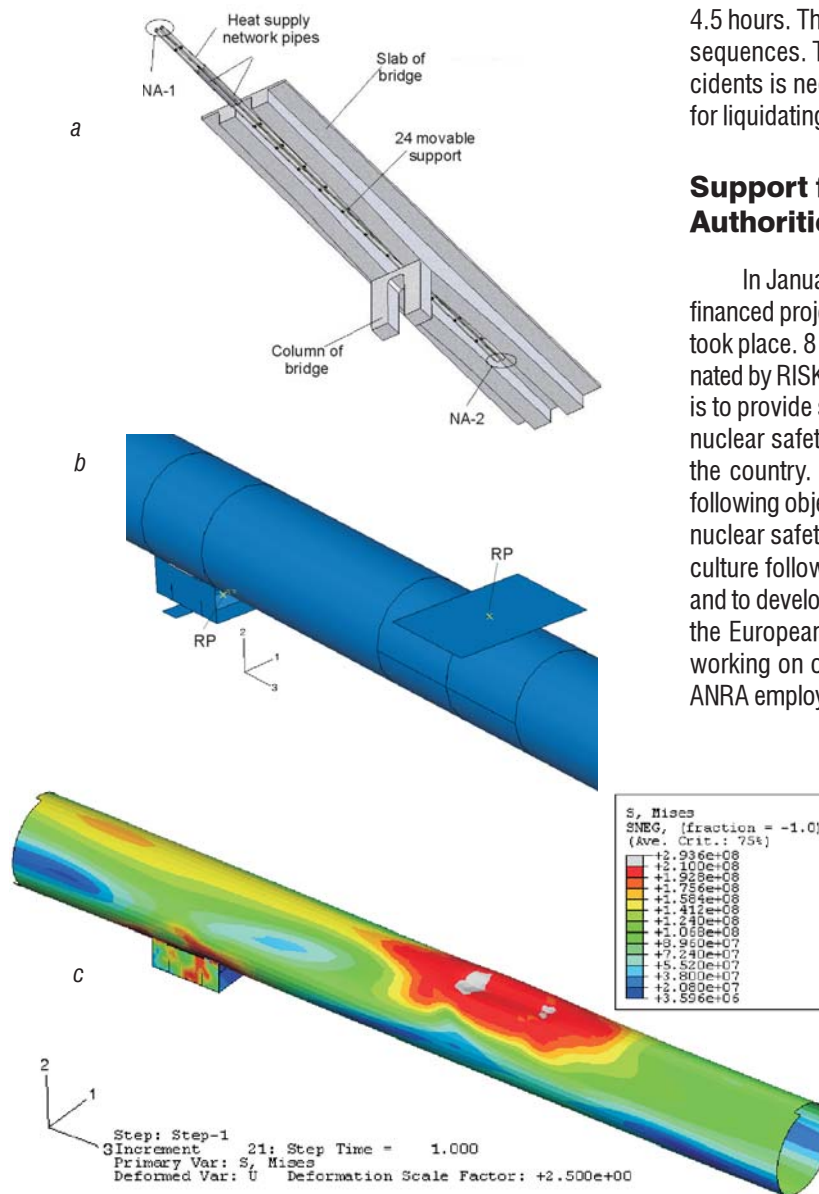


Scheme of typical pressurized-water reactor (PWR)



cannot be applied for evaluating the geometrical change of pipe cross-section due to the load effect and assessment of influence of supports geometry on the pipe. For this reason, finite element software BRIGADE/Plus was applied. Software Brigade/Plus is designed for linear and non-linear analysis at the influence of static and dynamic loads. The stress analysis of structures complicated geometry can be performed using this software. The strength analysis of heat supply network pipe via Kleboniškis bridge was performed at influence factual and imaginary consequences of the accident.

According strength analysis results of heat supply network pipe via Kleboniškis bridge and radiographic control results of welds it was recommended to change a part of pipe under the damaged bridge in case of the slab bridges has moved vertically downwards.



Analysis of heat supply network pipe via Kleboniškis bridge: a – principal model of heat supply network segment (view from below) from fixed support NA-1 to fixed support NA-2 with bridge segment; b – finite element model in the contact area of bridge and the pipe; c – Von Mises stress distribution in the contact area of bridge and the pipe

Under the contract with SC *Kauno energija*, **Thermohydraulic Analysis of Transients and Accident Processes in Kaunas Integrated Heat Supply Network** was carried out. It includes the analysis of pressure variation in Kaunas integrated heat supply network under the condition of sudden stopping of Jonava pump station water pumps. The analysis showed that due to the sudden stopping of Jonava pump station pumps, the pressure difference in supply and return pipelines is decreasing, which would worsen the heat supply conditions for consumers opposite to Jonava pump station. After the sudden stopping of Jonava pump station pumps, the pressure in supply and return pipelines fluctuate awhile; however, the fluctuations only very slightly exceed the limitations of pressure change that were present before launching Jonava pump station. This would not pose additional breakdowns in other areas of other Kaunas integrated heat network. The analysis also showed that if the water supply pipe under Kleboniškis bridge had cracked and no measures had been taken to stop the water leakage, about 5000 tones of water would have leaked out through the crack in 4.5 hours. Therefore, such accident would have undesirable consequences. This proves that timely deterministic research of accidents is necessary because its results enable planning means for liquidating consequences of various possible accidents.

## Support for foreign nuclear safety Authorities

In January 2009, the first meeting of European Commission financed project **Support for Armenian Nuclear Safety Authority** took place. 8 countries of the EU participate in this project coordinated by RISKAUDIT IRSN/GRS International. The aim of the project is to provide support for Armenian organization ANRA regulating nuclear safety in order to ensure nuclear and radiation safety in the country. The implementation of the project is aimed at the following objectives: to support and strengthen national Armenian nuclear safety regulatory system, to promote an effective safety culture following the principles of Convention on Nuclear Safety and to develop the regulating methodology and practice applied in the European countries. The researchers of the Laboratory are working on one of the tasks of this project: the development of ANRA employees training system. In 2009, a meeting of this working group took place in LEI, where the present ANRA employees training system was discussed, training methodologies used in Finland, Belgium and Lithuania were presented and recommendations for employee training given by IAEA were discussed. The project will be completed in 2010.

## Ignalina NPP safety assessment and improvement

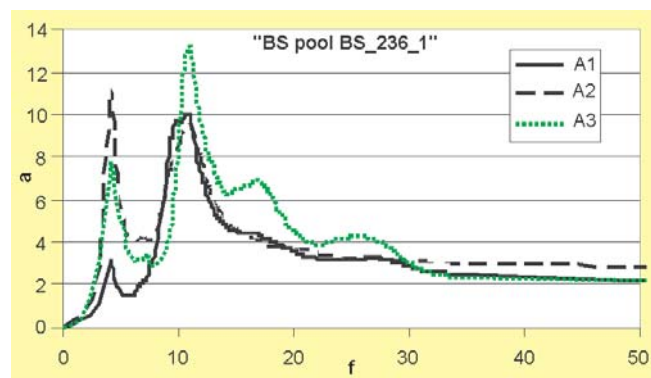
In 2009 cooperation with Ignalina NPP was successfully continued. As result of the project **Control System of Leaktightness of Fuel Cladding of Spent Fuel Assemblies in the "Hot Chamber" of Unit 1**, the control system of leaktightness of fuel cladding was implemented at the Ignalina NPP Unit 1.

Ignalina NPP spent nuclear fuel assemblies from reactor are loaded to spent fuel pools, where they are stored no less than 12 months. Afterwards fuel assemblies are directed towards the “hot chamber”, where they are divided into two parts (two bundles of fuel elements) and are loaded to transportation trays, where only leaktight bundles of fuel elements may be loaded. Therefore, leaktightness of nuclear fuel assemblies must be controlled during the whole process in “hot chamber”. As a result of the work carried out in 2009, the control system of leaktightness of fuel cladding was implemented in the 1<sup>st</sup> Unit of Ignalina NPP. The system enables to detect fuel assemblies with leaky fuel cladding in “hot chamber” of Ignalina NPP Unit 1 both at fuel assemblies reload from the tray and during dismantling of assemblies into two bundles of fuel elements. The installed system contributes in ensuring radiation safety while nuclear fuel is stored in spent fuel pools or during loading it into transportation casks and storing it in dry spent nuclear fuel storage.

In 2009, a project **Analysis of the Ignalina NPP Building 101/2 Unit 2 Reaction to Seismic Load** was completed. Implementing this project, the Institute of Geology and Geography and Vilnius Gediminas Technical University participated as subcontractors.

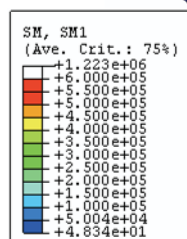
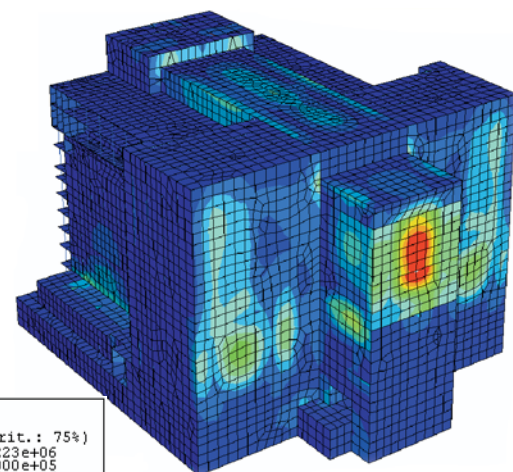
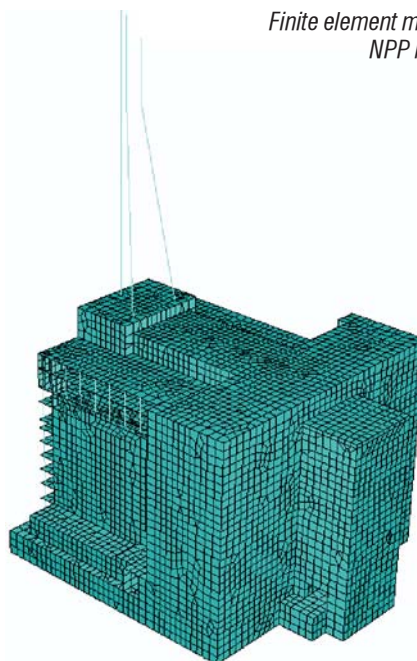
The seismic hazard assessment was carried out taking into account analysis results of seismic events and seismic-tectonic conditions in Ignalina NPP region. The models of the ground under the power plant, of soil-structure interaction and building were prepared. The seismic potential of Ignalina NPP site, based on probabilistic analysis results, is evaluated as high as  $PGA = 130 \text{ m/s}^2$  for probability  $10^{-4}$  for SL-2 ground motion hazard level. It is compatible to the Design Basis Earthquake  $M_{DBE} 5.0$ . The floor response spectra of Ignalina NPP Building 101/2 Unit 2 was performed using calculated ground response spectra at Ignalina NPP site. The influence of the soil-structure interaction was evaluated. The obtained floor response spectra of the bottom spent fuel pools are presented in the picture.

The strength analysis of building structures of 101/2 Unit 2 Ignalina NPP was performed in case of the seismic hazards for compartments important not only during the reactor operation, but also when it is stopped. Results of strength analysis show, that the structural integrity of the analysed compartments of the building 101/2 of Unit 2 is not violated and building is capable to sustain loads in case of possible earthquake in Lithuania.



Response spectra of fuel storage reservoir floor (in 20.00 m depth) during an earthquake measuring 5.0

Finite element model of Ignalina NPP reactor building

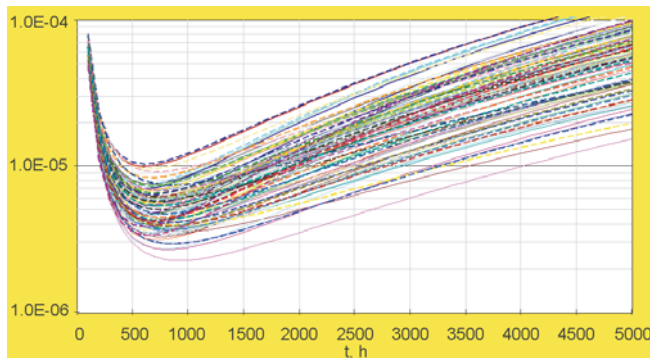


Distribution of bend moments in Ignalina NPP A2 Unit 101/2 building walls, during seismic loads

In the middle of 2009, a several year-long project **Probabilistic Safety Analysis of External Events and Events in Shutdown Reactor; Optimization of Testing Intervals for Safety Important Systems** was completed. According to the agreement, first of all, probabilistic analysis models were developed and statistical data research and events scenario analysis were carried out. At the same time, work of the other part of the agreement was implemented by supplementing of research methodology, development of analysis models, statistical data analysis and testing interval research. Calculations were carried out for the work mentioned, several interim reports were prepared and preparations for the work of 2009 were made. Implementing the final work related to *Optimization of testing intervals for safety important systems*, research methodology was extended, analysis models were renewed, and analysis of unavailability limits, testing interval optimisation and result uncertainty and sensitivity research were



performed. In addition, work on *Probabilistic safety analysis of external events and events in shutdown reactor* involved improving of probabilistic analysis models, renewing statistical data, performing emergency scenarios research and event-consequence analysis. All results were also summarised in the final report.



Possible system unavailability depending on initial data uncertainty and time interval  $t$  [h] between testing

According to the agreement with Ignalina NNP, a work **Flowmeter Repudiation due to Diagnostic Results in Energy Unit 2 in 2009** was performed. Flowmeters, determining flow size passing through, were installed in each technological channel of RBMK-1500 reactor. When the flowmeter fails, the operation of appropriate technological channel is interrupted until the next shutdown of the reactor, when the broken flowmeter is replaced with a new one. The diagnostics of flowmeter is being carried out before annual maintenance in order to avoid failures. The 2008-2009 analysis of diagnostic measures results was carried out and it was determined that 177 flowmeters had to be replaced in Ignalina NPP Unit 2 in order to guarantee a reliable operation of Unit 2 until the planned shutdown. During the analysis the most degraded flowmeters were selected. If they are replaced, the reliability of all flow measuring system will increase.

The projects **Justification of Changes, Included into Ignalina NPP Symptom Based Accident Instruction** and **Justification of Changes, Included into Ignalina NPP Accident Classification Instruction** were completed in 2009. This self-supporting work included substantiation the changes made in Ignalina NNP accident classification and symptom based accident instruction. The scope of research encompassed the operation of Ignalina RBMK-1500 reactor, during both cases: designed and beyond design basis accidents. The design basis accidents have been studied before designing the reactor (LEI has been carrying out such studies for 20 years), whereas the analysis of beyond design basis accidents in this type of reactors has been begun rather recently. Applying thermohydraulic analysis software packages RELAP5 and COCOSYS, special numerical models were developed for analyzing beyond design basis ac-

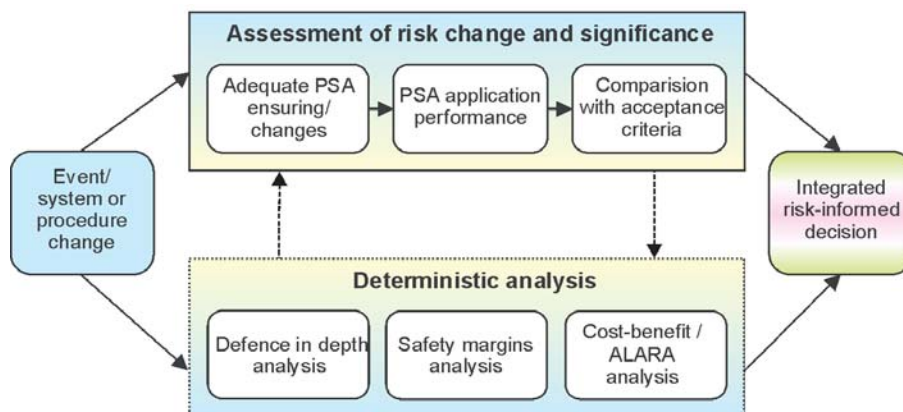
cidents. The mentioned models were used for carrying out the analysis of beyond design basis accidents and determining specific phenomena in RBMK channel-type reactors, their cooling circuits and the compartments, surrounding the circuit. The performed work enables Ignalina NNP operator and Technical Support Centre to control emergency situations quicker and safer as well as qualify their consequences.

According to the agreement **Application of Ignalina NPP Probabilistic Safety Analysis Model in VATESI Activity** between VATESI and LEI, the planned technical work was continued in 2009. Having obtained the software *RiskSpectrum RiskWatcher™* (hereinafter called as System of Unexpected Events Analysis - SUEA), probabilistic safety assessment (PSA) and analysis model was reviewed and relevant data feasibility assessment was carried out. Ignalina NPP PSA model usable by VATESI is adapted for unusual event analysis and application of RiskWatcher software which eases work with PSA model.

RiskWatcher software, taking into account estimates of risk, is used as a risk monitor for observing risk dynamics, modelling possible events' scenarios and planning system unavailability. This software operates on the basis of PSA model which consists of a set of fault trees and event trees, which express scenarios of analyzed events and their consequences. Considering the structure of PSA model, the data used and information given by VATESI, a research regarding the feasibility of data relevant for PSA model adaptation to develop SUEA was performed.

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

Moreover, as planned in the technical task, VATESI personnel training was organized, including the presentation of PSA theoretical fundamentals, implementation of PSA model application review and description of PSA and SUEA practical usage possibilities. While implementing the agreement, consultations together with technical support were provided and will also be provided in the future as indicated in the schedule. The final work of this project will be implemented in 2010.



Process of application of probabilistic safety assessment and analysis

Laboratory of Nuclear Installation Safety participated in the preparation of **Safety Analysis Report of Ignalina NPP Unit 2 Final Shutdown and Defueling Stage**. Since Ignalina NPP Unit 2 is going to be permanently shutdown and the fuel is going to be removed to spent fuel storages, the researchers of the Laboratory implemented the following work:

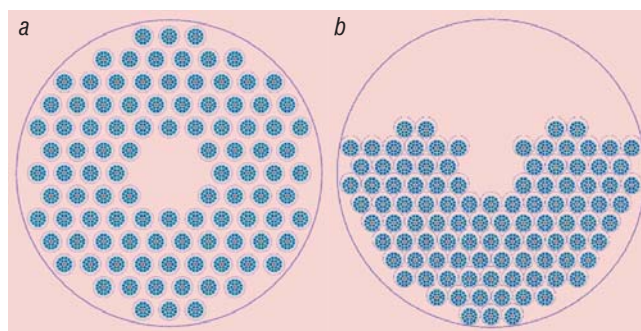
- Selection of initial events subject to accidents;
- Accident analysis, encompassing accidents in reactor when the fuel is still inside reactor core, and accidents in spent fuel pools when fuel assemblies are removed from the reactor core into spent fuel pools;
- Estimation of nuclear fuel characteristics;
- Systems, structures and components ageing assessment.

The results were obtained and compared to the acceptability criteria; the conclusions were made on their basis.

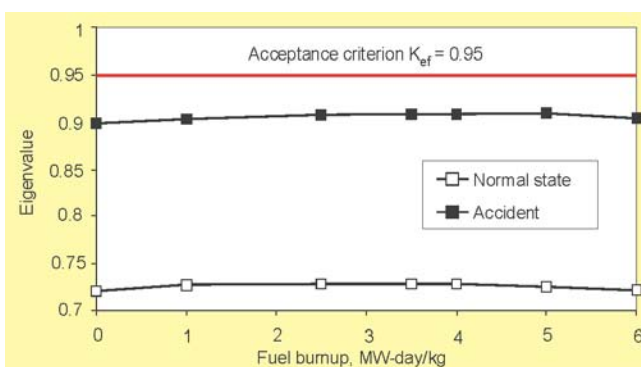
Accident analysis in permanently shutdown reactor has not been performed before. In order to conservatively evaluate consequences of possible accidents, this project overviews designed and beyond design accidents under a precondition of several safety systems failures at the same time. Aiming at a thorough analysis of possible accidents, not omitting any possible initial events, the researchers of the laboratory have analyzed the following various groups of possible accidents:

- Possible emission of radioactive materials due to accidents beyond reactor core (accidents in spent fuel storage pools: fall of fuel assemblies and casks, water leaking from spent fuel pools, water overflow of fresh fuel storage, etc.);
- Accidents causing reactivity increase in spent fuel pools due to loss of water, faults in handling the fuel, fall of casks with spent fuel, etc.
- Accidents causing mechanic fuel damages;
- Emission of radioactive materials due to a damage to reactor cavity or graphite cladding;
- Fuel overheating due to sudden reactivity increase;
- Fuel overheating due to the loss of coolant or its flow decrease;
- Technological processes causing failures due to a general cause (loss of electric power, ventilation failure, failure of heat supply to compartments, failures of coolers for heat removal, etc.);
- Internal events (fire, flooding of compartments, explosion, fall of heavy objects during transportation, loss of heat supply, formation of explosive gas in the course of reactor cooling circuit deactivation);
- External events (airplane crash, external fire, earthquake, strong winds, external overflow, sudden warming).

Considering the scenarios of all possible accidents, an appropriate level of present safety means was determined, the parameters showing the state of reactor and spent fuel pools were indicated as well as the relevant factors for implementing fuel transportation from reactor core to spent fuel pools. The following constituent parts of the report were prepared: Assessment of characteristics of spent fuel in the reactor, Control of systems, buildings and equipment ageing, Selection of initial events, Accident analysis, Conclusions and demonstration of acceptability.



Fuel selectors in 102-place transportation tank: a – normal state; b – emergency state (tank having fallen)



Analysis of reactivity increase in spent fuel pools due to the fall of cask with spent fuel assemblies

## Projects of decontamination and dismantling of Ignalina NPP equipment

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

**Development of the Ignalina NPP 117/1 Building Equipment Decontamination and Dismantling Project (B9-0)** was continued in 2009. It is the first project in Lithuania devoted for dismantling and decontamination of NPP equipment. Project is implemented by VT Group (United Kingdom), Nukem Technologies GmbH (Germany) and LEI consortium. The main objective of the project is to prepare an optimal dismantling and decontamination strategy for emergency cooling system of RBMK-1500 reactor and other equipment, which is located in building 117 / 1 of Ignalina NPP, as well as to develop the design and safety justification documentation necessary for implementing the project, and to provide support for the Client during the licensing (i.e. coordinating the prepared project documentation with Lithuanian Authorities) and during implementation of the project. In the frame of this project, personnel of the laboratory are involved in development of the strategy, basic and detailed design, and safety justification report. LEI is responsible for providing support during project licensing and implementation stages. Basic design and Safety justification report were completed and agreed with the Client in 2009, whereas in the beginning of 2010, these documents are going to be approved by Lithuanian Authorities. The principal activity of 2009 was directed to preparing the Detailed Design Docu-





During the implementation of the project, full documentation for reactor emergency cooling system cylinders and other Ignalina NPP 117 / 1 building equipment dismantling and decontamination was prepared

mentation of dismantling and decontamination of Ignalina NPP equipment. It includes all procedures and drawings that will be applied for performing the mentioned work. In 2009 all relevant Detailed Design Documentation was prepared and major part of it agreed with the Client. The remaining unapproved part of Detailed Design Procedures is going to be finalized in 2010 taking into account comments and recommendations of the Client.

**Development of the Ignalina NPP AE V1 Building Equipment Decontamination and Dismantling Project (B9-2)** was also begun in 2009. This project is under implementation by VT Group (United Kingdom), Nukem Technologies GmbH (Germany), Ansaldo (Italy) and LEI 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. In Ignalina NPP V1 building is located a number of systems to be dismantled and decontaminated – i.e. reactor gas circuit, exhaust gas cleaning system, system of reactor repair cooling tanks, ventilation system and emergency cooling system of reactor. In 2009, the Strategy of Ignalina NPP V1 building equip-

ment dismantling and decontamination was developed and submitted to the Client for approval. The researchers of the Laboratory also participated in preparation of Basic design and Safety justification report documentation which will be finalised in 2010.

The Laboratory is going to take part in other projects for Ignalina NPP equipment dismantling and decontamination that are relevant for new NPP construction because they are to be implemented in the same site where the building of new NPP and various radioactivity level storages are planned. For this reason, an analysis of the new and shutdown NPP interrelation, its impact on safety and the safety justification of new and shutdown NPP complex is important during the construction of new NPP, dismantling the present NPP, disposing radioactive waste and during operation the new NPP.

## Researchers' qualification and publication of scientific results

In 2009, there were 10 doctoral students in Laboratory of Nuclear Installation Safety and one doctoral thesis **Experimental Fission Reaction Studies: from Fission Product Yields and their Release Properties to Delayed Neutron Emission** (G. Stankūnas) was defended in the field of nuclear physics. Research results were presented in science research reports and 40 scientific articles (among them, 3 articles in ISI indexed journals), 33 papers were presented at scientific conferences. Laboratory researchers participated in the events related to thermonuclear field and presented papers in all main international conferences, where safe operation of nuclear power plants and physical phenomena occurring in them were analysed. Researchers actively participated in different international and national training courses, IAEA seminars, committee and coordinating meetings, activity of FUSION development committees and other organizations and scientific institutions.



The defence of G. Stankūnas' doctoral thesis on 22 December 2009

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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;
- Generalization of energy restructuring and liberalization experience in the European Union and Central and East European countries and its application implementing reforms in the Lithuanian energy sector;
- Development of energy information system, collection of statistical data on the energy sector development in Lithuania and worldwide.

In the completed state subsidy funded research project ***Application of Best-estimate Methodology for Process Modelling of Technical, Natural and Social Systems***, implemented together with partners from the Laboratory of Nuclear Installation Safety and the Laboratory of Hydrology, problems of the energy sector development were analysed. In this project, up-to-date modelling experience of forecasting electricity demand and power sector development were summarised as follows:

- The forecast of electricity demand till 2009 was prepared by specifying the earlier forecasts; possible change limits of the parameters, which have the greatest impact on the result of analysis (GDP increase rate, income elasticity, price increase and the effect of elasticity and saving) were reassessed;
- The impacts of sudden leap in prices in 2009 and the economic recession in 2009-2010 on the decrease of electricity demand was determined; the analysis of electricity demand prediction sensitivity was performed applying the SUSA software package;
- A mathematical model for the analysis of the perspective development of energy systems was created; it encompasses Estonian, Latvian, Lithuanian and Polish power systems and connections with Russian, Scandinavian and UCTE systems;
- The degree of uncertainty of external factors of energy system was identified as well as the dependences of external factors impact on modelling results; these dependences are considered appropriate to assess when correcting the comprehensive mathematical model of power system.

A state subsidy funded research project ***Lithuanian Energy Security Research*** was initiated. In the prepared interim report, the researchers of the Laboratory have made a strong contribution in preparing a common method of energy security assessment, forming its principles, composing mathematical models and modelling the probable threats for the Lithuanian energy sector.

Another state subsidy funded research project ***Development of Multiobjective Decision Making Methods and their Applica-***

***tion in Energy and Environmental Policy*** was initiated. In the first stage of this project, multiobjective decision-making support methods were analysed and systemized, their possibilities of application in the Lithuanian energy policy were determined. The project includes the analysis of energy and environmental policy priorities and the presentation of conceptual decision-making support model for the energy sector; the model is based on the rating of electricity generation technologies, plans of the energy sector development and the means of energy and environmental policy, primarily aiming at sustainable development of the energy sector.

## Scientific research work for the national economy

The researchers of the Laboratory have started a successful cooperation with the newly founded **Ministry of Energy of the Republic of Lithuania**. The Laboratory researchers, together with the Laboratory of Regional Energy Development, have won a competition and implemented the first stage of the scientific work ***Municipal Renewable Energy Sources (Biofuel, Hydroenergy, Solar Power, Geothermal Energy) and Public Waste Use for Energy Production***. In this study, the researchers prepared a conception for grounding the deployment of renewable energy sources use. A wider application of renewable energy sources should be fundamentally based on the consistent analysis of all possible energy flows, starting with realistically possible sources and finishing with the use of different energy types, obtained from those sources, for satisfying society needs. Moreover, all local and imported (or possible for import) non-renewable energy sources, used for energy and non-energy needs, and their environmental impact should be complexly analysed. The whole of fuel and energy sources must satisfy the consumers' needs at the lowest possible costs, considering the obligations of Lithuania to the European Union and the determined strategic aims. The use scope and economic expedience of renewable energy sources, including the share of public waste, are closely related to the use possibilities of other alternative renewable and non-renewable energy sources and technological efficiency. Only a detailed and diverse analysis of all possible energy sources, starting with their pro-

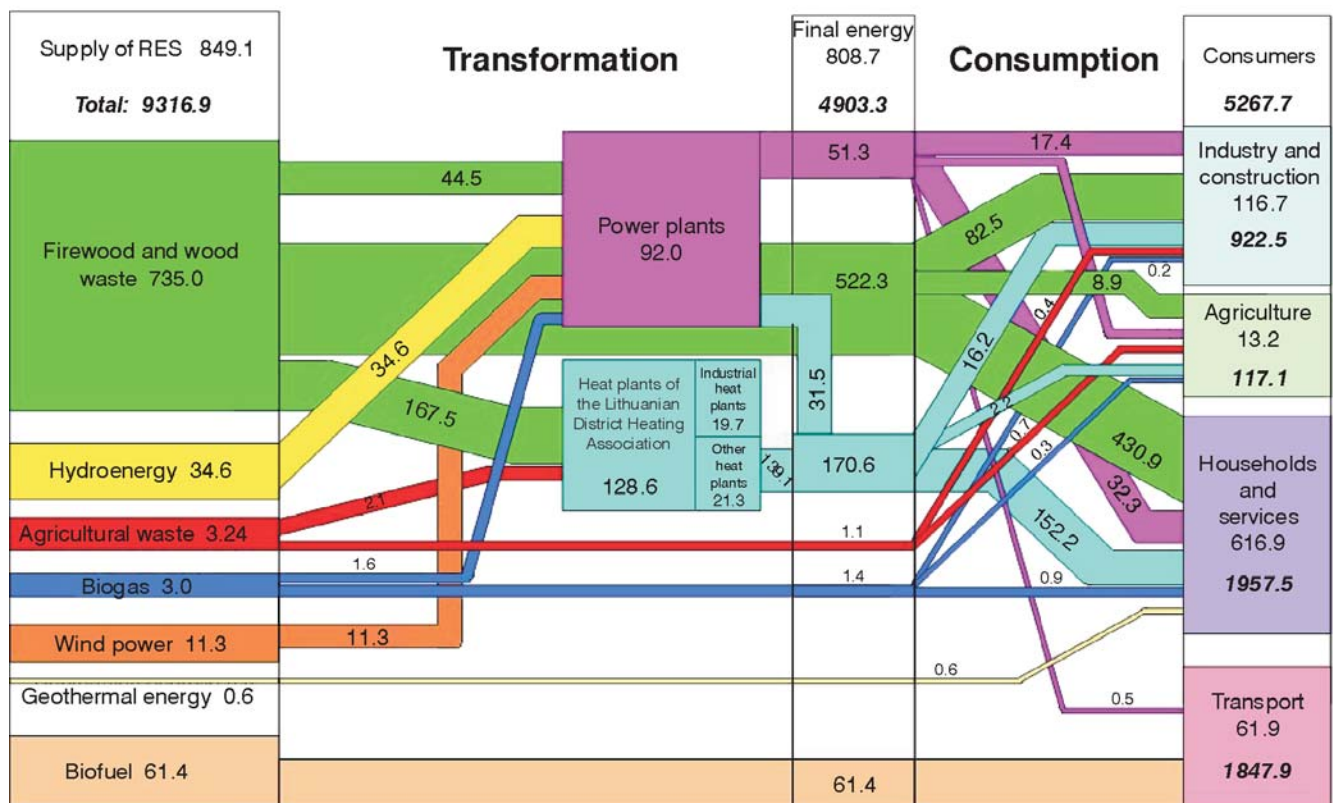


duction or import, natural resources processing and transformation into energy types suitable for consumers and finishing with their transportation to consumers and use in their equipment, enables determining efficient technologies, scope of every energy source use in Lithuania and separate municipalities, based on economic, environmental, social, political and other aspects. For solving this task, an optimisation model was developed by composing an oriented network graph and applying mathematical MESSAGE software. The branches of this graph represent possible technologies of renewable energy sources extraction, transformation, transportation, distribution as well as electricity and heat production, whereas its nodes represent different renewable energy sources or energy types produced. In this stage, a large amount of information, relevant for such a comprehensive analysis, was collected. The researchers of the Laboratory have collected and summarised data on the stock of lands, expenses for growing and harvesting farm plants, biogas and biofuel production technologies and their technical-economic indicators, tendencies of energy consumption and energy production in Lithuania, using renewable energy sources technologies in district heating systems and decentralised heating supply sector. The researchers have also prepared the forecast of the final energy demand and distribution of energy consumption in the economic sectors according to the municipalities for the year 2008, and carried out a review of renewable energy sources support means, applied in Lithuania and the EU countries.

The researchers of the Laboratory had to perform a significant analysis, which involved validation of the planned new nuclear power plant unit capacity. Under the order of LEO LT and in cooperation with the specialists from Laboratory of Systems Control

and Automation and Kaunas University of Technology, a scientific research **Possibility Study of Maximum Unitary Capacity in Lithuanian Electric Energy System** was implemented. This research presents the analysis of interrelation in the GDP changes and tendencies of electricity consumption in the Baltic States and Poland, and forecast of the final electricity demand, including needs of the energy sector, maximum load in the Baltic countries. Aiming at optimal operation of new nuclear power plant and the whole power system of the Baltic countries, the development of the common Baltic power system was optimised on the criterion of the minimum costs for development and exploitation, searching for solutions in the possible developmental alternatives. The analysis was performed applying a mathematical model, prepared using MESSAGE software; all advantages of this model were preserved and its additional modification enabled to mathematically describe and solve the problem of reserve capacity distribution in different power plants. The study includes a presentation of optimal long-term structure of electricity generation in the Estonian, Latvian and Lithuanian power systems, capacities, its operational regimes, reserve (primary, secondary and tertiary) capacities, scope of electricity import-export till 2045, based on assessing the future connections with UCTE, Nordel and existing connections with IPS/UPS electric energy systems. Following the analysis of various future development scenarios of the Baltic States (more than 90 variants were analysed), a comprehensive strategy of storing reserve capacities and their distribution in the system was carried out. The study also recommends the interrelation principles of power systems of the Baltic countries, estimating possible relations with UCTE, IPS/UPS, Nordel systems, which would aid in ensuring necessary reserve, reliable and stable operation of power system.

**Diagram of Renewable Energy Resources Flows in 2008, thous. toe**



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

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

## Participation in the international programmes

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

In 2009, a relevant EU FP7 project **Energy Technological Foresight and Scenario Development (PLANETS)** was continued (in this stage of the project, methodology for energy technologies sustainability assessment was developed; it is adjusted for assessing sustainability of electricity generation technologies and transport technologies).

Relevant questions regarding the Lithuanian energy sector development, including aspects of wider use of renewable energy sources, were analysed in international projects of the *Intelligent Energy Europe* programme. In 2009, three following projects were completed: **European Tracking System for Electricity (E-TRACK-II)**, **Sustainable Energy in New Building-market Introduction of Feasibility Studies (SENTRO)** and **Investments in RES Heating Systems through Direct Tax Measures (REFUND+)**. Projects which were continued are the following **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-SHAPING)**.

The project **Greenhouse Gas Reduction** coordinated by the IAEA was completed and its results were presented in an international conference in Buenos Aires. The project **Comparative Analysis of the Storage of Nuclear Waste and Carbon Dioxide (CO<sub>2</sub>)** coordinated by the IAEA was continued (in 2009, 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).

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

- Specialists to model scenarios of the energy sector development (Dr. A. Galinis participated in IAEA training courses in Zagreb as an expert delegated by this Agency, responsible for application of MESSAGE model to solve tasks of long-term energy planning);
- Specialists to model scenarios of the energy sector development in Ghana (Dr. D. Tarvydas participated in one IAEA project on the Ghana energy sector development strategy and was responsible for application of MESSAGE model to develop concrete objects);
- Centralized assessment of greenhouse gas inventories in New Zealand, Sweden, Romania and the EU-27 countries (Dr. I. Konstantinavičiūtė);
- Examination of national reports on greenhouse gas in Belarus, Ukraine and Russia (Dr. A. Mikalauskienė).



Dr. D. Tarvydas and  
Dr. A. Mikalauskienė in  
the library

The year 2009 was significant in improving the qualification of Laboratory researchers: two PhD theses of social sciences were defended in the Council of Economics Sciences. A. Mikalauskienė defended her thesis **Assessment of Market Simulating Means of Climate Change Reduction in Lithuanian Energy Sector**, and D. Tarvydas: **Economic Assessment of Means for Economic Safety Increase**. PhD Candidates V. Bobinaitė and V. Lekavičius participated in the IAEA training courses in Argonne National Laboratory (USA).

On 22 September 2009, the Laboratory organized a seminar **Policy development for improving RES-H/C penetration in European Member States (RES-H Policy)** in Lithuanian Energy Institute. 25 specialists from different Lithuanian energy companies and organizations attended this seminar. It was organized according to the project **Policy Development for Improving RES-H/C Penetration in European Member States (RES-H Policy)** of the *Intelligent Energy Europe* programme.

In 2009, researchers of the Laboratory participated in the conferences in Argentina, Austria, Brazil, the Czech Republic, Italy, Poland, Germany and other countries, where 17 papers were presented. Researchers of the Laboratory published 20 scientific articles in Lithuanian and international journals and proceedings of international conferences (3 articles in ISI indexed journals).

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# Laboratory of Regional Energy Development

## Main research areas of the Laboratory:

- Analysis and modelling of energy sector development of municipalities, which enable to forecast in short and medium periods;
- Analysis of activity indicators of heat sector companies, taking into account economical and social factors and impact of regulation measures;
- Integration of local and renewable energy sources into regional energy development programmes;
- Development of data basis for energy sector development of municipalities and macroeconomic analysis of issues at regional level.
- IR thermography diagnostics of buildings, economy of electrical power and technological processes, and certification of building energy efficiency.

## Research of regional energy issues

The state funded scientific research project **Planning Principles and Implementation Possibilities of Sustainable Energy Development** was continued in 2009. It investigates the principles and implementation experience of sustainable regional energy development issues of Lithuanian regions and urban energy sector and planning state.

Regional sustainable energy development is one of European energy policy elements, related to implementation of sustainable society development concept, which will enable to achieve target objectives – security and reliability of energy supply, affordability for all social groups and meeting the obligations in the field of climate change prevention.

Previous measures cannot ensure the implementation of these objectives. Energy dependence of countries on imported sources is further increasing, structure of energy sources changes slowly, and there is danger that obligations will not be met in the field of climate change prevention.

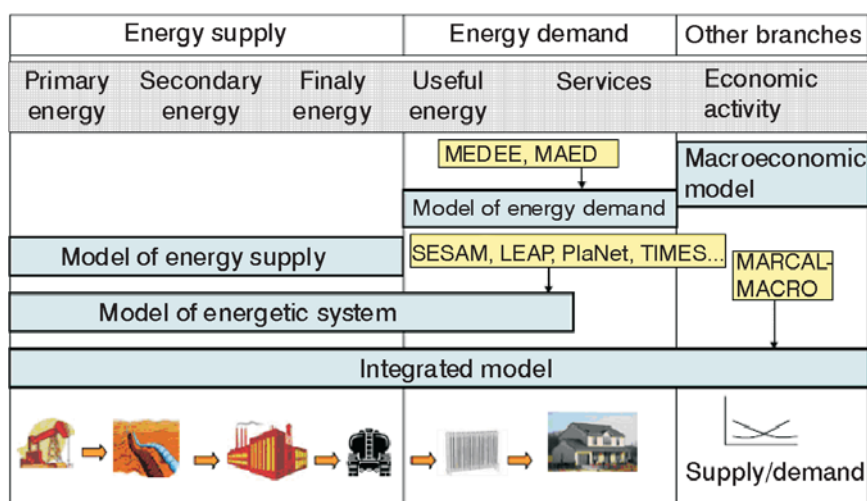
From social point of view development trends of Lithuanian regions (districts) have been negative. Regional differences increased despite declared activities for equal development. Data of recent years indicate a certain shift in trends: economical and social differences among the regions do not increase.

Since the dependence of EU countries on imported energy sources rises, the safety and reliability of energy supply may be enhanced by the reshaping of energy supply infrastructure and integration of local and renewable energy sources into energy supply systems. For this reason energy policy has been recently reoriented to increasing energy efficiency, promotion of the use of renewable energy sources and reduction of impact on climate change. New objectives for regional energy development are currently being planned. Due to energy market de-monopolisation, this process encompasses more and more local companies that offer services in the fields of energy supply, more efficient energy use, energy equipment maintenance and energy resources; these companies have different interests and goals, therefore importance of general planning approach increases.

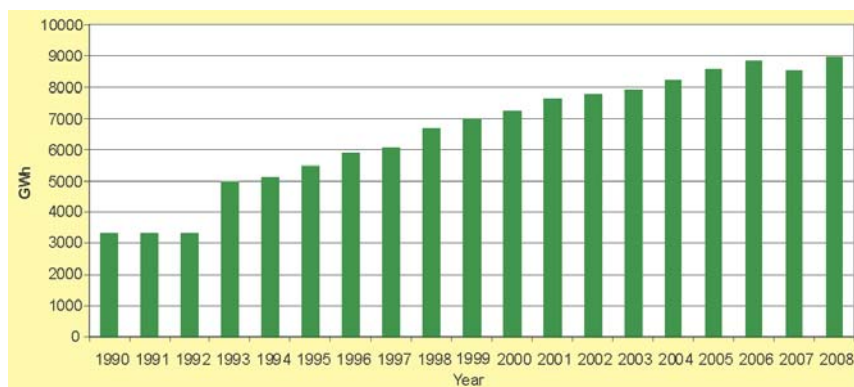
In 2009 a scientific research project **Use of Renewable Energy Sources (Biofuel, Hydroenergy, Solar Power, Geothermal Energy) and Municipal Waste in Municipalities for Energy Production** was completed in cooperation with Laboratory of Energy Systems Research under the agreement with Ministry of Energy. Two main objectives were aimed at in this research. The first aim was to assess biofuel potential in the country, to analyse the possibilities of biofuel production and use, and to provide recommendations for the purposeful development of biofuel use, whereas

the second objective was to prepare a study of scientific engineering practice. Its guidelines would enable the implementation of sustainable short and long-term regional development of renewable energy sources and municipal waste for energy use in Lithuania: under the basis of National Energy Strategy, National Energy Efficiency Programme and Cogeneration Development Plan. Safety improvement of state energy sector and reduction of pollution were highlighted when formulating the objectives.

Researches of the Laboratory prepared data on production technologies and potential of firewood and wood cutting waste, production technologies as well as technical and economic indicators of wood pellets and briquettes, transportation expenses, fuel input, survey of agricultural crops and their



Classification of energetic models



Production of wood and other types of renewable solid fuel in 1990-2008

use for energy production. An agricultural, industrial and municipal waste were also considered. Additionally, the researches carried out the assessment of existing legislative basis for energy development in municipalities.

## International projects



**REDUBAR project (Investigations Targeted to the Reduction of Administrative Barriers for the Use of Gaseous**

**Fuels Produced Decentralised from Renewable Energy Sources)** in the framework of *Intelligent Energy Europe* and supported by European Commission was completed in 2009. Initiator and coordinator of the project – Gas-und Umwelttechnik GmbH (DBI), one of the largest German gas institutes.

At present biogas in Western Europe is usually used at their production site for electricity generation, whereas heat obtained during the process is not used. This project was initiated aiming at higher energy efficiency using biogas.

The objective of the project was to analyse and submit recommendations eliminating administrative and technological barriers and developing legal measures to use biogas for heating, cooling and electricity generation.

While implementing the project, the EU “good practice” of biomethane injection into natural gas networks of the countries, which participated in the project, was overviewed and analysed. Standards of natural gas are applied in many EU countries, and the standards of biomethane are currently employed in Germany, the Netherlands, Sweden, etc. Additionally, legislative basis which regulates third party’s connection to the natural gas networks, transporting natural and other combustible gases, including biomethane, was overviewed.

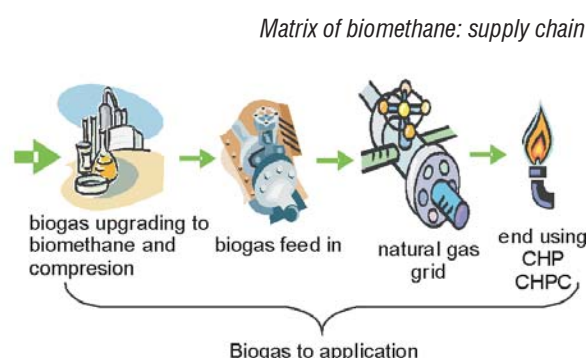
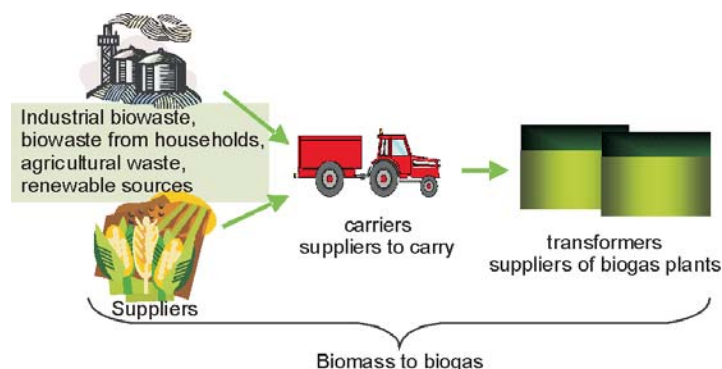
During the course of the project, a precedent estimation, comparing energy production costs during energy generation from natural gas and biomethane, was presented; a theoretical model of cost-benefit analysis for biomethane plant was introduced (however, the programme was presented only in German). Moreover, a theoretical biomethane production-end use chain analysis was performed which assesses the development of biomethane market in partner countries of the project. This chain shows the processes after eliminating the obstacles or reducing their impact on biogas market.

In cooperation with the researches from Laboratory of Heat-equipment Research and Testing and Energy Efficiency Research and Information Centre, the researcher of the Laboratory is implementing a partially EU financed project **Bioenergy Promotion of Baltic Sea Region**. The aim of the project is promotion of stable, competitive and theoretically integrated development of bioenergy in the Baltic Sea region.



REDUBAR project partners’ meeting in Prague

A project Ecoheat4EU was initiated by Euroheat&Power together with Lithuanian District Heating Association in summer 2009 following the EU support programme Intelligent Energy-Europe. Duration of the project is 25 months and it aims at eliminat-





ing the obstacles and determining necessity for support as well as promoting the development of district heating and cooling supply sector in EU countries. The main results planned for this project are the following:

1) A set of measures for national decision makers and the participants of District Heating Supply Market: recommendations and road map for creating an effective DHC development which would promote legal environment and strategies;

2) Information for EU politicians about present and future initiatives of European scale in the fields of district heating and cooling supply;

3) Practical tool for monitoring the impact of DHC development and national heating supply markets, which would enable determining the effectiveness of support measures: "DHC Barometer";

4) Wide cooperation and targeted dissemination of the results on the project website, which operates as a comprehensive database: distribution of project reports and newsletters, arrangement of conferences and seminars, announcing articles on the websites of partners of the project.

The Laboratory of Regional Energy Development has implemented commissioned research and analyses under the agreements with Lithuanian companies and organizations, such as *Radviliškio šilumos tinklai*, *Lietuvos šilumos tiekėjų asociacija* and *JSC Kauno termofikacinė elektrinė*. This work considered many problems: from technical analysis of investment projects, formation of heating supply vision to analysis of legal regulation issues of energy supply.

## Services

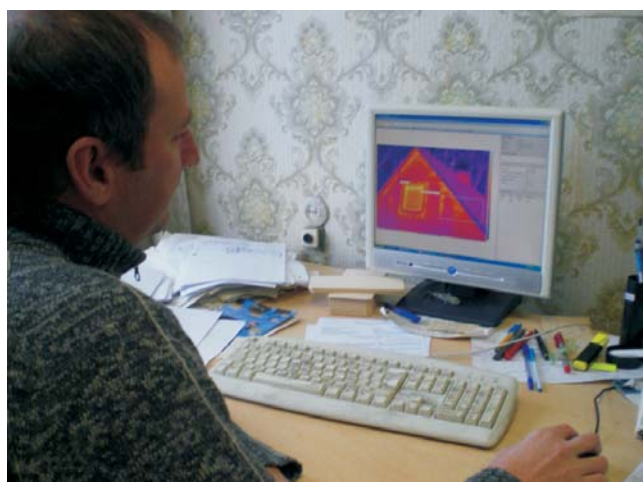
Thermo-visual research is carried out using IR thermography camera *Flir B400* that has a temperature measuring range from  $-20^{\circ}\text{C}$  to  $+350^{\circ}\text{C}$ . This research is applied for investigating and maintaining dwelling houses and industrial buildings, incl. roofs, piping, economy of electrical power, chimneys and mechanical facilities. It is also used for determining the problems of leaking and filling level in the tanks/containers, observing and controlling the quality of the processes.

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

A PhD Candidate J. Bubelienė has completed the studies, prepared and presented a doctoral thesis ***Grounding Promotion Means of Renewable Energy Sources Use in Lithuania***. This dissertation was certified.

The rank of doctoral students was joined by M. Stankevičius who is preparing a doctoral thesis ***Technology for Economic Policy Model Formation on Sustainable Regional Energy Development Promoting the Use of Renewable Energy Sources***.

In 2009 researchers of the laboratory published 1 article in the journal *Renewable and Sustainable Energy Reviews* and 1 in the journal *Energetika*. Researchers of the laboratory presented 6 papers at Lithuanian and 2 at international conferences; the papers were published in conference material. 4 doctoral students are preparing theses in the Laboratory. Researchers of the laboratory perform scientific research, advisory activities and provide services in accordance with agreements with Lithuanian public institutions, companies and organizations.



Thermovisual research

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# Laboratory of Renewable Energy

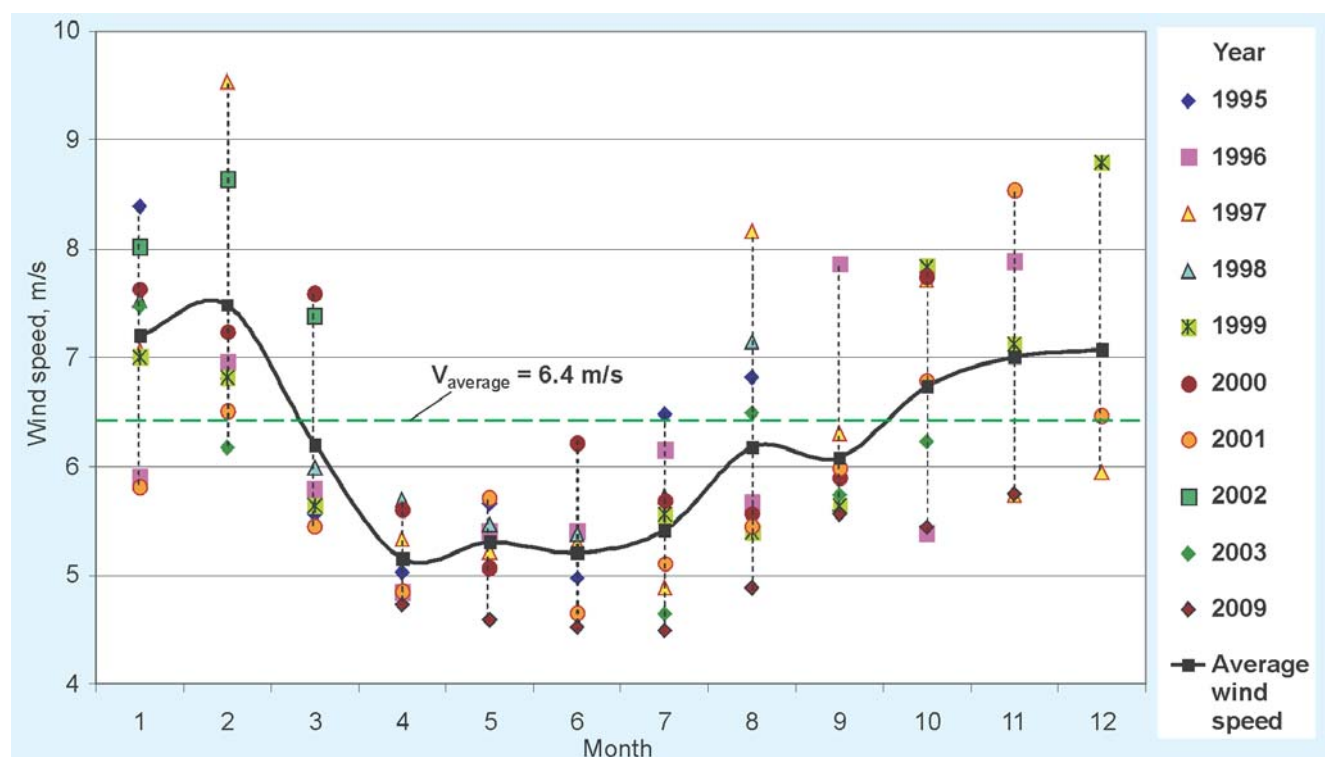
## Main research areas of the Laboratory:

- Analysis of the use of renewable energy sources (RES) for energy production and assessment of utilization development in implementing the decisions of the European Parliament and the Council directives;
- Research, modelling and prediction of wind flow variation in the Baltic coast and other regions of Lithuania;
- Research of efficiency and environmental problems of biogas and biofuel production and usage;
- Research of solid biomass usage efficiency for energy production;
- 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.

The research carried out in the Laboratory is related to the development of renewable energy sources (RES) use for energy production in the state. The directive 2009/28/EC of the European Union provides for noticeable enlargement of RES use in Lithuania until 2020, i.e. RES energy production should constitute 23% of total primary energy consumption, 20% of which should be used for biofuel and constitute 20% of total amount of oil products used for transport. The production of electric power should constitute 10% of its total amount consumed in the state. For that reason, new technologies and perspectives of their application in Lithuania are analysed, data on RES consumption is collected and milestones are foreseen for further RES penetration into state's energy market aiming at optimally ensuring the implementation of the requirements of the European Parliament and of the Council directives and Strategic Energy Technology Plan (SET Plan). New tasks

arise while seeking these goals; therefore, the analysis of various scenarios is relevant in the search of optimal solutions to these tasks.

In 2009 a state subsidy funded research project *The Research of Wind Energy Prediction and the Developmental Possibilities of Biomass Resources Use in Energetics* was initiated. Following the newest statistical data, the study provides a variation analysis of wind, biomass fuel and alternative fuel resources use for energy production and the forethought of the directions of developmental possibilities. Additionally, the research of wind power plant capacity exploitation characteristics and the analysis of the methods of wind energy prediction are presented in the study. The perspective of solid biomass, biofuel and biogas use was assessed and the technical-economic conditions for biofuel production in Lithuania were analysed.



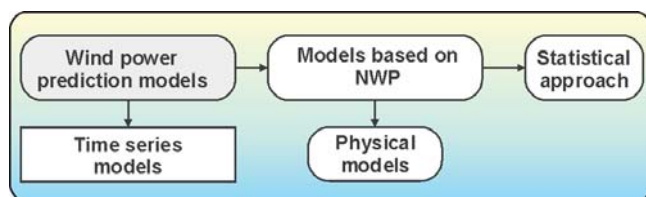
Monthly dynamics of average wind speed in the coast of Lithuania (height 50 m). The measurements were carried out using WICOM-C equipment



## Research of energetic wind parameters and analysis of wind power short-term prediction methods

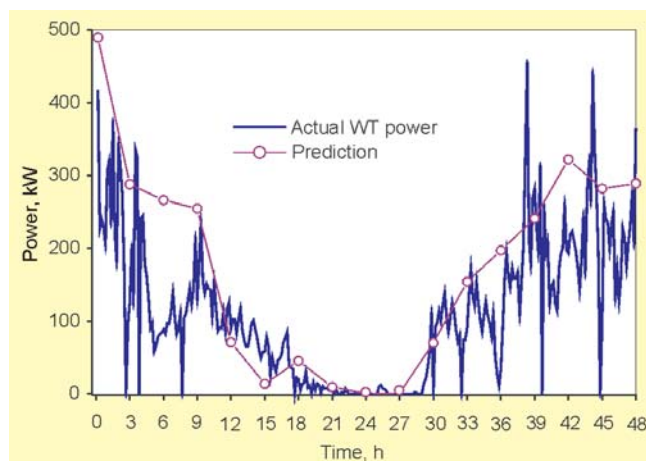
Wind speed and direction measurement data was collected, analysed and summarised in the research. A variation study of consistent patterns of wind speed and turbulence was carried out in the coastal region, using modern measuring equipment of energetic wind parameters *WICOM-C*. The consistent patterns of wind flow change were examined applying *WASP* software and the measurements of wind speed parameters. The analysis of wind power plant capacity prediction methods was presented and their advantages and disadvantages were examined. The distribution of wind speed was described using the Weibull distribution function. A variation analysis of consistent patterns of wind power plant capacity factor was carried out in the power plants of coastal and other regions of Lithuania. Since a strong correlation link between wind flows was discovered in the coast, the research performed in one area of the region can be applied to make rather accurate predictions for wind power plant indicators in other coastal regions.

The peculiarities of wind forecast methods and informational systems of wind power prediction applied in other countries were analysed. Wind power prediction models are divided into two types: *time series models* and the models that employ the data of *numerical weather prediction (NWP)*.



Types of wind power prediction models

Time series model uses real-time measurement data of wind speed or wind power that are analysed using the methods of time series analysis to compose a wind power prediction for several hours ahead. The models based on NWP data recalculation for wind farms are used to compose a longer-term prediction (usually up to 48 h).

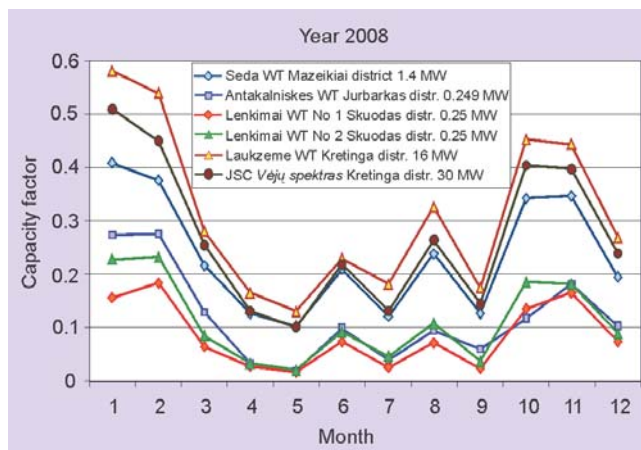


An example of wind power plant capacity prediction for 48 h

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

The research was carried out in association with Danish Risoe DTU science centre.

Monthly capacity factors of separate wind turbines and wind farms, operating in the coastal and continental part of Lithuania, were calculated and compared in this study.



Variation of wind power plants, built in various regions of Lithuania, capacity factor in 2008. WT is wind turbine; WF is wind farm

It was determined that the average capacity factor of coastal wind power plants was 0.27-0.33 in 2008, i.e. wind power plants used 27-33% of their nominal capacity. Therefore, the capacity factor shows that wind power plants explored were operating at their nominal capacity for 2365-2890 hours in 2008. The values of capacity factor of Lithuanian wind power plants are similar to German and Danish wind power plants.

## Economical and environmental efficiency research of solid biomass, biogas and biofuel production and use

### Solid biomass

The variation of different types of solid biomass fuel consumption and production scope is analysed in the Laboratory. It was determined that wood fuel consumption has increased more than twice, that is, from 284.9 ktoe to 735 ktoe, which corresponds to 2.6% and 7.9% of primary energy consumption of the state. In 2008, more than 360 of biofuel boilers were operating in Lithuania. Their total capacity installed reached about 610 MW.

Forest cutting waste still remains the least used source of wood fuel. 2.5 million m<sup>3</sup> of cutting waste emerges annually, while in practice no more than 1 million m<sup>3</sup> can be used for biofuel. It is necessary to expand forest territories and their productivity in order to enlarge biomass resources. The most attention should be granted to the quick-growing grey alders as their potential for biofuel production is underused (the territory is nearly 130 thousand ha).

The growth conditions for grey alders are close to optimum in Lithuania as they grow rapidly, early mature, often and richly

crop and also sprout well. The amount of biofuel production would rise and the energy would be produced more efficiently if the problems of biofuel collection, storage and transportation were solved. For this reason, reconstruction of boiler rooms into composite cycle type, modernization of gaskets in the private sector (pellets/straw for pellets use) and adjustment of coal stoked power plants to biomass and coal mixture burning is also necessary.

### Biogas

The beginning of biogas energetics in Lithuania is related to the use of biotechnologies in metantanks to process animal husbandry waste or city sewage sludge. The technologies of biogas production from liquid organic waste are perceived as an alternative solution to many problems. *Environmental, energetic, social and agricultural problems* could be dealt with by using anaerobic technologies of organic waste processing. The environmental effect purports the fact that organic materials are effectively (up to 40–60%) decomposed in bioreactor under anaerobic conditions. This reduces the negative effect on the environment of processed sewage. Having removed CO<sub>2</sub> and other extraneous admixtures, biogas has recently been supplied to the natural gas networks or used for transport. Presently 7 biogas power plants operate in Lithuania. Biogas as fuel is used in boiler rooms or stationary cogeneration power plants to produce thermal and electric energy. In the Laboratory, environmental problems are solved and biogas production processes are analysed assessing assumptions for expansion of production.

### Biofuel

A survey of biofuel production and consumption development in Lithuania and the EU countries was carried out. The prospect of using biofuel was assessed and technical-economic conditions for biofuel production development in the country were analysed. The analysis of legislation and scope of biogas production shows that it is purposeful to promote the use of this type of fuel by economic and organizational means in the transport sector pursuant to the commitment of Lithuania in the area of the EU biofuel use (to use 5.75% of total fuel consumed for transport till 2010, and 20% till 2020).

The analysis of technological processes of biofuel and resources of raw materials indicates that oil pressed out of rapeseeds

grown in Lithuania and synthetic methyl ether are the main raw materials for biodiesel production in the country. It was determined that bioethanol may be substituted for synthetic methanol used for biofuel production, which would enlarge the amount of RES used in the area of biofuel consumption.

Usually bioethanol replaces a share of petrol in internal combustion engines; however, the possibility of bioethanol use for diesel engines has recently been taken into interest. This is done to expand the base of raw materials and to enlarge the share of renewable energy in diesel fuel. Bioethanol can be used in the process of oil and fat esterification and re-esterification as a substitute for the currently used methanol.

### Participation in international programs

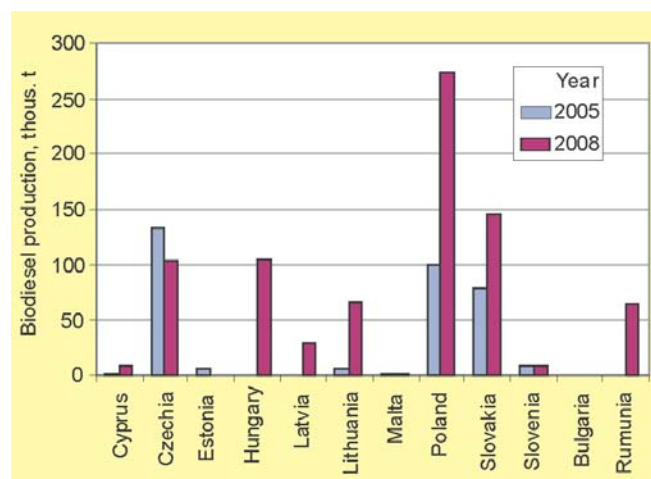
Studies related to rational consumption of biomass resources for producing biofuel and solid biofuel use for producing thermal and electric energy are carried out in the Laboratory. Data covering the whole technology cycle from raw material collection, preparation, processing into solid biofuel and combustion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



### Sixth Framework Programme project *Co-firing – from Research to Practice: Technology and Biomass Supply Know-how Promotion in Central and Eastern Europe (COFITECK)*

The objective of the Sixth Framework Programme project 2009 is to prepare and spread the information collected about the burning of biomass and other types of fuel mixtures to the concerned employees of heat and electricity production companies. A publication *Technology and Biomass Supply Know-how Promotion in Central and Eastern Europe* was prepared. The perspective of biomass mixture burning and the possibility of reduction of global warming potential were analysed. The peculiarities of biomass mixture burning related to the preparation of biomass, effect on the boiler efficiency, pollution of thermal surfaces, clinker formation and corrosion were determined. The studies show that in pursuance of reduction of CO<sub>2</sub> emission into the atmosphere and the enlargement of biomass use for energy production, the adjustment of fossil fuel-fired power plants to biomass and coal mixture burning is the cheapest and most efficient means, especially, the direct mixture burning.

When implementing the project, an international conference, meetings and seminars were organized concerning the issues of fuel mixture burning in Lithuania. Employees and consumers of scientific and energetic companies are continually introduced to the data of the study.



Growth dynamics of biodiesel production in the new EU member states





In the closing COFITECK conference in Poznań, Dr. E. Perednis is reading a paper on the achievements of biomass fuel mixture burning in Lithuania



**Seventh Framework Programme  
project *Integrated European  
Network for biomass and waste  
reutilisation for Bioproducts  
(AQUATERRE)***

The project was begun in 2008 in cooperation with the scientists from Iceland, Italy, United Kingdom, the Netherlands, Spain, Germany, Romania, Bulgaria, Denmark, Belgium, Ukraine, Sweden, France and Austria. The objective of the project is to carry out researches in the field of biomass and its waste utilisation, to inventory the existent biomass resources in Europe and to determine the development of biofuel production in the EU countries in cooperation with science research centres, business and other partners. A survey on the data of literature and scientific studies was carried out. Using the Geographical Information System (GIS) maps of Europe biomass resource use were developed and schemes of economic factors and environmental impact were determined. This was performed in accordance with optimal lifetime development cycle scenarios (LCA) estimating the impact of a product on the environment in all stages of production process. The information collected on the most beneficent cases of biomass use in Europe is to be applied for the publishing of *White Paper*.

The following *Intelligent Energy – Europe* projects were implemented in the Laboratory in the year 2009:

- **Market Development of Gas Driven Cars Including Supply and Distribution of Natural Gas and Biogas (MADEGASCAR)** 2007-2010;
- **Regional Bioenergy Initiatives Increasing the Market for Biomass Heating in Europe (REGBIE+)** 2006-2009.
- **Solutions for Biomass Fuel Market Barriers and Raw Material Availability (EUBIONET III)** 2008-2011.

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



During implementation of EU project **MADEGASCAR**, quite a number of advantages of natural gas use were determined in comparison to other alternative fuel used for transport. Natural gas is the most ecological and cheapest type of fuel even in comparison to biological fuel (biodiesel and bioethanol). Used for fuel, natural gas has the following advantages:

- The resources of natural gas are much more extensive than oil resources in the world;
- Natural gas is the cheapest fuel in the world;
- The expenses for fuel are lesser up to 20% in comparison to liquefied petroleum gas and diesel and up to 40% in comparison to gasoline;
- Compressed natural gas (CNG) engines are more durable;
- The level of noise and vibration of diesel engines is twice lesser;
- The quality of natural gas is ensured;
- The exhaustion of CNG cars is lesser than required by the standards of EURO5;
- The higher CNG octane number promotes the industry to produce more effective and precise car engines;
- Minimal environmental taxes;
- Natural gas networks are rather well developed in Lithuania;
- The use of natural gas for transport would increase its equality of use during the year.



Dr. Juozas Savickas's photograph taken after the symposium "The Use of Natural Gas for Transport in Kaunas District"

Vilnius, Klaipeda and Kaunas municipalities have begun to use natural gas for public transport in. The process of implementation of this project resulted in cooperation with other EU countries, exchange of experience, building the first gas filling stations and collecting experience in this field in pursuance of sourcing the cheapest fuel.



During implementation of project **REGBIE+**, the assessment of biomass resources in various EU regions is carried out, as well as in Lithuanian, Kaunas district. The process of renewal of these resources and the thermochemical process of biomass firing, while burning solid biofuel in layers, were analysed. The processes of pellets production and burning in furnaces were investigated. Possibilities of biomass use in energy production were analysed by estimating experience of other countries (Sweden, Germany, Austria, etc.). Promoting means were provided for and new technologies of biofuel preparation and firing by searching for more efficient heat production methods were proposed. Researchers of Lithuanian Energy Institute together with specialists from other countries implementing this project, dealt with the above-mentioned issues, exchanged the up-to-date achievements in the field.



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 is carried out, national biomass programs are analysed and biomass fuel potential is estimated, giving most of attention to industrial and agricultural waste and assessment of potential of new biomass fuel types. Price mechanisms are also

analysed, biomass fuel certification and sustainable development criteria are determined.

## Science promotion activity

In 2009, 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, while science representatives were invited to actively participate in informing the society on the issues of science promotion. Events on the topics of climate change, effective energy use and renewable energetics were organized for energy consumers, students and other interested people.



30 April 2009, M. Marciukaitis's doctoral dissertation defence



The publications published during the implementation of international projects

In 2009 the researchers of Laboratory published 5 articles in scientific journals and other science publications; 3 of them in the ISI indexed journals. 4 science-promoting articles were published. Researchers of the laboratory participated in 1 international and in 4 Lithuanian science conferences. A doctoral dissertation in technological sciences was defended.

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# Energy Efficiency Research and Information Centre

## Main research areas of the Centre:

- 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.

The enhancement of energy production and its consumption efficiency is one of the most important directions in the development of energetics both in Lithuania and in the European Union.

Following the provisions of the European Parliament and Council directive 2006/32/EC on energy end-use efficiency and energy services of 5 April 2006, The National Action Plan for Energy Efficiency of Lithuania was prepared and approved 4 December 2008.

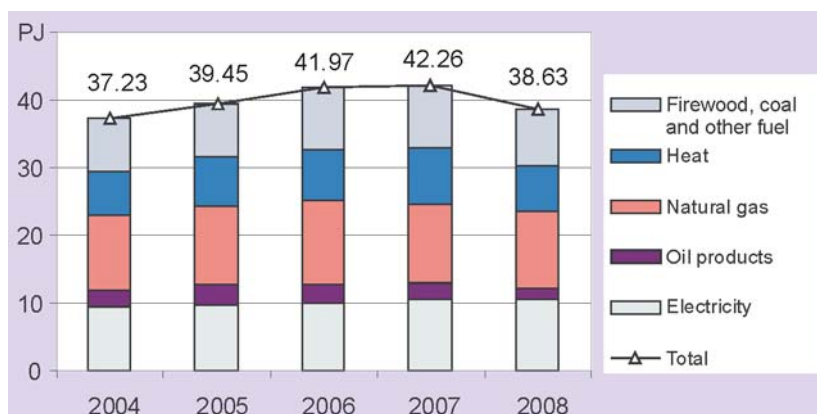
The existent energy saving potential was assessed, means for energy use efficiency enlargement were determined, national energy saving indicators were identified and a strategy for reaching these indicators was suggested in this document.

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

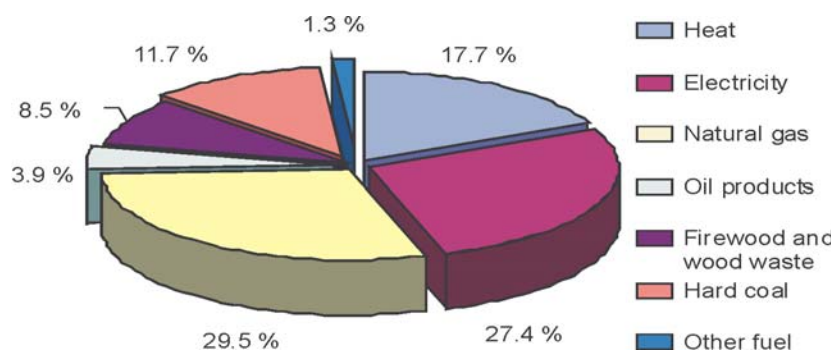
In 2009 a state funded research project ***The Development of New Energy Production Technologies in Lithuania and the Study of Increasing Energy Consumption Efficiency Possibilities in Public Buildings*** was initiated.

The paper involves the sectors of industry, public buildings that contain one of the largest energy saving potentials. The enhancement of the use of this potential is a substantial factor, which would enable the implementation of energy sector development policy mentioned above; however, presently there is a lack of researches on this topic.

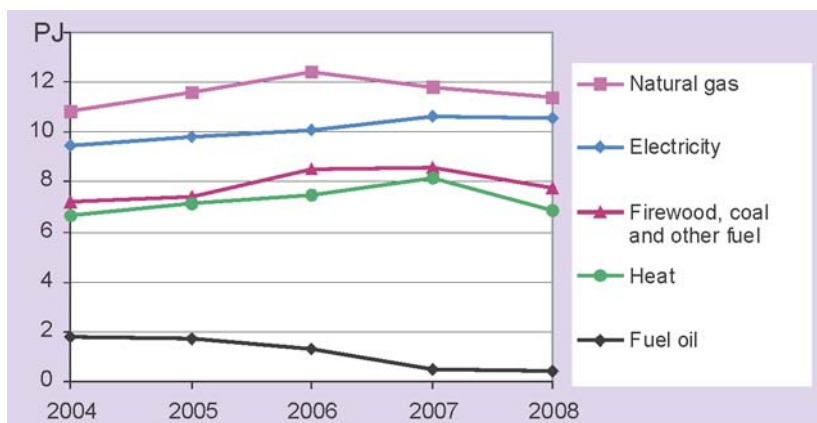
During the implementation of the project, the data on industry sector development of Lithuania in 2005 – 2008, fuel and energy consumption and the greatest industrial consumers of electric power, natural gas and thermal energy were collected. The data of 2008 was compared to the last year and earlier periods of time;



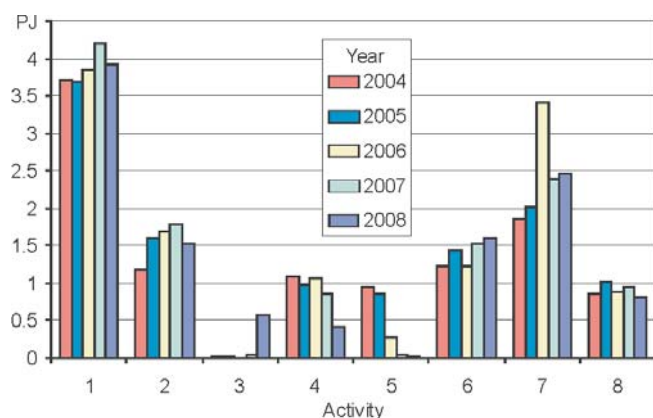
Distribution of fuel and energy final use in industry in the period of 2004-2008



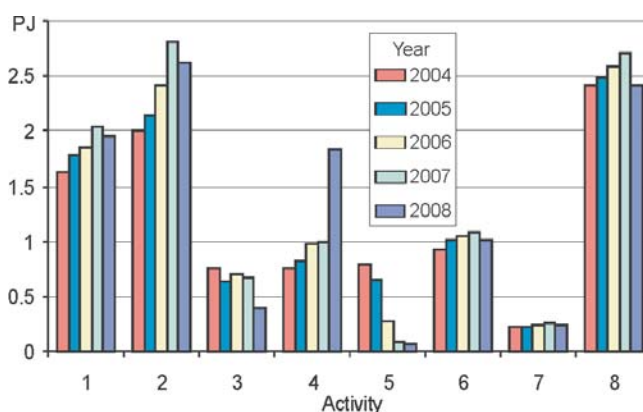
Final use of fuel and energy in industry in 2008



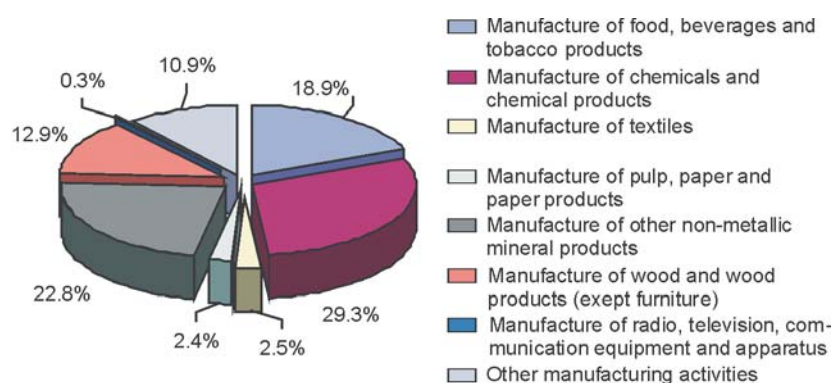
Changes of fuel and energy consumption in industry for the period 2004-2008



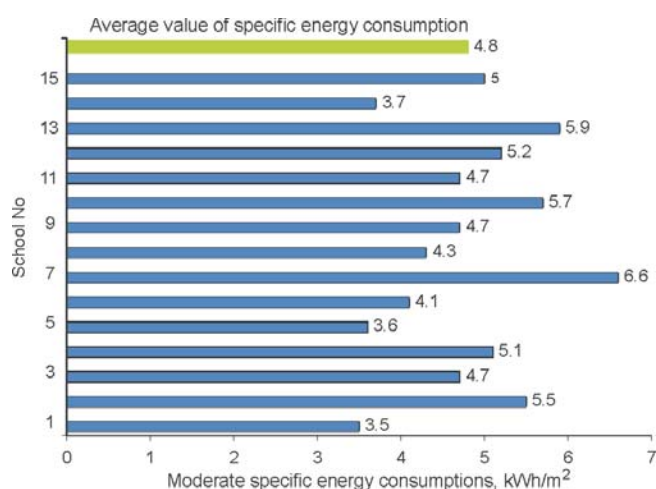
*Largest natural gas consumers of the industry: the manufacture of 1 – food and beverages, 2 – other non-metallic mineral products, 3 – pulp, paper and paper products, 4 – textile products, 5 – radio, television and communication equipment and apparatus, 6 – wood and wood products (except furniture), 7 – chemicals and chemical products, 8 – other industry activities*



*Largest electricity consumers of the industry: the manufacture of 1 – food and beverages, 2 – other non-metallic mineral products, 3 – pulp, paper and paper products, 4 – textile products, 5 – radio, television and communication equipment and apparatus, 6 – wood and wood products (except furniture), 7 – chemicals and chemical products, 8 – other industry activities*



*Distribution of final energy (heat, electricity, natural gas, liquid fuels, firewood, wood waste and coal) consumption according to the industrial activities in 2008*



*Moderate specific energy consumption on 1-15 weeks 2008 of Kaunas schools that took part in the Active Learning of Energy Saving activity*

moreover, the analysis of the data was carried out.

The information on the foreign leading companies of heat-pumps production was collected and detailed data on the companies whose production, specifically heat-pumps absorbing ambi-

ent air heat, is distributed by their agents in Lithuania was presented. Moreover, the data on the companies that produce heat-pumps with natural refrigerant R744 (CO<sub>2</sub> gas) was introduced; physical-thermal characteristics of the refrigerant and principal properties of other refrigerants were provided. An overview of fundamental European and Lithuanian legislation regulating the course of refrigerant application was presented. The data on recent heat-pump installation in various countries and the possibilities of its development in the future were introduced.

Information was also collected on the distributed cogeneration power plants of small capacity, giving special attention to the solid biomass fired power plants. The data on such cogeneration power plants recently introduced to the market was presented suggesting the brands that could be installed in Lithuania.

The installation of new technologies is closely related to the information that the consumers are aware of: the new technologies will not be effective unless the consumers are persuaded to apply them. The abovementioned 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 basis for the change of the behaviour of principal future energy consumers.

The study assessed students' knowledge about energetics, energy use effectiveness and renewable energy sources in the chosen schools of Lithuania. In consideration of the results, the package of Active Teaching of Energy Saving that could be introduced to the present educational programmes at schools was prepared. One of the main educational themes is the monitoring of energy consumption in schools that would enable the assessment of energy saving potential there. For this purpose the com-





*A seminar on bioenergy production and consumption in Lithuania and its participants*



parative methodology of energy consumption in schools based on the experience of other European countries was applied; it is mainly oriented to the principles of Active education in schools. New data on energy consumption in the chosen schools and their distinctive energy input was collected and compared, whereas the results made will be compared to the schools of other European countries.

## Participation in international projects

Two *Intelligent Energy-Europe* projects of the EU were completed in 2009 and a project of EU Baltic Sea Region Programme 2007-2013 was started.



### ***The European Greenlight Programme in New Member States***

The main objective of this project was to assess the use of electric power for the lighting of town areas and public buildings and also to suggest the means for diminishing consumption of electric energy for lighting. During the implementation of the project, about 40 different Lithuanian organizations (municipalities, universities, schools, sport centres, airports, etc.) joined its programme. Several organizations prepared and successfully fulfilled electric power saving projects for the lighting of town areas and public buildings.



### ***Sustainable Energy Actions for Europe's Cohesion***

This international project promotes the installation of innovative energy technologies in the EU zone. The EU energy policy, which encourages the development of individual zones by reducing the differences of economic development in individual regions of the countries, was assessed with the help of strategic partners of the project. During the implementation of the project, the strategy of Kaunas region

energy sector development was prepared together with several examples of the projects that could be partially funded by EU Structured and Cohesion Funds. The results of the project were introduced in eight national seminars and the publication was prepared and translated into eight foreign languages.



**Bioenergy Promotion**

### ***The Baltic Sea Region Bioenergy Promotion Project***

A new international project was pursued in cooperation with The Laboratory of Heat-Equipment Research and Testing in 2009. This project, which is partially funded by the EU Baltic Sea Region programme resources, 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, while the primary principle of the project is bioenergy production and consumption following the coherence criteria. During the implementation of the project, which will take 3 years, conditions for international and interregional cooperation in the region will be created. At the same time opportunities for exchanging information, knowledge and technologies will be provided by coordinating improvement of policies and legislation in the field of bioenergy development.

According to the topics of the researches carried out, 2 seminars were arranged, the results of the studies were introduced in 3 scientific articles and 3 scientific papers were read in scientific conferences (1 of them being international).

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# Laboratory of Systems Control and Automation

## Main research areas of the Laboratory:

- Mathematical modelling of power systems and network, investigation of control issues;
- Modelling of information-control systems of power systems and optimisation research.

With rapid development of information and communication technologies (ICT), more automatic control and protection equipment, including intelligent electronic devices, is introduced into power systems (further PS). PS control algorithms are getting more complex as they must ensure co-ordinated operation of all those devices for PS to run in the scheduled mode and to properly interact with other PS. New approaches are undertaken, for instance, GPS-based wide area protection system. It is endeavoured to process more information (telemetry data, telesignals) from different PS points in real time in order to:

1) Generate control solutions that adequately correspond to the PS status and to send the respective commands to remote PS controllers;

2) Choose optimal settings of automated devices.

The target is to achieve optimal ratio of the centralised and decentralised control. Flexible alternating current transmission systems (FACTS), i.e. power electronic controllers, are introduced 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, allows distur-

bance localization in national systems or enables to avoid its spreading across interconnected system.

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

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

In 2009, the Laboratory performed a great number of contractual research projects for entities of the Republic of Lithuania:

In accordance with the contract ***Investigation of Dynamic Regimes of Perspective Lithuanian Power System Scheme for 2025*** with Lithuanian Transmission System Operator SC *Lietuvos energija*, the major part of the project was accomplished and the following interim study reports were presented:

- Scheme of Lithuanian Power System development till the year 2025;
- Development of mathematical model of Lithuanian Power System for 2010, 2015, 2025.
- Static regimes of Lithuanian Power System in 2025;
- Dynamic regimes of Lithuanian Power System in 2025.

In the study ***Scheme of Lithuanian Power System Development till the Year 2025***, the perspective scheme of Lithuanian power system development till the year 2025 was worked out. It



contains options of deployment of new generation sources as well as options of development of 110-330 kV transmission networks up to 2025, with full pictures for interim points of 2010 and 2015. The options are based on forecasts for generating capacity needs and maximum loads in Lithuanian system.

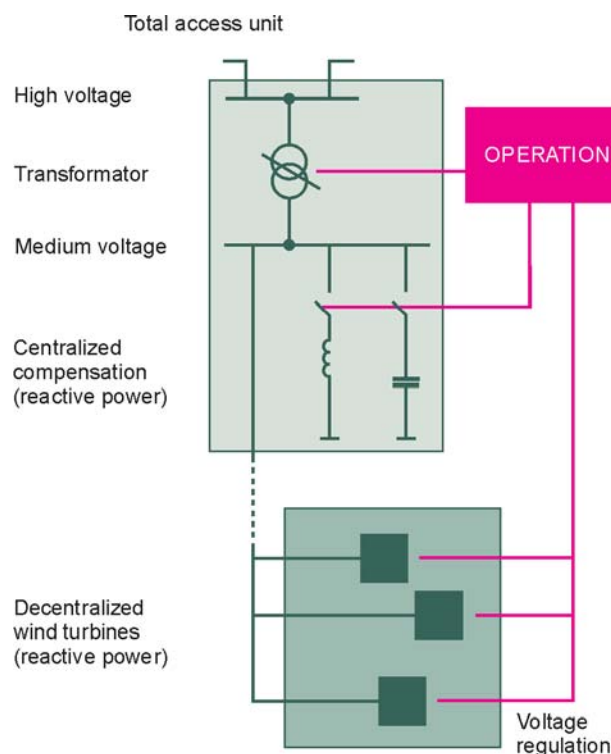
During the implementation of the study **Development of Mathematical Model of Lithuanian Power System for 2010, 2015, 2025**, a numerical model of Lithuanian Power System (110-330 kV transmission networks) was prepared to perform various electrical calculations. The model reflects three periods of time, i.e. 2010, 2015 and 2025. New generators and network equipment were taken from the abovementioned study **Scheme of Lithuanian power System Development Till the Year 2025** and introduced to the model. The model is designed for static, dynamic and short circuit calculations of 110-330 kV transmission networks of Lithuanian Power System.

Furthermore, in the study **Static Regimes of Lithuanian Power System in 2025**, test data files of PS were compiled and their regimes were calculated. "Heavy" Baltic PS regimes of 2025 with maximum export, import and transit powers were examined. Given the different synchronicity of interconnection with adjacent PS, the identification of Baltic PS vulnerable nodes in post-fault situations of N-2 type was performed.

The study **Dynamic Regimes of Lithuanian Power System Scheme in 2025** was focused on the dynamic regimes of perspective Lithuanian power system scheme for 2025. The mathematical model of Lithuanian power system was revised to be tailored to dynamical applications of software package PSS/E. When simulating serious accidents in the system, dynamic stability of generating units was examined.

Within the contract with SC LEO LT, the project **Feasibility of Maximum Generating Unit Capacity in Lithuanian Power System** was carried out. The size of generating unit in projected new Lithuanian nuclear power plant was determined for various situations of Baltic PS operation. It was performed by means of PS long-term development optimization model, with variation of generation sources across the Baltic countries, of interconnections with former Nordel, UCTE and IPS/UPS power systems, and of volumes of power import/export. Finally, the maximum unit capacity was determined from its primary, secondary and tertiary reserving conditions and from the security constraints on network loading and dynamic stability.

Furthermore, one more project was carried out for the SC LEO LT: **Study on the Integration of Wind Power Plants into Power System**. The financial support schemes for wind power developers in Europe were reviewed and a recommended scheme for Lithuania drafted. The statistical behaviour of generation of existing wind power parks in Lithuania was analysed and the possibilities to compensate the generation fluctuations by balance reserves were discussed. Margins of total wind generation extension for Lithuania were determined, considering the cases with/without extension of balance reserves and electric networks. At the same time, the development principles for the off-shore wind power plant parks were formulated and the respective extra investments evaluated.



Principal scheme of voltage control of wind park with Enercon PP

Within the contract with JSC Šilutė Wind Projects **Analysis of Transmission Network Stability and Voltage Levels after Connection of Large Wind Power Park**, the projected connection of 250 MW-capacity wind power park to the Klaipėda-Sovetsk transmission line of 330 kV was investigated. The scope of the study included static and dynamic stabilities of Lithuanian PS, voltage levels and fluctuations, voltage instability margins and additional volumes of reactive power compensation. The study determined the amount of balance reserve capacities in Lithuania needed to balance the varying generation of the projected wind park.

The study **Examination of Technical and Legal Conditions for JSC "Korelita" to Obtain Electricity Distribution and Electricity Public Supplier Licences** examined the possibilities of JSC Korelita to receive electric power distribution and public supplier licences. The study was carried out by assessing the conformity of characteristics of electricity network controlled by the company with the distribution network technical criteria necessary for obtaining electric power distribution license. Additionally, the study aimed at theoretical description of distribution network criteria (characteristics) which are set forth by on legislation.

In 2009, the results of research were published in 2 articles in peer-reviewed journals. Researchers of the Laboratory presented 2 papers at international and 1 at Lithuanian conferences.

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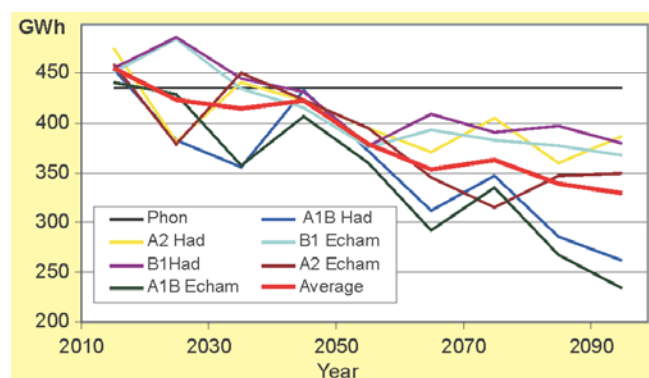
# Laboratory of Hydrology

## Main research areas of the Laboratory:

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

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

Such river run-off changes of the 21<sup>st</sup> century are not beneficial for all water consumers. Applying RiverWare software, a reduction in the output of Kaunas hydropower station from 2021 was predicted, while in the middle of the 21<sup>st</sup> century annual energy production in Kaunas hydropower station may decline by 17-25%.



Prediction of energy production in Kaunas hydropower station according to A2, A1B and B1 gas emission scenarios, Had and Echam global climate change models in the 21<sup>st</sup> century

In 2007-2009 the Laboratory researchers, together with the Laboratory of Nuclear Installation Safety and Laboratory of Energy Systems Research, were implementing a state subsidy funded scientific research project **Application of Best-estimate Method-**

**ology for Process Modelling of Technical, Natural and Social Systems** (supervisor Dr. Habil. A. Kaliatka).

## Objects and tasks of research

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

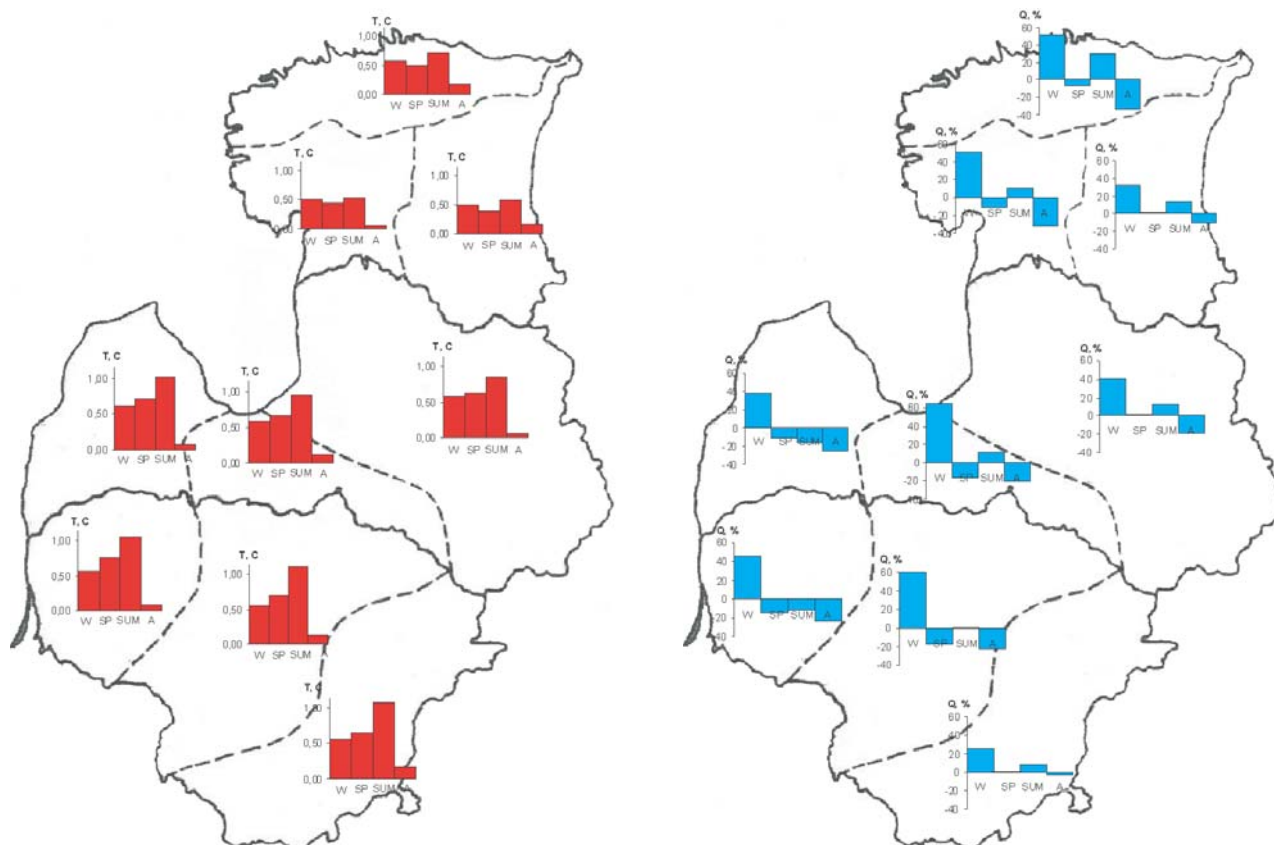
Applying the hydrographic and hydrometeorological database and the newest modelling systems MIKE 21, RiverWare and HBV, the Laboratory solves the following tasks:

- environmental impact assessment of anthropogenic activities on water bodies and justification of environmental protection measures;
- hazard and risk analysis of hydrotechnical constructions;
- protection and managing of the Baltic Sea shores;
- investigation of harbour quays interaction with water flow and selection of optimal constructions;
- determination of environmental conditions using water bodies for different objectives;
- estimation of mixing and dispersion of sewage under critical conditions in water bodies;
- exploitation of sea harbours and waterways, maintaining the guaranteed nautical depth;
- sensitivity and uncertainty analysis in modelling of hydrodynamic and hydrologic processes of water bodies.

## International cooperation

Since 2007, together with Nordic countries, a joint project **Climate and Energy Systems**, funded by the Nordic Council of Ministers, has been implemented. Researchers from Norway, Sweden, Finland, Denmark, Iceland, Lithuania, Latvia and Estonia participate in this project. The main purpose of this research work is to assess the impact of climate change on energy sector. Scientists of the Laboratory participate in the activities of the research group of the statistical analysis of climate and river run-off.

In 2009, data series of regional air temperature, precipitation and river run-off of many years were examined. The territory of Lithuania, Latvia and Estonia was divided into 9 parts which represent the impact of maritime and continental climates. In this way, regional data series of air temperature, precipitation and river run-off were composed; they enable analysing annual and



Changes of air temperature (°C) in winter, spring, summer and autumn, and river run-off (%) (in comparison to the data of 1991-2007 and 1961-1990) in the Baltic countries

seasonal changes in parameters (trends and cyclic variations). Additionally, the changes of regional series were determined in comparison to the data of 1991-2007 and 1961-1990. In recent decades, an increase of air temperature has been observed in all territory of the Baltic countries: temperature increases most in summer (in comparison to 1961-1990, the change is up to 1 °C), whereas the least: in autumn (up to 0.2 °C). The major annual changes in air temperature were determined in Lithuania and Latvia, while smaller in Estonia. The analysis of river run-off regional series changes, in comparison to the data of 1991-2007 and 1961-1990, showed that common tendencies are present in all Baltic countries: river run-off increases in winter, spring floods begin earlier, and spring river run-off and maximum flood run-off decline. Annual distribution of river run-off also depends on the peculiarities of maritime and continental climates.



#### European Network of Freshwater Research Organisations EurAqua

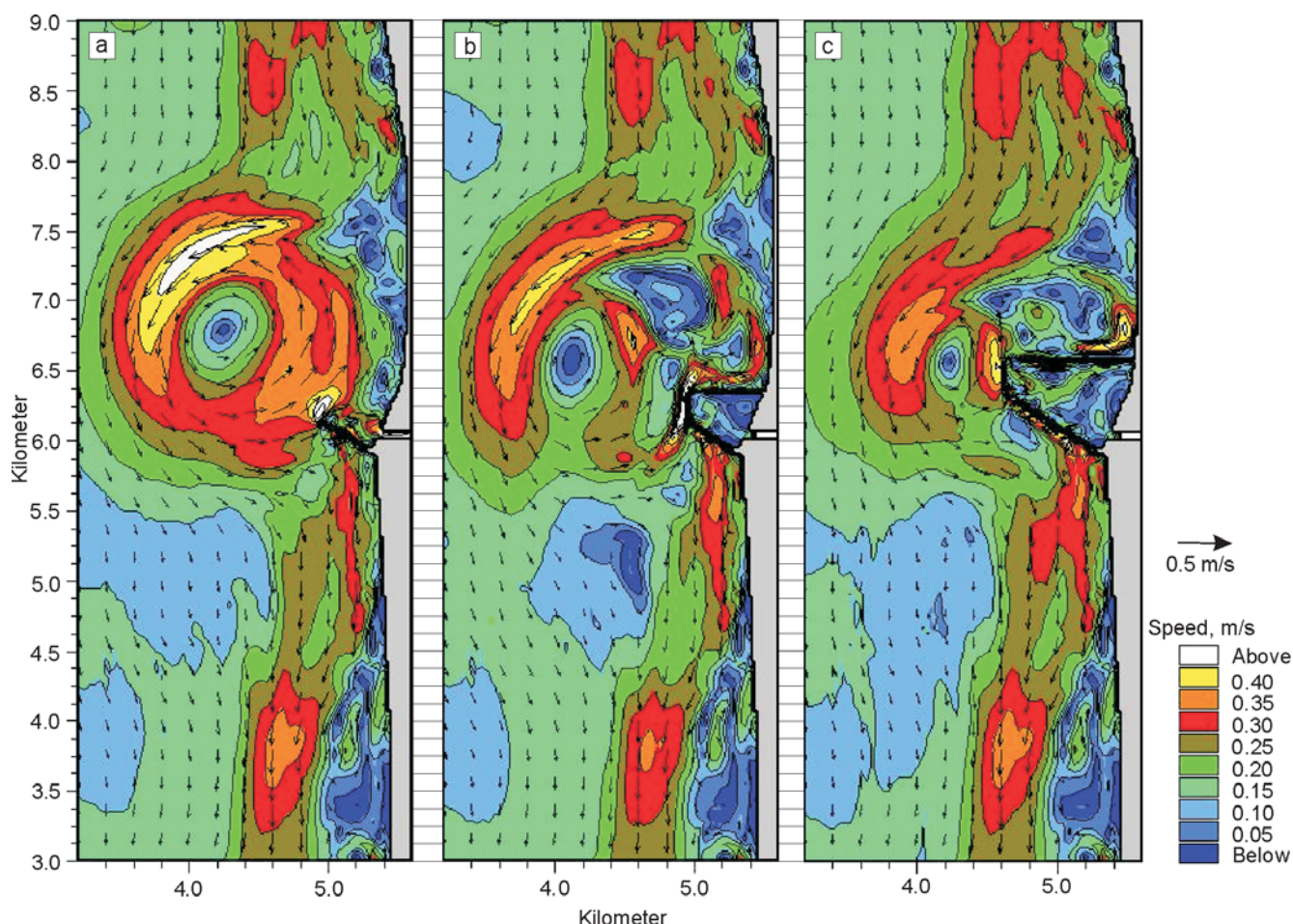
In 2008, Laboratory of Hydrology was accepted into EurAqua organization, which consists of the most influential scientific institutions of 24 European countries performing research of water resources. The main objectives of EurAqua are the following:

1. To participate in the formation of water research policy in the European Union;
2. To formulate and propose the most significant and topical

themes on water resources research;

3. To form consortiums with EurAqua scientific institutions by preparing joint proposals for Framework Programmes projects;
4. To prepare scientific articles and technical reviews on problematic areas in European water resources research;
5. To organise conferences on relevant topics (the impact of climate change on water resources, flood analysis and forecast in Europe, etc.).

In 2009, the researches of the Laboratory, together with Spanish scientists (consulting company ALATEC) participated in preparing a scientific study *Feasibility Study for the Reconstruction of Šventoji Port*. The aim of this study was to select the most optimal variant for Šventoji port development considering both economic and environmental factors. In order to substantiate the planned structure of Šventoji port, the following principal port reconstruction alternatives were designed: “0” – zero alternative (present condition of Šventoji port); “1” – short breakwaters (400 m long), port depth 6 m; “2” – long breakwaters (800 m long) port depth 6 m; “3” – long breakwaters (800 m long) port depth 8 m. Scientists of the Laboratory performed an expensive modelling of wave, sediment transport and hydrodynamic processes in the Baltic Sea coast, in various meteorological conditions. Having compared various alternatives, it was determined that the largest changes in hydrodynamic processes occurred when the West wind was blowing. Reconstruction of Šventoji port under the “1” alternative matches minimal requirements of the port and has the least impact on lithodynamic processes in the shores. The “2”



Flow structure of the Baltic seashore (beside Šventoji port) when the West wind of 20 m/s is blowing: "0" (a), "1" (b) and "2" (c) alternatives

alternative for port reconstruction would raise shore erosion in both Southern and Northern sides. The expansion of port depth up to 8 m (the "3" alternative) would increase the impact of the port on sediment transport processes.

### Cooperation with state and scientific institutions

The Laboratory of Hydrology closely cooperates with the Institute of Environmental Engineering of Kaunas University of Technology, have joint doctoral studies, since 1995 have been publishing scientific journal *Environmental Research, Engineering and Management*. Aiming at the development of up-to-date infrastructure for the common needs of Lithuanian sea sector scientific research and technological development, the Laboratory of Hydrology contributes to the activity of the association *Baltijos slėnis*. The primary and main objective of the Integrated Science, Studies and Business Centre (Valley), related to Lithuanian sea sector development, is to integrate separate institutions and departments of maritime science. The initiators for establishing the Valley are Klaipėda University, Institute of Geology and Geography, Institute of Ecology of Vilnius University, Institute of Botany, Kaunas University of Medicine, Lithuanian Energy Institute and maritime business companies. Two directions of scientific research and experimental development are planned, that is, sea envi-

ronment and maritime technologies. In pursuance of integrating the diffuse national scientific potential, working in the field of maritime science, and effectively using the modern scientific research equipment and ship, a National Maritime Science and Technology Centre is going to be established.

### Major applied research works

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

- Under the agreement with Klaipėda State Seaport Authority, the projects on harbour entrance channel dredging were prepared;
- Under the agreement with the Ministry of Environment of the Republic of Lithuania, environmental recommendations for construction and exploitation of small-scale hydro power plants, were prepared;
- The possibilities of cooling the heated water in Drūkšiai lake were assessed, while preparing the report on environmental impact assessment of the new nuclear power plant in Visaginas.

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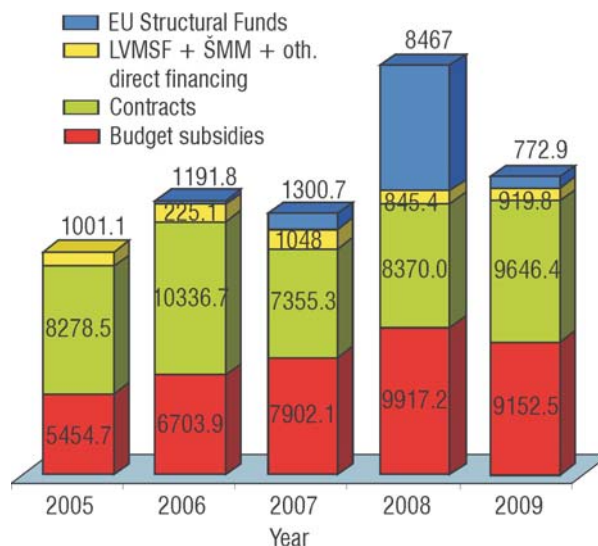


# Financial Highlights

## The Financial Sources of the Institute Consist of:

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

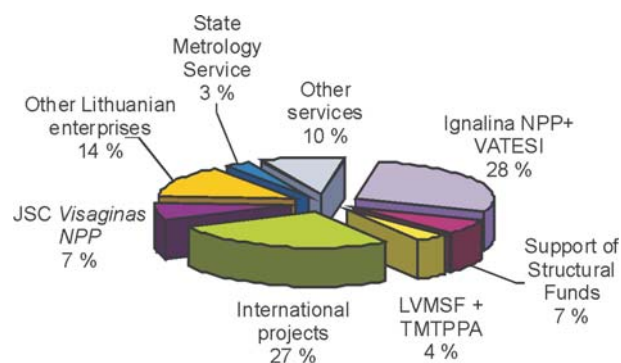
## Variation of Income Structure (Thous. LTL)



## Structure of Income and Total Expenses (LTL'000)

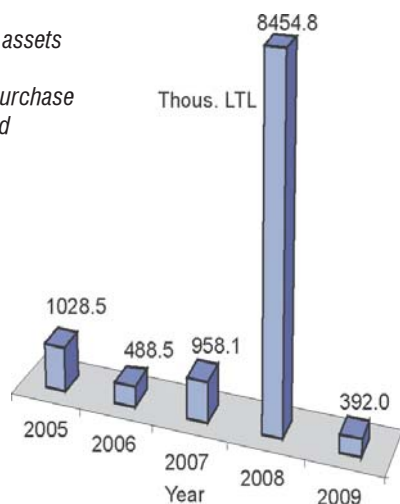
Year	2005	2006	2007	2008	2009
<b>Income:</b>					
State Budget Subsidies	5454.7	6703.9	7902.1	9917.2	9152.5
Contracts	8230.9	10208.6	9439.1	8370.0	9646.4
SF Support		225.1	1048.0	8467.0	772.9
Other Income	1048.7	1320.4	1356.2	1136.9	1155.3
<b>Total:</b>	<b>14734.3</b>	<b>18458</b>	<b>19745.6</b>	<b>27891.1</b>	<b>20727.1</b>
<b>Expenses:</b>					
Salaries (soc. ins. incl.)	9345.5	10709.1	12919.9	15650.0	13722.0
Operating Expenses	3559.0	4696.6	4881.8	5059.0	3749.0
Capital Funds	1548.4	1185.5	2010.4	9757.3	392.0
<b>Total:</b>	<b>14452.9</b>	<b>16591.2</b>	<b>19812.1</b>	<b>30466.3</b>	<b>17863.0</b>
Long-Term Projects Assets	2878.0	4744.8	4678.1	2102.9	4967.0

## Income of 2009 from Local and International Projects



LVMSF – Lithuanian State Science and Studies Foundation  
 ŠMM – Ministry of Education and Science of Republic of Lithuania  
 VATESI – State Nuclear Power Safety Inspectorate  
 TMTPPA – Agency for International Science and Technology Development Programmes in Lithuania

## Dynamics of assets devoted for equipment purchase for the period 2005-2009



# Main publications

## Books

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2. Lithuanian Energy Institute 2008 // Annual report. Kaunas: Lithuanian Energy Institute, 2009. ISSN 1822-0088. 70 p.

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3. **Brinkienė K., Kėželis R., Čėsniėnė J., Mėčius V.** Evaluation of wear resistance of plasma sprayed ceramic coatings // Materials science (Medžiagotyra). ISSN 1392-1320. 2009. Vol. 15, No. 4, p. 302-305.
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*Comprehensive list of publications is faced on Lithuanian Energy Institute webpage:  
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# Lithuanian Energy Institute Events in 2009

January 22.  
EU award granted  
to Kaunas city  
municipality



March 2. IAEA seminar on safety analysis power plant modification



March 17. General session of Lithuanian Academy of Sciences.  
2008 Lithuanian Academy of Sciences award laureates' diplomas granted to Dr. Habil. A. Pedišius, Dr. J. Tonkonogij, Dr. G. Zygmantas and Dr. N. Pedišius



The nominal prize of Algirdas Žukauskas granted to the director of the Institute, the Corresponding Member of the Lithuanian Academy of Sciences Prof. Dr. Habil. Eugenijus Ušpuras



March 18. Kaunas  
University of  
Technology  
Career Days 2009



April 20. Nordic Energy Research delegation at the Institute



April 20. Prof. Brunonas Gailiusis' 70<sup>th</sup> anniversary



April 24. E. Ušpuras  
elected as the director  
of the Institute for the  
second term



April 24. On the occasion of  
Lithuanian Energy Day Dr.  
Habil. A. Kaliačka received an  
acknowledgement from the  
Speaker of the Seimas of  
the Republic of Lithuania



May 11. 10<sup>th</sup>  
meeting of  
European  
Association for  
Nuclear Energy on  
radioactive waste  
disposal



May 12. Seminar of Science, Study  
and Business "Valley Santaka".  
Speech given by "Valley Santaka"  
director E. Mačikėnas



May 28-29. 6<sup>th</sup> International conference of young scientists on energy issues CYSENI-2009



June 9. Seminar of Science, Study and Business "Valley Santaka"



June 10. Dr. Arthur Jonas Ragauskas' lecture "Biofuel and Alternative energy in the USA"

September 18. Seminar of IEE programme RES-H Policy project



October 15. FP7 "Cooperation" programme "Space" thematic area information day at the Institute



October 19. Beginning of IAEA Basic Professional Training Course in Nuclear Safety



November 9-10. Technical meeting of IAEA project "Use of Numerical Models in Support of Site Characterization and Performance Assessment Studies of Geological Repositories"



November 24-27. Defense of state subsidy funded research projects



November 26. Institute Association of Young Researchers seminar "Building insulation"



December 17. Seminar "Bioenergy Production and Consumption in Lithuania"



December 22. Lithuanian Confederation of Industrialists nomination "Successfully Operating Company" granted to the Institute



December 29. Seeing off 2009



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UDK 061.6:620:9(474.5)  
Li233  
ISSN 1822-0088