

LITHUANIAN ENERGY INSTITUTE

2007
ANNUAL REPORT



LITHUANIAN ENERGY INSTITUTE in 2007

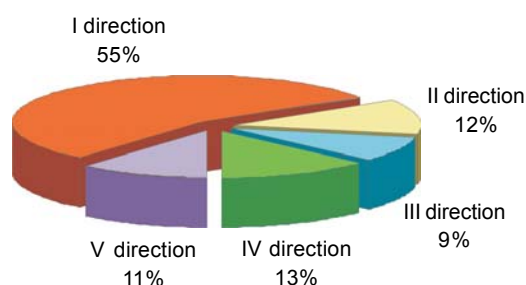
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Lithuanian Energy Institute is a state scientific research organization, established for Lithuanian energy and long-term scientific research of international significance and experimental development.

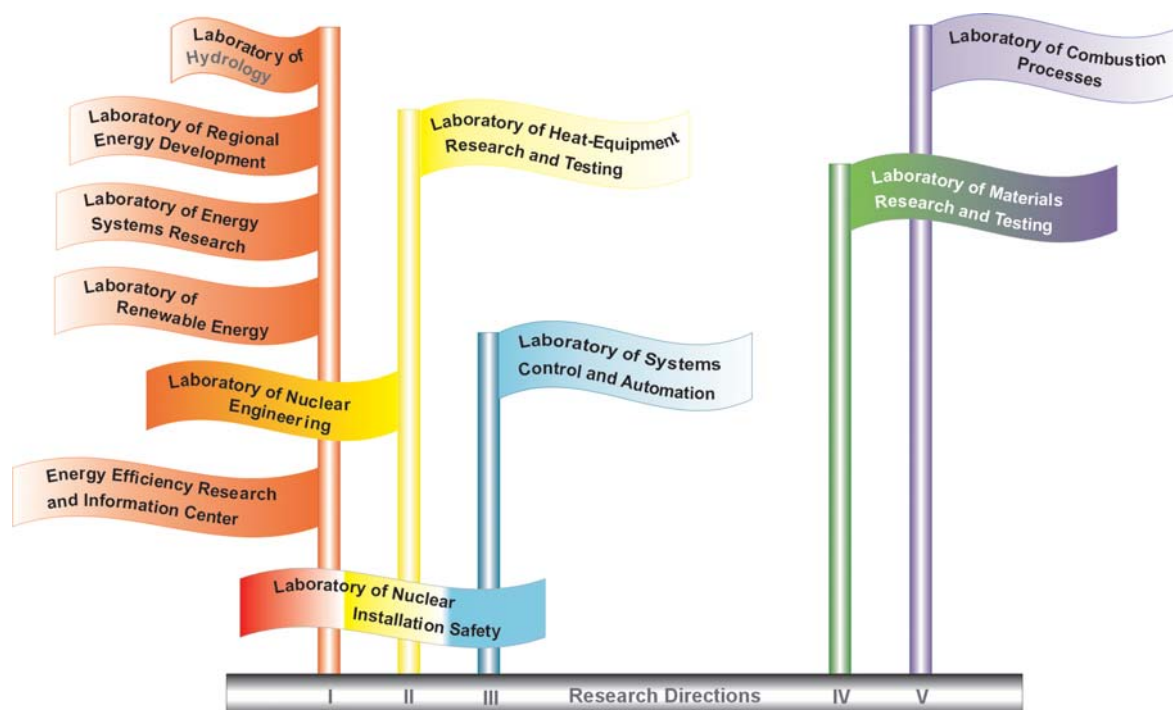
The Institute carries out research of hydro and gas dynamics, heat transfer, fundamental and applied research of materials science and nano technologies, which are needed to develop the most advanced and future energy technologies, to justify their safety and reliability, and estimate their impact on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

Scientific research activity of the Institute is carried out according to five research directions as supplemented and confirmed by the Government of the Republic of Lithuania in 2003:

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



Distribution of researchers according research directions



"Fuel reuse of Ignalina NPP Unit 1 in Unit 2 reactor" was granted a golden medal of Lithuanian Industrialist Confederation competition "Lithuanian product of the year 2007"



In 2007 researchers of Lithuanian Energy Institute carried out 18 state funded research projects, five of which were successfully completed, whereas the remaining thirteen projects will be continued in the period of 2008-2009. 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 Council of Lithuanian Energy Institute. Information concerning projects funded by the Ministry of Education and Science of the Republic of Lithuania is presented in this publication as well. It is expedient to note that state funded projects such as the development of Lithuanian energy security assessment method and security and reliability assessment of energy supply, new hydrogen technologies, and fuel cells are especially important to Lithuania.

Research results of numerical modelling of discrete elements of granular material dynamics, creation of tire combustion facility and decomposition of organic fuel aiming to extract hydrogen are analysed in state funded project **Experimental research of gasification and decomposition of fuel and waste particles, and numerical modelling research aiming to improve the output of hydrogen and other gases**. Research concerning carbon nanotubes manufacturing using the chemical vapour precipitation method is presented. Mixture and segregation methodology for the qualitative and quantitative assessment, calculation method-

ology of calorific waste gasification technology and design methodology of experimental facility, and experimental facility of glycerol research were developed. Research of glycerol fraction thermal decomposition synthesizing hydrogen as well as augmentation of carbon nanostructures were carried out.

Research of experimental and numerical heat transfer of mixed convection at aiding and opposing flows in case of the transitional flow in a wide range of parameter change of thermogravitational forces were carried out in the project **Heat transfer research in the flat channel in the zone of laminar vortex (transitional) flow**. Analytical dependencies of heat transfer in laminar, transition and turbulent flow cases were obtained. In case of laminar mixed convection, at opposing flows, dependencies were proposed to determine the place of flow rupture from the channel walls as well as relative heat transfer.

In experimental project **Research of nanocrystalline zirconium electroceramics used for the hydrogen fuel cell systems** possibilities were analysed to synthesize higher chemical activity yttrium stabilized zirconium oxide powder without using mechanical granulation. The possibility to employ it for the formation of dense YSZ ceramics and ceramic coatings, which are widely used in the constructions of thin layer oxide fuel cells for the formation of anode and electrolyte layers, was investigated. Yttrium stabilized zirconium based oxide powder was sintered and

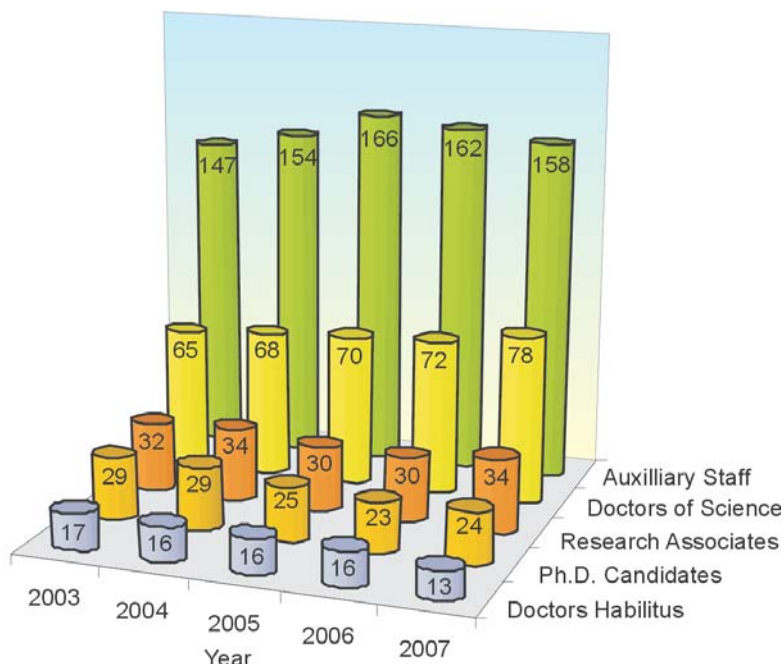
<i>Title of completed project financed from the state budget</i>	<i>Direction of scientific activity</i>	<i>Leading researcher</i>
<i>Experimental research of gasification and decomposition of fuel and waste particles, and numerical modelling research aiming to improve the output of hydrogen and other gases</i>	<i>V</i>	<i>Dr. A. Džiugys</i>
<i>Heat transfer research in the flat channel in laminar vortex (transitional) flow region</i>	<i>II</i>	<i>Dr. R. Poškas</i>
<i>Experimental research and numerical simulation of fuel channel Zr-Nb alloy ageing and crack formation developing the concept of "leak before break"</i>	<i>IV</i>	<i>Dr. A. Grybėnas</i>
<i>Investigation and mathematical modelling of factors, which determine activity of municipal heat sector and impact of regulation measures</i>	<i>I</i>	<i>Dr. V. Kveselis</i>
<i>Research of nanocrystalline zirconium electroceramics used for the hydrogen fuel cell systems</i>	<i>IV</i>	<i>Dr. K. Brinkienė</i>

its characteristics was determined. Research was carried out employing sintered raw material for the formation of YSZ ceramics and plasma coatings. The structure and properties of derived coatings and ceramics were investigated. Optimal parameters of synthesis of YSZ coatings were determined, the impact of technological factors on the conductivity of YSZ coatings were investigated, dependencies of operational properties of YSZ ceramics and coatings were obtained.

In the project **Investigation and mathematical modelling of factors, which determine activity of municipal heat sector and impact of regulation measures** the overview of heat sector development of many Lithuanian municipalities, assessment of reforms, theoretical base of regional energy development and investigation of issues, research results of factors, which influence heat sector of municipalities, were presented. Main analysed factors – heat consumption, possibilities of wider use of biomass and other renewable energy resources, and competitive ability of district heating. The consequence analysis of heat sector activity and decentralization reform, theoretical research of energy sector were carried out, the dependencies of economical indicators of heat sector on various factors and regulating policy measures were obtained.

In the project **Experimental research of fuel channel Zr-Nb alloy ageing and formation of cracks and numerical simulation developing the concept “leak before break”** the impact of hydrogen degradation on RBMK-1500 TMO-2 fuel channel Zr-2.5Nb zirconium alloy was analysed. Formation conditions of hydride cracks, their propagation velocity, and limit stresses were determined. Simulation of fracture parameters of zirconium alloy with hydrides was carried out employing finite element method. Deterministic analysis results of “leak before break” were obtained for TMO-2 fuel channel pipes after 17 years of operation at simulated boundary 70 ppm hydrogen concentration and increase of delayed

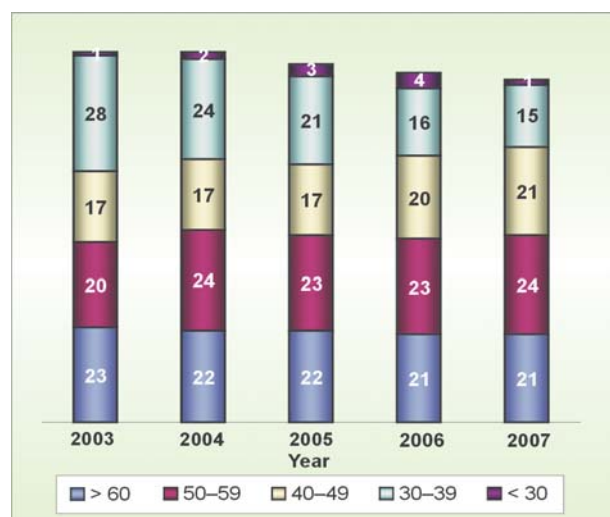
Variation of staff number



hydride cracking velocity, which is evoked by the change of mechanical characteristics due to radiation impact. In accordance with these results new numerical models and methodology “leak before break” were developed for the analysis, which evaluates working conditions and possible degradation of fuel channel zirconium due to its texture changes, which occur during hydrogen absorption process under the impact of temperature, corrosion and radiation. Dependencies of zirconium alloy crack length on hydrogen concentration and stress intensity were obtained.

It is worth mentioning that in 2006 one of the largest and most successful projects in the history of the Institute was completed: researchers of Lithuanian Energy Institute together with specialists of Ignalina NPP developed and implemented the *technology of nuclear fuel transportation from Ignalina NPP Unit 1 to Unit 2 for fuel reuse*. At present, the developed set of nuclear fuel transfer is successfully operated in Ignalina NPP, where specialists mastered technological processes of nuclear fuel transportation and from the beginning of set’s operation to the end of 2007 318 fuel assemblies were transported from Unit 1, 282 from which were loaded to Unit 2 reactor. Taking into account the current price of nuclear fuel, which Ignalina NPP pays to Russian nuclear assemblies producer, it may be stated that input of nuclear power plant concerning the development and manufacturing of this complex has already paid off. For this work LEI and Ignalina NPP was granted a golden medal of Lithuanian Industrialists Confederation competition “*Lithuanian product of the year 2007*”.

Dynamics of age of scientists



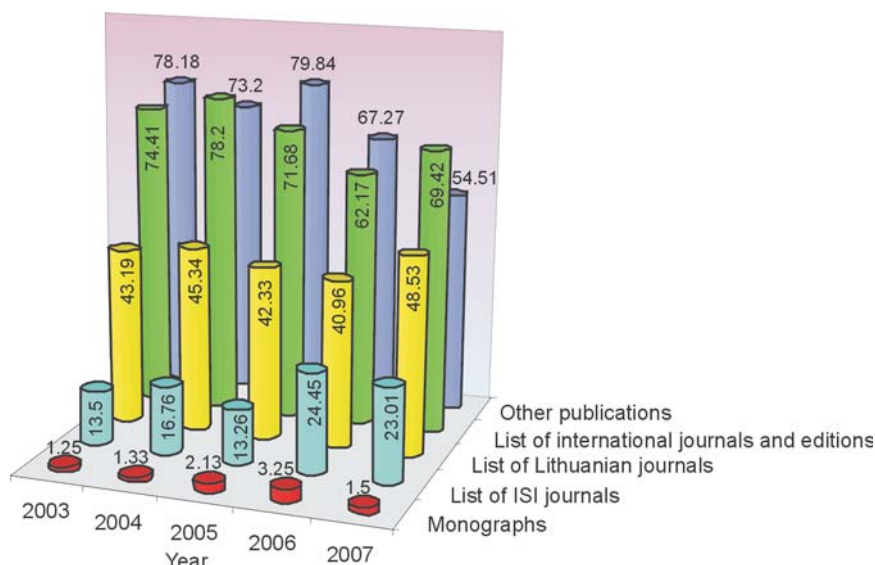
Security and reliability of energy supply is one of the most acute issues in the European Union as well as worldwide. This issue is particularly relevant for Lithuania due to strong integration of its energy sector to the former Soviet Union energy systems. The concept of energy supply is treated rather differently. Usually energy security is understood as an objective to ensure energy needs of individual energy consumers and protect the economical interests of the society and state from internal and external hazards to energy supply as well as rise of prices. It is assumed that it is necessary to have as

many energy supply sources as possible from different countries, hoping that in case of energy supply disruption from one country it will be possible to compensate this shortage by energy supply from other countries.

Such concept of energy security is partially correct, however, it covers only one part of this issue. The biggest drawback is that it is not based on simulations and assessments of all possible hazard consequences, their interdependence and uncertainty analysis of results. Thus, following such concept it is not always possible to make correct economically, politically and technically justified decisions.

In accordance with the methodology, developed by Lithuanian Energy Institute, scenarios of energy accidents, disturbances of energy raw materials supply, economic blockades, price crises and other energy supply disturbances are investigated. Possible energy supply disturbances are simulated using economical and reliability and risk models. Construction of new power plant was one of the analysed scenarios. When evaluating security of energy supply, the price of acceptable security level is important. A great deal of attention is given to geopolitical view points of security of energy supply, the issues of national energy security are analysed in Lithuanian energy strategy.

Researchers of the Institute successfully and efficiently cooperated with Lithuanian and international institutions and private companies. Projects worth almost 11 million Litass were carried out, out of them projects worth approximately 7 million Litass – contracts from Lithuanian institutions and industrial enterprises (the Ministry of Economy and the Ministry of Environment of the Republic of Lithuania, State Nuclear Power Safety Inspectorate (VATESI), State Enterprise Radioactive Waste Management Agency

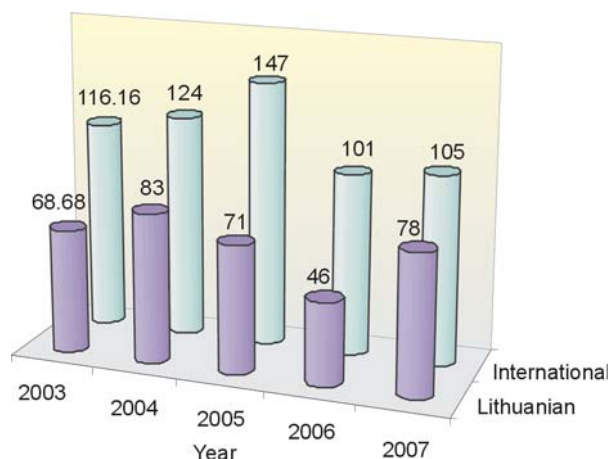


Variation of publications number
(Author's contribution evaluated)

(RATA), Ignalina Nuclear Power Plant, SC *Lietuvos energija*, SC *Lietuvos dujos*, SC *Achema*, Klaipėda State Seaport, other). Some of the projects were implemented together with scientists and experts from the United Kingdom, France, Russia, Germany and other countries.

In 2007 Institute researchers actively participated in different EU financed programs. Researchers of the institute together with partners from different countries completed two projects, financed from the funds of the Sixth Framework Programme and six projects of *Intelligent Energy – Europe*. LEI implemented three projects of INTERREG III, one project of COST and IAEA. Institute continues to implement two projects of EUREKA, four projects of COST and IAEA, one project of the Leonardo da Vinci and Nordic Energy Research Programme, several projects of PHARE and even eleven projects of *Intelligent Energy – Europe*.

One of the most significant Seventh Framework Programme priorities is Technological Platforms. Seeking better participation in the Seventh Framework Programme, the Institute together with other Lithuanian industry, research and education institutions took part in initiating a number of Technology Platforms – *Hydrogen and fuel cells (H₂/FC)*, *Future manufacturing technologies*, *National heating energy*, *National biomass and biofuel manufacturing and consumption*, and *National biofuel technology platform*.



Number of reports in scientific conferences (Author's contribution evaluated)

Lithuanian Energy Institute successfully participates in implementing projects of the EU Structural Funds. One of the most successful examples is the establishment of **Center for Hydrogen Energy Technologies**. In the period of 2004–2006 the feasibility study was carried out, where all possibilities of implementing the planned infrastructure project (establishment of the center) were evaluated, the optimal option of this project implementation was chosen and comprehensively justified. Besides, together with researchers from Vytautas Magnus University, a three year project **Organization of Hydrogen Energy Technologies Training** was implemented, the main objective of which was to raise the qualification of scientists and researchers and prepare new specialists in the field of hydrogen energy technologies, aiming at the quality of the



Repair of heat transfer and nuclear facilities laboratory administrative building

research, carried out in Lithuania, which would satisfy the level of EU scientific research, i.e. would become competitive on the EU scale. Finally, from the EU Structural Funds of the financing period of 2007-2013, the Institute received a grant to renew the current infrastructure and purchase equipment necessary for the research and establish **Center for Hydrogen Energy Technologies**, creating conditions for the development of dynamically complex fundamental and technological research in the strategic topic of EU research and development.

Lithuanian Energy Institute participates not only in the projects of Structural Funds, supervised by the Ministry of Education and Science of the Republic of Lithuania, but also in the projects of Structural Funds, which are within the competence of the Ministry of Economy of the Republic of Lithuania. Successfully collaborating with SC *Naujas kalcitas* a new project **Scientific research of development and application in manufacturing of high calorificity materials and waste gasification technology, which reduces fuel input**, funded by the Lithuanian Business Support Agency and SC *Naujas kalcitas*, has been implemented since the beginning of 2007. The objective of the project – to create a technology, when gasifying used tires and other waste materials, the derived gas will be used in the process of lime production, replacing standard fuel by 30%. The Institute together with the Ministry of Economy of the Republic of Lithuania and Lithuanian Business Support Agency signed the agreement for implementation of Structural Funds project **Repair of heat transfer and nuclear facilities laboratory administrative building (10C 3/b) of Lithuanian Energy Institute**, the aim of which is to renew the laboratory-administrative building striving to improve thermal characteristics of the building and thus ensure more efficient consumption of thermal energy in the public sector.

Lithuanian Energy Institute is one of 19 partners who participates in

Lithuanian Science Council implemented project **Development and implementation of Natural Sciences postdoctoral traineeship**, the main objective of which is to create an organizational mode of postdoctoral traineeship, by implementing competitive mechanism of practices. The objective of the project is to develop and implement a system of postdoctoral traineeship, which would attract PhD students to scientific activity and would create conditions to begin independent scientific research.

In 2007 the Institute spent approximately one million Litass for the scientific equipment. From these funds Laser Doppler anemometer equipment, acoustic-optical spectrometre AOS4-1, analyser of hydrocarbons VE7HFID, analysis system of images, samples intake ISOSTACK, gas analyser TESTO 350XI, system of gas supply to reaction chamber and other equipment and specialized software were purchased. However, state-of-the-art experimental equipment and software itself do not ensure significant research results. Therefore, considerable attention was given to the increase of qualification and competence of scientists and to young gifted researchers.

In the recent years the tendency is observed that research institutions cannot expect contracts with industrial enterprises without having certificates from supervising institutions to implement a certain activity and not implementing Quality Management System in an institution, which satisfies the requirements of ISO 9000 series standards, and Environmental Management System, which satisfies the requirements of ISO 14000 series standards. Lithuanian Energy Institute was the first Lithuanian science and education institution to implement the Quality Management System and Environmental Management System. Lithuanian Standardization Department on the 17th of February of 2004 issued a Certificate Institute's Quality Management System, which satisfies the requirements of LST EN ISO 9001:2001. On the 15th of February of 2007 Lithuanian Standardization Department issued the certificate, which satisfies the requirements of LST EN ISO 14000:2005, also prolonged the validation time of Certificate LST EN ISO 9001:2001.

Laser Doppler anemometer



PHD STUDIES

Since 2003 Lithuanian Energy Institute has shared integrated PhD studies with Kaunas University of Technology in the following research directions:

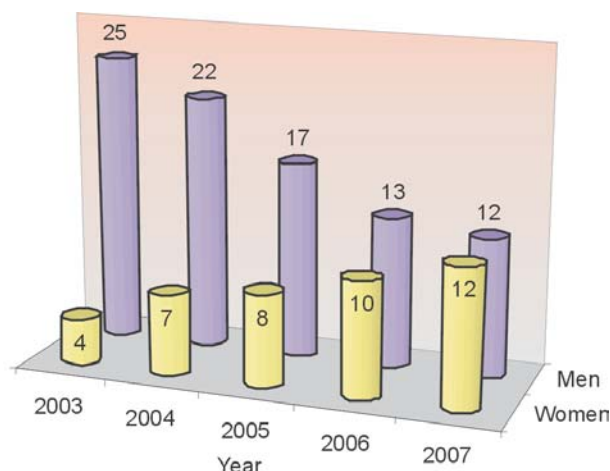
- Economics (04S);
- Environmental engineering and regional management (04T);
- Power and thermal engineering (06T).

In the period of 1992-2008 54 PhD candidates completed PhD studies, doctoral theses were defended by 37. In 2007 there were 24 PhD candidates.

In 2007 Kaunas University of Technology together with Lithuanian Energy Institute granted the Doctor of science degree to the following researchers of the institute:

- 28 February Arūnas STANKEVIČIUS for power and thermal engineering work **Investigation of influence of hydrodynamic factors to reproducing air volume and flow rate values;**
- 29 May Viktorija VALINČIŪTĖ for power and thermal engineering work **Research on plasma spray pyrolysis in the processes of coating synthesis;**
- 29 May Mindaugas VAIŠNORAS for power and thermal engineering work **Analysis of water hammer phenomena using RELAP5 code;**
- 27 December Arūnas SIRVYDAS for power and thermal engineering work **Investigation of mixed convection with opposing flows in a transition region of the vertical flat channel.**

On the 21st of December 2007 Vytautas Magnus University granted the Doctor of science degree to Regina ERLICKYTĖ for the work **Regularities of scots pine (*Pinus sylvestris* L.) radial increment formation due to variation of emissions of “Akmenės**

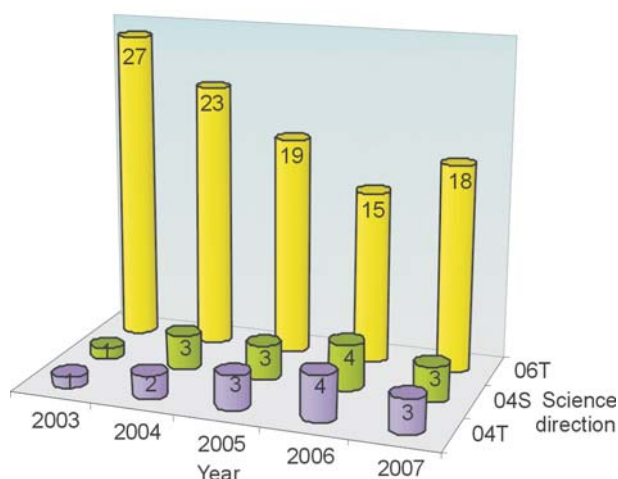


Structure of PhD Candidates' number in 2003–2007

“cementas” and “Achema” plants in the field of ecology and environmental management.

Lithuanian Academy of Sciences awarded Mr. Liutautas Marcinauskas for the scientific work **Formation of carbon coatings and modification of surfaces employing electric arc plasma**, submitted to young researchers competition. Mr. Mantas Povilaitis was awarded for his work **Modeling of plasma interaction with the first thermonuclear reactor wall** in the competition for university students in the field of technical sciences.

The annual conference **Youth Energy** aimed at PhD students and young scientists has been organized since 2004. It is aimed at educating young researchers' ability to present their ideas and research results in public, defend them reasonably and discuss, listen to remarks and recommendations of other scientists, prepare articles and get acquainted with works of their colleagues. PhD Candidates of other universities and institutes are invited to participate in the conference. In 2007 the conference was attended by 26 young scientists: 13 – from Lithuanian Energy Institute, 6 – Kaunas University of Technology, 2 – Vilnius Gediminas Technical University, 5 – A. V. Luikov Heat and Mass Transfer Institute (Belarus).



Arrangement of PhD Candidates of Lithuanian Energy Institute according to the science directions

Conference “Youth Energy 2007”



LABORATORY OF HEAT-EQUIPMENT RESEARCH AND TESTING

Head of the Laboratory –
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Main research areas and applied work of the Laboratory:

- provision of metrological support to the Lithuanian energy sector in the field of fluid flow measurements, establishment and maintenance of state flow standards and ensuring measurement traceability to national and international standards; test of thermal equipment and gas appliances carried out with the aim to determine its conformity to the requirements of Lithuanian and European normative documents;
- research of influence of liquid physical properties and flow disturbances on the metrological characteristics of reference and working volume and flow rate meters, operating under different principles. Proving the reliability of metrological characteristics of meters calibrated by fluids-substitutes for measuring real flow of technical and nutritional liquids;
- research, testing and conformity assessment of characteristics of measuring devices of liquid fuel, water, heat and gas, gas appliances and water heating boilers, heated with gaseous, liquid and solid fuel (including biofuel).

Accredited services of the Laboratory in conformity with LST EN ISO/IEC 17025 and 17020 standards:

- calibration of measuring instruments and facilities designed for their calibration/verification, tests and conformity assessment of measuring instruments and water heating boilers and gas appliances;
- testing and conformity assessment of gas appliances

and water heating boilers, heated with gaseous, liquid and solid fuel, including biofuel; in the field of gas appliances the Laboratory has been notified and granted the identification No 1621.

For testing and conformity assessments of water heating boilers the Laboratory meets the requirements of LST EN 303 - 5:2000.

Calibration and measuring capabilities of the Laboratory, confirmed and announced by the International Bureau of Weights and Measures (BIMP)

Quantity	Measuring range	Measuring conditions	Expanded uncertainty $\pm\%$	Type of reference facility
Gas volume and flow rate	0.016–6000 m ³ /h *0.005–9700 m ³ /h	Air, 20 \pm 2°C, atmospheric pressure	0.13–0.30	Facility with bell type prover, critical nozzles and reference meters
Gas flow velocity	0.20–60 m/s *0.05–60 m/s	Air, 20 \pm 2°C, atmospheric pressure	7.0–1.0 *50–7.0–1.0	Pitot tube, nozzles, ultrasonic anemometer
Water volume and flow rate	5–500 dm ³ 0.4–30 m ³ /h *5–1500 dm ³ *0.01–100 m ³ /h	Water, 20 \pm 5°C, pressure 0.45 MPa	0.08 0.12	Facility with balances and flow diverter
Volume of oil products	500–5000 dm ³ (1–120 m ³ /h)	Exxsol D80, 20 \pm 2°C, pressure 0.45 MPa, viscosity \leq 20 MPa·s	0.12	Facility with reference tanks (vessels) at "start - stop" regime

* Extensions of already accredited fields, but not presented for BIMP.



Research associates of the Laboratory (from left to right): A. Bertašienė, Dr. V. Janušas, A. Stankevičius, Dr. N. Pedišius, A. Bončkus, I. Briliūtė, Dr. G. Zygmantas, Dr. J. Tonkonogij, Dr. Habil. A. Pedišius, Dr. V. Ilgarubis (sitting)

Research of air (gas) velocity, volume and flow rate meters

Measurement of low air velocity values

Laser-Doppler anemometer (LDA) was used for the reproduction of air velocity units. Research was carried out to reduce the uncertainty of reproduction and transfer to working anemometers. The obtained results in low velocity range 0.05 - 5 m/s may be defined in the following way:

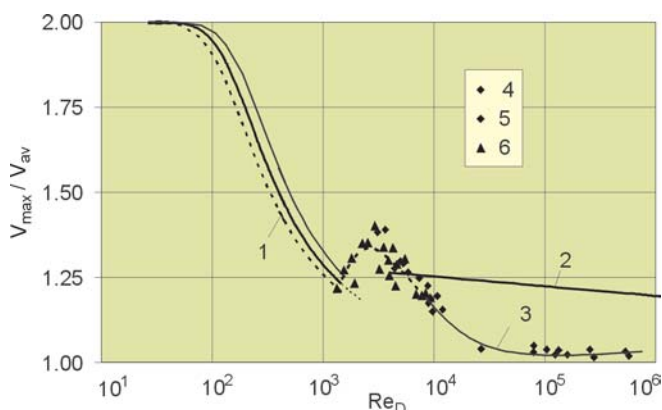
1. It is most expedient to employ wave methods in the state standard to reproduce velocity units, realized using LDA and ultrasonic anemometer (UA);
2. Though UA measures the average velocity in the channel cross-section, its resolution comprises 0.003 m/s, and from 0.03 m/s its readings become strongly alike the

values, calculated according flowing air volume measurement by meters, the volume measuring uncertainty of which comprises $\pm (0.15-0.30)\%$. Thus it may be successfully employed for the control of LDA reproduced local velocity values in accordance with experimentally determined relation between LDA and UA readings.

Such relation was experimentally determined and approved in the initial channel section for laminar and turbulent flow on the basis of regularity analysis.

Experimental measurements very well correlate with theoretical calculations and they reveal that while analyzing low velocities it is impossible to escape transitional flow regularities.

In the beginning of transitional flow, at $Re_D = 10^3-2 \cdot 10^3$, and in the end of it, at $Re_D = 4 \cdot 10^3$, the relation of maximum and average



Variation regularities of maximum and average velocities ratio in the initial region of the round channel:

- 1 – laminar flow solution at $x/D = 2.5$, 3 or 3.75 from the bottom curve, respectively;
- 2 – developed turbulent flow;
- 3 – solutions of turbulent flow in the initial region according FLUENT 6.1 code;
- 4–6 – experimental measurements of velocity distribution

velocities comes to rather stable asymptotic values, present in the interval 1.24 – 1.26. Determined change of velocity distribution supplements fundamental hydrodynamic regularities in the transitional flow regime. Tentatively this enables to make a conclusion that after performing the analysis of experimental and calculation results, it is possible to approach the values and their uncertainties, indicated in the table:

Velocity, m/s	Current level of uncertainties ± %	Forecasted uncertainties ± %
0.05	50	20
0.2	7.0	3.5
3	3.0	1.0
30	1.0	0.3
60	1.0	0.3

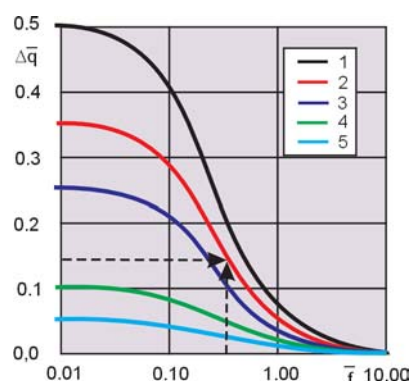
Research of turbine gas meters

Error evaluation method of turbine gas meters, suggested in the report of 2006, was improved in 2007, after introducing T related to meter inertia time instead of Furje criterion, since it may be easily determined using an experiment and takes into account all parameters which influence the process. The response of several turbine gas meters to sudden flow rate change was investigated and change of time constant T was defined.

This improved method was employed to evaluate the influence of any flow pulsation nature. Calculation results are defined using dependence $\delta \equiv 1 - \exp(-k \cdot \bar{f})$, and they reveal that nondimensional meter error $\bar{\delta} \equiv \delta / \delta_{rib}$ depends only from nondimensional pulsation frequency $\bar{f} \equiv f \cdot T$ and changes according to the exponential law. The law little depends from k and it may be assumed that $k = 5.2$.

The obtained results, according to the measured turbine meter frequency fluctuation, enable to determine the flow rate fluctuation and correction for the flow rate value, measured by the

meter, which is very important in practice, in explaining the causes of differences of real gas consumption and measured with meters.



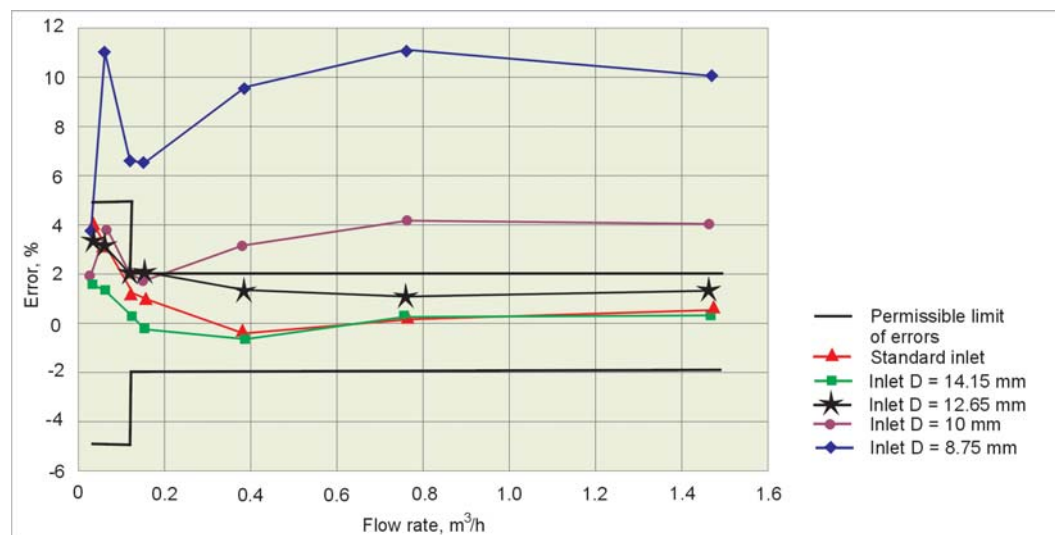
Dependence of turbine meter readings on the frequency of flow rate pulsations: 1–5 – nondimensional amplitude of flow rate pulsation 0.05, 0.10, 0.25, 0.35 and 0.50, respectively

Research of liquid (water and oil products) meters

Research of the impact of physical properties of liquids and installation conditions of meters on the accuracy of measurement was continued in 2007.

It was determined that improperly installed domestic water meters do not always satisfy the metrological requirements. Rotation of vane type single-jet water meters at 45° and 90° around vertical axis always causes bigger negative error, which exceeds the biggest permissible errors in the field of low flow rates.

Research reveals that after changing the entrance diameter and its cross-section area, respectively in the ranges 1.011 – 0.625 and 1.021 – 0.391, due to the reduction of entrance cross-section the error curve always moves to the positive side. In the



Additional errors of vane type single-jet water meter due to inflow cross-section contraction

investigated cases, the variation of van type single-jet meter errors reached up to 20% for the disadvantage of a consumer. Positive displacement meters are least sensitive to installation conditions.

The impact of viscosity variations of oil products depending on their type (diesel fuel and petrol of different type) and temperature on measuring errors of positive displacement meters was investigated. Recalculation calibration curve of positive displacement meter depending on viscosity variation range (which in many cases differs from the calibration results presented by a producer) must be determined in order to ensure the measurement accuracy.

Taking into account future demands, the preliminary analysis of works, related to measurements of hydrogen consumption, was carried out.

International comparisons of measurements

In the field of gas volume and velocity measurement 3 international comparisons according to international projects COOMET No 219/Sk - 0B and No 219/Sk - 0A and EURAMET No M.FF - K3 were completed.

The first comparison, where participated three EURAMET members, i.e. LEI (Lithuania), SMU (Slovakia) and PTB (Germany) as well as COOMET members – Belgim (Belarus), VTML (Ukraine) and FGUP VNIIR (Russia), was carried out to investigate measuring capabilities of turbine gas meters in the range from 100 to 1000 m³/h.

The second comparison was carried out to investigate measuring capabilities of small domestic diaphragm gas meters in the range from 0.12 to 10 m³/h.

Measuring capabilities of Laboratory standards correlated well with reference values, which were presented by national laboratory, responsible for comparisons.

The Laboratory also completed the comparisons among Lithuanian laboratories, involved into water and gas meters verification to ensure that their services guarantee the accounting accuracy of important resources.

Research of water heating boilers, burning wood fuel

In 2007 the Laboratory accredited the tests of water heating boilers, burning solid fuel, including wood, in accordance to all LST EN 303 - 5:2000 requirements and conformity assessment to these requirements. The facility was supplemented with the up-to-date measuring system of solid particles present in smoke. Thus the only technical facility of such kind, which confirms the requirements of European standards, was developed in Lithuania.

The parameters of efficiency and emission with smoke gas of two types of boilers, burning wood pellets and firewood, were investigated.

Other activities

Researchers of the Laboratory, besides testing, calibration and validations, performed the following activities:

- prepared a document project, regulating sampling verification procedure of gas meters in Lithuania;
- carried out 15 expert assessments according to contracts with different Lithuanian organizations;
- published 5 articles in reviewed journals, presented 4 papers in international conferences (2 of which published in conference proceedings) and 6 papers in conferences in Lithuania;
- research associate Arūnas Stankevičius was granted Doctor of Science degree;
- the cycle of works *Development of state standards and experimental facilities for reproduction of liquid, gas and heat values as well as for research and testing of their measuring instruments (1995–2006)* by a group of researchers (Dr. Habil. A. Pedišius, Dr. J. Tonkonogij, Dr. G. Zygmantas and Dr. N. Pedišius) was submitted to the competition of Lithuanian Science awards 2007 by Lithuanian Energy Institute, State Metrology Service, SC *Lietuvos dujos*, Energy Agency, and Lithuanian Association of Heat Energy suppliers.



LABORATORY OF COMBUSTION PROCESSES

Head of the Laboratory –

Prof. Dr. Habil. Anupras ŠLANČIAUSKAS

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Main research areas of the Laboratory:

- efficiency increase of combustion processes;
- creation and development of burners;
- research of hydrogen separation from organic fuel;
- experimental research of solid waste utilization-gasification;
- numerical modelling of granular media.

Utilization of glycerol fraction derived from biodiesel production

In accordance with the requirements of the EU, the amounts of biodiesel production are currently being expanded. As the amount of this biofuel increases, so does the amount of its by-product – glycerol. In order to present efficient solutions for utilization of glycerol fraction, an international consortium of diverse erudition, qualifications and experience was formed, under the international EUREKA project *Utilization of glycerol fraction derived from biodiesel production* (E13590 Use-Glycerol). This consortium consists of Polish, Lithuanian, Spanish and Cypriot science research institutions, universities and small and medium enterprises.

Key tasks of the Laboratory of Combustion Processes:

- to perform thermal decomposition research of glycerol phase, the objective of which is to develop autothermal glycerol conversion process to separate hydrogen.
- to perform glycerol combustion research, the objective of which is to develop a burner to burn glycerol fractions.

An experimental research setup was developed, where gas copiously enriched with hydrogen can be produced by gasification of byproduct of biodiesel production – glycerol – in optimum conditions. Measurements with pure glycerine and glycerol taken from various technological locations of the biodiesel production plant and containing real water and methanol impurities were performed. It has been determined that in case of partial oxidation the largest amount of hydrogen (22.3 vol. %) is produced by reforming the low-purity glycerol fraction, and in case of autothermal reforming – by reforming pure glycerine (29.1 vol%). Presence of water in glycerol fraction reduces concentration of hydrogen and especially CO in the reaction products. It has been determined that lighter hydrocarbons CH_4 and C_2H_4 are produced by converting pure glycerine.

An experimental burner of 40 kW power for mixed fuel, natural gas and glycerol fraction, was designed, fabricated and installed in 2007. The initial tests of glycerol combustion demonstrated that in case of properly adjusted burning process, glycerol is completely combusted to $\text{CO} \sim 100 \text{ mg/m}^3$, $\text{NO}_x \sim 90 \text{ mg/m}^3$, $\text{SO}_2 \sim 0 \text{ mg/m}^3$ residual concentrations throughout the entire load range. However, measurements of content of solid particles in the

flue gas detected especially high concentrations amounting to 14.5 g/m^3 . X-ray diffraction analysis of these particles revealed that the structure of the produced white particles is mostly consistent with the crystallographic structure of sodium pyrophosphate $\text{Na}_4\text{P}_2\text{O}_7$. This substance sticks to the heating surfaces of the boiler, and the resulting layer of deposits degrades heat transfer efficiency.

Initial experimental combustion tests were carried out with the partner JSC *Tauragės šilumos tinklai*. If part of thermal or electrical energy was produced with partial substitution of the usual sulphurous fuel by glycerol, pollutant emissions from the fuel burning facilities could be reduced. This effect is confirmed by experimental combustion tests with the mixture of glycerol–shale oil carried out in the plant. Combustion of glycerol with sulphurous shale oil reduced amounts of emissions of SO_2 (from 1300 mg/m^3 to 600 mg/m^3), NO_x (from 250 mg/m^3 to 200 mg/m^3).

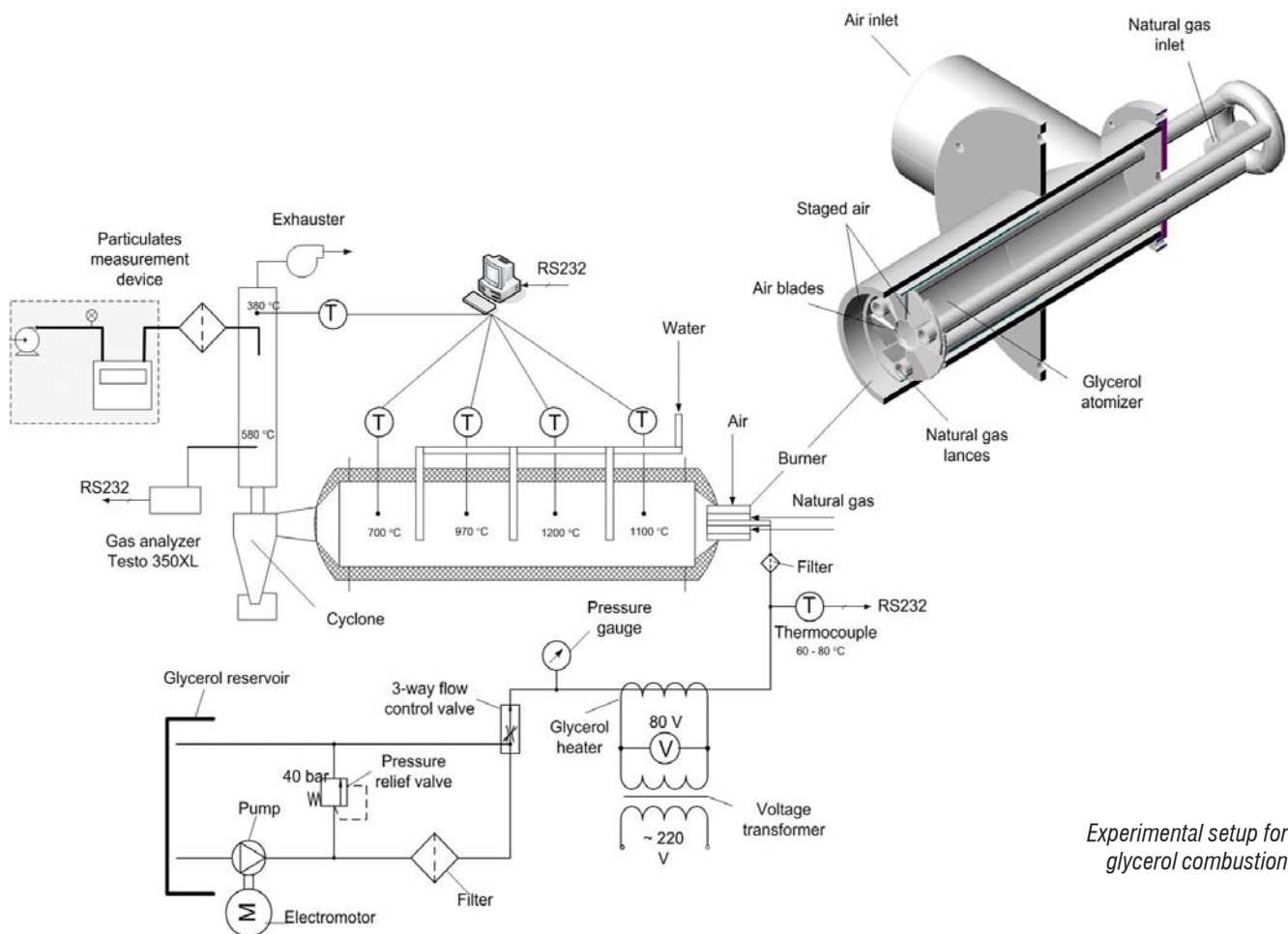


Meeting of participants of the international EUREKA project E13590 Use-Glycerol. (November 22, 2007, Eibar, Spain)

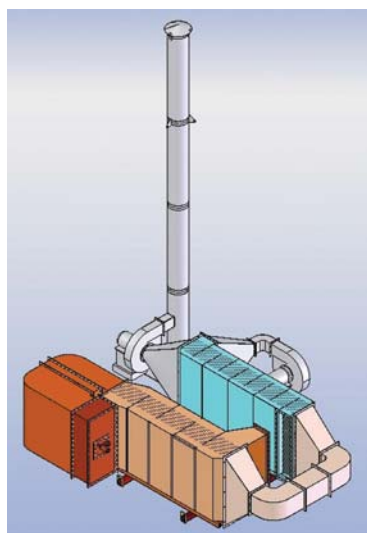
Applied works for industry

Liquid fuel burners are continuously reconstructed and improved in the laboratory because environmentally-friendly combustion of this type of fuel is troublesome, low emissions of NO_x , CO and solid particles must be achieved. The boiler KVGM-20 in Šilutė district heating facility was upgraded.

Development of a novel incineration device was completed this year: burn out of odours and recirculation of heat produced by incineration of varnishes back to production. This is an environmentally-oriented device enabling considerable savings of pro-



cess heat. It is based on incineration of air polluted with volatile substances and a consequent economical system of heat exchangers and gas flow control.

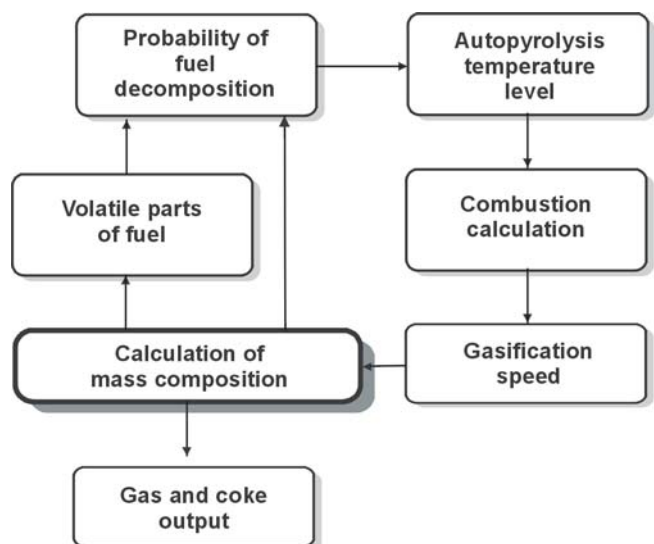


General view of volatile organic compounds incineration device for flue gas treatment.

Research of organic fuel gasification

Gasification by autopyrolysis is combustion of a portion of the fuel in an insulated reactor and evaporation of volatile components from the total amount of the fuel at preferably high temperatures.

A methodology for gasification process calculation of high-calorie waste is developed. It is an iterative calculation relating the content of volatile compounds in fuel, probabilities of chemical compounds, level of autopyrolysis, combustion heat and mass balance, gasification rate (capacity) according to the surface exchange. These calculations yield the most essential parameters of the gasification process: amount of produced gas, its temperature, gas calorie content, relations between the air and fuel flows and the gas yield. This methodology is applicable for development of technologies for biofuel and high-calorie waste gasification.



Calculation process of fuel gasification

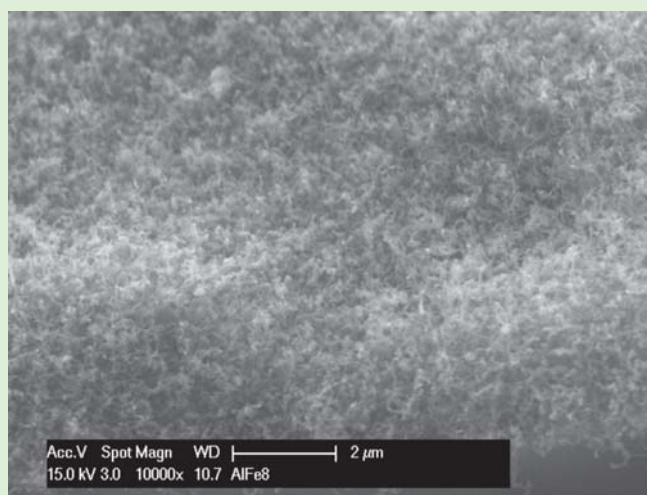
Research of carbon nanostructures

Research of carbon nanotubes (CNT) attracts much attention, but their application is limited by complex fabrication process and low yield. Therefore, it is important to advance technologies for their growth on various surfaces, as well as catalyst and surface preparation. Research of CNT synthesis using nichrome catalyst was carried out. Synthesis was performed in the air, and significance of oxygen for catalyst particle formation from the substrate was established. Carbidization or oxidation of metal surface changes the lattice constants of metal grains situated at the metal surface (compared to those in the bulk), therefore, the surface metal grains shift with respect to each other at the sites of defects or grain boundaries, where the strains are the largest. Metal grains can also split into smaller particles due to effect of dissolved carbon and oxygen. In this way, particles of nanometer size required for CNT synthesis are created. The diameter of the obtained nanotubes is 50–100 nm, the length is approximately 60 μm , the growth rate approximately 10 $\mu\text{m}/\text{min}$. Dependence of CNT amount upon the temperature was established. The distance between the atom layers is consistent with the distance between the graphene sheets indicated in literature. By changing the temperature and process conditions, abrupt changes of the nanotube

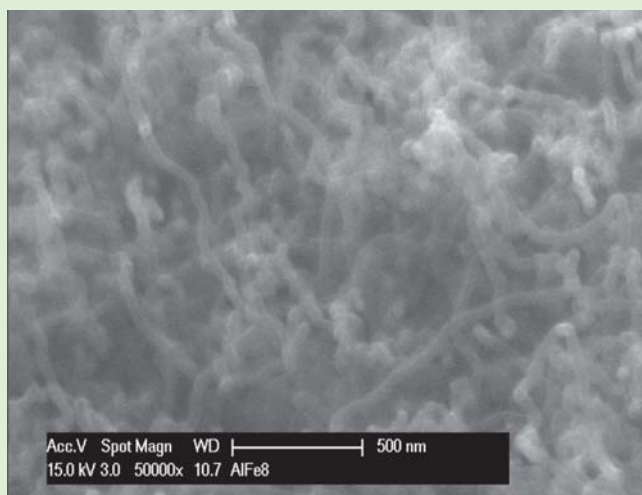
diameter by a factor of two or more can be achieved on the same structure.

In order to determine mechanical properties of the fabricated CNTs, tests by an atomic force microscope were carried out. The calculated elastic modulus of 0.56 GPa is rather small, which is characteristic of CNT with large diameters and large amount of defects in the structure of the nanotube wall.

In order to obtain a layer of vertically oriented CNTs (a CNT forest), it is very important to prepare properly the catalyst, because catalytic particles with the diameters similar to that of the CNT are necessary for CNT growth. These catalytic particles must not merge into the larger ones at the reaction temperature, therefore, various protective coatings are applied that inhibit the motion of the catalytic particles during the synthesis. Catalyst production by chemical synthesis is attractive due to its simplicity, the possibility to produce the catalyst particles of exact sizes, applicability to mass production. The optimum reaction conditions were established that differ from those required in case of mass CNT synthesis, because in order to obtain vertical orientation, simultaneous oversaturation of the catalyst particles is required.



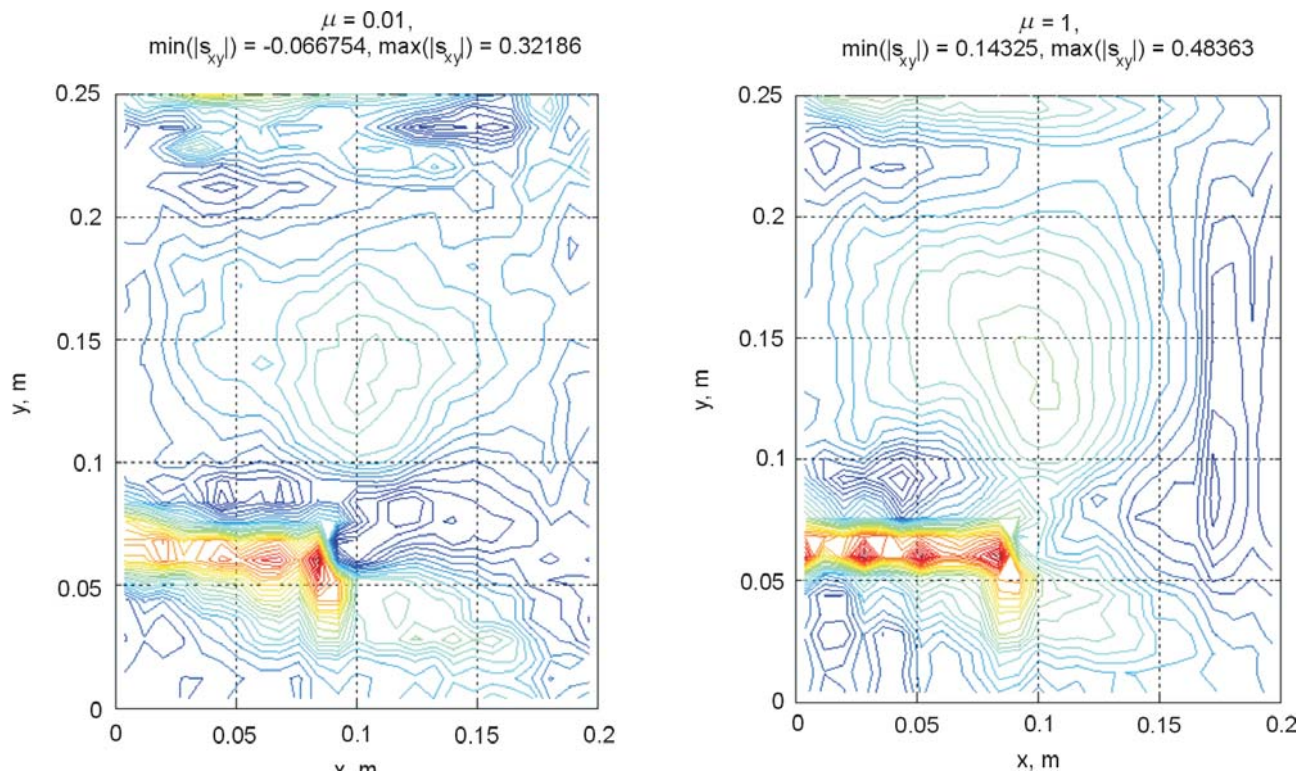
Nanotubes, obtained using Fe – Al catalyst



Simulation of mixing, segregation and combustion of granular media

Processes of mixing and segregation are among the most important ones characterising behaviour of granular matter in mechanical and other systems. On the other hand, there is no sufficient theory to describe the movement of granular materials. Mixing and segregation are also important in the solid fuel combustion process. For this purpose, using the software developed earlier, numerical simulation of mixing and segregation of granular matter was performed in order to examine the mixing process and segregation intensity taking into account the mechanical properties of the particle material. Various theories were suggested to explain segregation in granular materials, but different mechanisms can prevail at different conditions, besides,

different mechanisms can manifest themselves simultaneously. The particles mix in the bulk of the material. Two types of the mixing processes can be identified – the “convective” mixing defined by the mean velocity of the material as the particles move inside the bulk due to the mean flow, and the “local” mixing, when separate particles exchange places with the neighbouring particles. It has been determined that mixing is more intense at higher values of the dynamic friction coefficient, and more intense mixing results in faster segregation. This dependence on the dynamic friction coefficient is similar to the case of fluid dynamics, where mixing is more intense in more viscous fluids. However, intensity of mixing increases significantly at low friction between the particles. This nonmonotonous dependence might indicate that segregation takes place due to different mechanisms that prevail at different material properties.

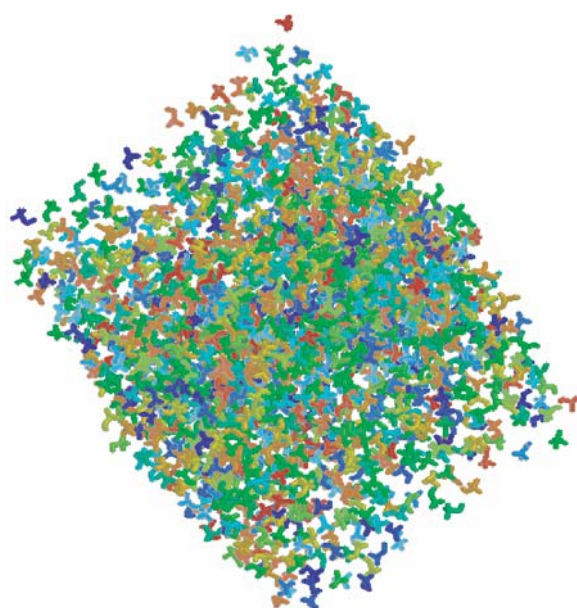


Distribution of vorticity in granular media at low (left) and high (right) values of dynamic friction coefficient

Molecular dynamics

Molecular dynamics is the simulation method used to determine the material properties, based on solution of equations of motion of microscopic constituent particles, taking into account their interactions. Depending on the nature of the simulated materials, the particles used as the elementary units might be atoms, molecules, functional groups (e.g. such as hydroxyl group

– OH, methyl group – CH₃, aminoacid residues, etc.) or the virtual particles (spatially localized electric charges, in order to account for additional particle interactions). Molecular dynamics (MD) is related to the discrete element method. The same numerical methods are applied for solving the equations of motion, however, the description of particle interactions is essentially different: long-range electrostatic interactions must be included in MD, besides, molecular structure must be taken into account, including vibrational molecular excitations. As the available computational resources increase, molecular dynamics is ever more widely applied in various fields of chemical engineering. Application of the methods of MD is initiated to examine the combustion processes in more detail, determining the properties of various components (liquid and gaseous hydrocarbons and other fuel components, combustion products) at different reaction conditions.



Instantaneous image of methanol molecules position during modelling

In 2007 researchers of the Laboratory presented 1 paper in international and 3 papers in Lithuanian conferences, published 3 scientific articles in publications, listed into international databases of Lithuanian Science Council and 1 article in the publication, included into the list of Institute of Scientific Information.

LABORATORY OF MATERIALS RESEARCH AND TESTING

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Main research areas of the Laboratory:

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

Due to diversity of research direction the Laboratory is comprised of three divisions: Surface Engineering, Materials Testing and Plasma Technologies.

Division of Surface Engineering

Research in the field of hydrogen energy

In 2007 researchers of the Laboratory continued works in the field of hydrogen energy. Two international projects of the Sixth Framework Programme were successfully completed: **FET – EEU** (implemented in 2005–2007) and **NENNET** (2004–2007). During the first project, researchers of Lithuanian Energy Institute made new contacts and retained old ones with Lithuanian and international institutions. After NENNET completion, it was stated that its implementation was successful and provided the following outcome: enabled to unify Lithuanian science forces in the field of

hydrogen energy aiming at generating new knowledge and successfully participating in European Research Area. This project as well as successfully continued EU Structural funds project **Organization of hydrogen energy technologies training**, implemented by Lithuanian Energy Institute and Vytautas Magnus University, directly contributed to the tender for receiving the financial support from the European Structural Funds. The support has been confirmed and implemented – the **Center for Hydrogen Energy Technologies** will be equipped in the Laboratory base.

Besides mentioned Sixth Framework Programme projects, Doctoral studies are carried out in FP6 Marie Curie HYTRAIN project together with JRC Institute for Energy (The Netherlands) and Vytautas Magnus University (Lithuania). Researchers of the Laboratory actively participate in **International Theronuclear Energy (FUSION) project: Characterization of tungsten coatings, used in theronuclear synthesis reactors**, during which tungsten and tungsten carbide coatings are composed, and thorough research of their properties is carried out.



Employees of the Laboratory working in the field of hydrogen energy

Instead of completed NENNET and FET – EEU projects, a new Sixth Framework Programme two-year specific support action project **HYSIC: Enhancing International Cooperation in Running FP6 Hydrogen Solid Storage Activities** has been started. Cooperation with foreign researchers working in the field of hydrogen storage is promoted and developed, exchange of samples, data and knowledge is initiated.

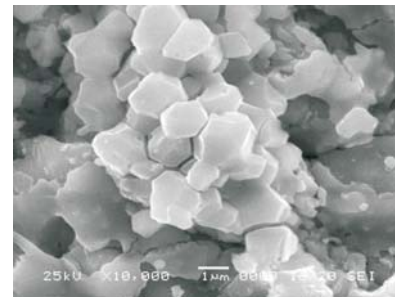
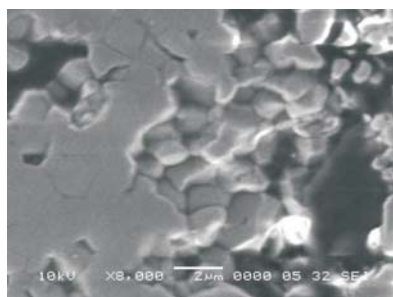
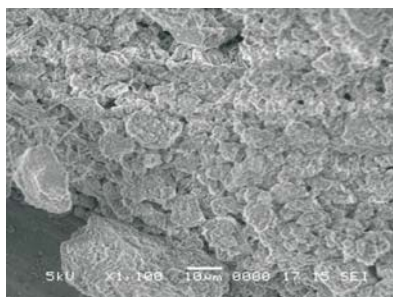
Continuing the cooperation with partners from Nordic countries, works were initiated in the new network project of Nordic countries energy research – **Nordic Center of Excellence for Hydrogen Storage Materials**.

In 2007 the researchers of the laboratory participated in the research of the 22nd group of International Energy Agency Hydrogen Implementing agreement (IEA HIA) – **Fundamental and Applied Development of Materials for Hydrogen Storage**. The obtained results were presented in international conferences, seminars and published in science journals.

Researchers of the division actively participate in the following **COST** programs: **the COST Action 542 Efficient Energy Storage for Mobile and Stationary Equipment**.

Main types of supercondensers and used materials were

introduced, research concerning replacement of expensive metal (Pt, Pd) catalysts with Ni / NiO thin layer structures was carried out. Application of industrial thin layer carbon structures, obtained using plasma spray methods and TiOx thin layer structures, obtained using magnetron sputtering methods on graphite GR 280 in supercondenser electrode synthesis was investigated. Use of these materials in the future should significantly reduce the cost price of supercondensers. Obtained materials and structures were analysed using X-ray diffraction and scanning electronic microscopy methods. Measuring scheme of condenser volume was constructed. First research of volume measurement was carried out.



SEM pictures of synthesis products. Combustion temperature: a – 1000°C, b – 1200°C, c – 1400°C

Division of Materials Testing

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

In 2007, the possibilities to synthesize yttrium oxide stabilized zirconium powder (YSZ) were investigated and the possibilities to use them for dense zirconium oxide ceramics, used in thin layer oxide fuel cell constructions, and to compose ceramic coatings, were analysed. Chemical analytically pure powder retraction method was chosen for the general precipitation of components out of saline deliquescent in water. Chemically sintered YSZ powder was investigated using the scanning electronic microscopy and X-ray diffractometer, main characteristics of their structure were determined. Thermal processes occurring in the material at 100–1000°C were analysed additionally, the phase composition of powder after combustion was determined, the impact of temperature on the properties of retrieved ceramics was analysed. Optimal technological conditions to compose dense YSZ ceramics from sintered powder using semi dry pressure method were found. After combustion at high temperature the ceramics were retrieved, the relative density of which account for 96.8%. The stability of obtained ceramics characteristics in SOFC operation temperature was investigated thermally processing samples at 1000°C. During research significant changes of structure and phase composition were not determined. During additional research the possibility to use sintered powder for the composition of plasma coatings was analysed.

Long-term materials for artificial joints, performed in the frame of COST 533

One of the directions of scientific activities of the institute is to perform research of technologies of material durability and new multifunctional materials. Laboratory of Materials Research

and Testing joined the second and third work groups of COST 533. Participating in the work of the work groups, the technology of bioinert titanium oxide coating formation on the titanium steel trays was mastered. Research was carried out by plasma spray method forming resistant to attrition and long-term bioinert zirconium oxide coatings of tetragonic structure on the titanium steel trays for the development of artificial joints. The structure and properties of coatings were investigated. Experiments of coating attrition and qualitative abrasion methods were carried out, terminological characteristics of coatings and surface roughness were estimated.

Materials testing and assessment of their qualitative indicators

The Laboratory is accredited to carry out tests of plastic and insulated pipes, building mortars, polymer bitumen sheeting, thermal insulating products, refractory materials and products. Constant renewable of technical investigations basis enables to carry out building products testing in accordance with the requirements of International and European standards.



In 2007 the Laboratory continued research of hydrogen and hydrides degradation impact on mechanical and physical properties of zirconium-based alloys. The Laboratory works together with Ignalina NPP. The Laboratory participates in International Atomic Energy Agency (IAEA) coordinated project **Slow hydrogen-induced cracking of fuel cell zirconium-based alloy**. The objective of the project is to develop recurrent experimental procedures which will enable to assess velocity of slow hydrogen-induced cracking in zirconium-based alloy fuel cell tubes. Conditions of hydrogen-induced cracking and its fragmentation are investigated under different conditions employing specific geometric samples and devices.

Research of metal ageing processes and properties degradation under the impact of operation factors

Works are carried out in investigating metal ageing processes, which take place in operating facilities of thermal power plants at high temperatures and under the impact of tensions. A great deal of attention is given to the application of state-of-the-art methods, on the basis of which it would be possible to estimate the real remaining operation reserve of constructional elements.

On the basis of obtained experimental data and applying numerical methods and taking into account operation conditions, the operation reserve of separate facilities or their construction elements is determined.

In 2007 initiated project **Justification of Ignalina NPP Unit 1 safety system servo-drives operation reserve** is carried out in the Laboratory of Materials Research and Testing and in the Laboratory of Nuclear Installation Safety. Specific complex experiments of rapid emergency safety system servo-drives, calculations and statistical reliability assessment are carried out to determine the real unexhausted reserve of servo-drives.

The COST Action 538: High Temperature Plant Lifetime Extension is carried out, with the participation of 17 European countries. The investigation of the surface microstructure of heat resistant steel 12X1MO samples, aged under laboratory conditions and operated in the production, using optical and scanning electronic microscopy was carried out. Variations of steel structure were estimated and compared with the experimental results of X-ray diffraction. Variations of carbide compositions and sequence of their composition were estimated qualitatively and quantitatively during the experiments.

Division of Plasma Technologies

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

The following activities are carried out in the Division of Plasma Technologies:

- development and research of constant current plasma sources;
- research of processes and phenomena taking place in reaction arc zone and low-temperature plasma;
- research of dynamics and heat-mass transfer processes of high-temperature gas flows in atmosphere and reduced pressure environments;
- plasma and high-temperature flows diagnostics and development of diagnostics measures;
- research of plasma pyrolysis and plasma process of hazardous materials neutralization and assessment of its lifetime cycle;
- research and employment of plasma spray pyrolysis process;
- synthesis of catalytic and tribologic coatings and properties analysis;
- research of thermal and heterogenic processes when reacting combustion products outflow the catalytic surface;
- plasma neutralization of extra hazardous materials;

- synthesis of micro and nano dispersed granules and mineral splint from hardly alloyed materials and investigation of properties.

Researchers from the division of Plasma Technologies perform state funded work **Research of high-temperature spray pyrolysis process, designed for plasma synthesis of coatings**. Its objective is by using numerical and experimental methods to investigate consistent patterns of plasma spray pyrolysis during catalytic and tribologic coatings synthesis under plasma flow of various composition reacting gas with dispersed particles aiming to improve the quality and properties of composed coatings.

Performing scientific experiments the reactor was created to burn extra hazardous materials, which satisfies the environmental requirements and conditions. Its technical characteristics were determined, experimental plasma equipment with current



plasma-chemical reactor and plasma generator was manufactured.

Research of plasma coatings' composition and their properties are carried out. Plasma equipment, designed for the composition of protective, solidified and catalytic coatings, was used. Active aluminium oxide, carbon compounds, diamond-like carbon and various catalytic coatings, the specific surface of which reaches 100 m²/g, were obtained. The mechanisms which generated combustion products jet of permanent characteristics as well as a new methodology for the investigation of catalytic properties of coatings and mass transfer processes near the active wall surface were created.

The impact of ceramics chemical composition, structure, limit thickness, crystallite orientation, number of defects and impurities on its electric conductivity was analysed together with researchers from other European countries. Yttrium stabilized zirconium oxide coatings were composed, their structure and properties were analysed. The dependence of structure, phase composition of obtained coatings and size of crystallites on the parameters of plasma process and conditions of thermal processing was determined.

Plasma nitriding process, which significantly increases the solidity of the surface and substantially reduces the frictional coefficient of the surface, was realized to change the properties of surface layers of stainless steel constructional materials. It was suggested the nitriding process to realize in atmospheric pressure plasma current, in which the concentration of nitrogen 3–4 times exceeds the concentration of nitrogen ions in rarefied gas plasma. In such case, the nitriding process would be economical, whereas expensive vacuum technology would not be needed.

Researchers from the division of plasma technologies participate in the following international programs and projects:

- **COST D41 action *Inorganic oxides: surfaces and boundary layers***, till 2010. This action is related with metal oxides coatings synthesis processes and research of their surfaces and internal structure. Its main objective is to improve scientific knowledge on the properties of oxide coating surfaces and structure at microscopic level, applying theoretical knowledge and practical experience to investigate measures and methods, which enable to create the coatings of desirable properties, to control the deposition process. 16 European countries participate in the activity.
- **Eureka project *E!3539 State-of-the-art manufacturing methods of mineral splint from local raw materials and waste***, (initiated and coordinate by division researchers), till 2009. It is suggested to realise the

development of mineral splint and granules in atmospheric pressure air plasma current reactor, in which high temperature and high concentration of active ions are achieved. Performed research reveals that the main factor, which conditions the process efficiency is the flow of atoms and molecules activated in plasma. Developed experimental plasmachemical facility, designed for the research of Si, Mg, Ca and Al oxides and their compounds processes. The splint, diameter of which is 0.5–2 μm, is developed in plasma reactor, with constant current plasma generator. The cooperation proceeds with researchers from Catania University (Italy) and JSC *Termotechnika* (Lithuania).

- Bilateral cooperation programme between Lithuania and Ukraine 2007–2008:

Project ***Equilibrium characteristics research of atmosphere and reduced pressure plasma, used for modification of material surfaces and fuel conversion***. The work is designed for the research of dynamic and thermal characteristics of atmosphere and reduced pressure plasma, used for the synthesis of catalytic and tribologic coatings and solid fuel conversion into gaseous in facilities. Plasma condition issue is analysed, measuring methods of plasma current parameters are developed, dynamics and heat transfer of plasma currents are investigated, properties of plasma generators and plasma are identified, possibilities to create specific plasma generators to realize processes of coating composition are analysed. Common projects are carried out together with Ukraine Gas Institute (Ukraine, Kiev).

Project ***Plasma technology development for ultradispersed particles synthesis and coatings with specific properties***. While performing this project and cooperating with researchers from Odessa National University, technology of dispersed particles synthesis in electric arc and plasma flow is developed, the problem of symmetric ultradispersed particles mixture with plasma forming gas and introduction to plasma flow is solved, porous coatings of high specific surface, designed for micro and nanostructural catalysts, are developed.

In 2007 researchers of the Laboratory actively participated in different training programs, presented 5 papers in international and 7 papers in Lithuanian conferences, published 21 scientific article in Lithuanian and international journals and other publications.

LABORATORY OF NUCLEAR ENGINEERING

Head of the Laboratory –
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Eksperimental facility to investigate mixed convection in inclined channels

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

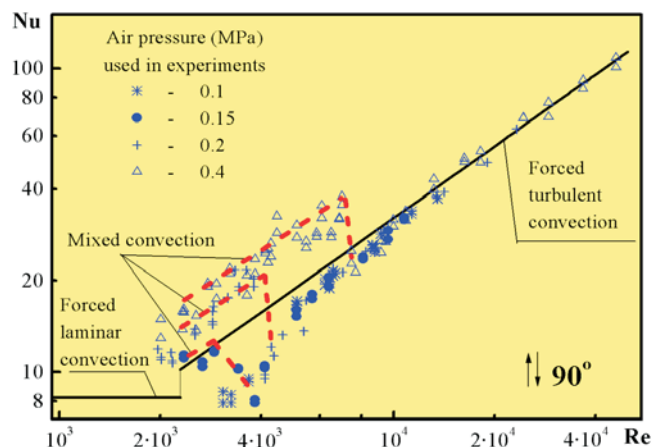
The Laboratory has a comprehensive experience of 30 years in investigations of heat transfer and flow hydrodynamics in different components of energy facilities, whereas in the recent years in geological structures and shafts as well. It is observed that in many energy facilities the impact of thermogravitational forces is manifested in cases of laminar and turbulent flows. Under certain conditions the impact evoked by thermogravitational forces on heat transfer usually becomes a reason for accidents in different facilities. Thus mixed convection scientific research has been begun since 1985 in the Laboratory (originally in pipes, later (2002) in flat channels as well).

In 2007 experimental and numerical investigations in vertical flat channel in transitional flow zone were continued. The results of experimental and numerical investigations in transitional flow zone for aiding and opposing flows were analysed and correlated. Obtained heat transfer and flow hydrodynamics results in case of mixed convection for opposing flows fundamentally change the understanding concerning the laminar flow transition to the turbulent under the impact of thermogravitational forces.

Main research areas of the Laboratory:

- experimental investigation of heat transfer and turbulent transport regularities 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 transfer and turbulent transport in single-phase flows in various channels and geological structures;
- management of spent nuclear fuel: modelling of fuel characteristics, safety and environmental impact assessment of storage and disposal facilities, normative and legislative base;
- management of radioactive waste: strategy, safety and environmental impact assessments of treatment technologies and storage and disposal facilities, normative and legislative base;
- evaluation of different factors related to decommissioning of nuclear power plants: planning 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 with construction of new nuclear power plant in Lithuania.

Numerical modeling under different cases of mixed convection was carried out applying FLUENT (USA) code, which also is used performing heat transfer modeling in geological repositories in accordance with international project implemented together with International Atomic Energy Agency (IAEA).



Heat transfer in stabilised region of the vertical flat channel in case of mixed convection with opposing flows (points – experimental data)

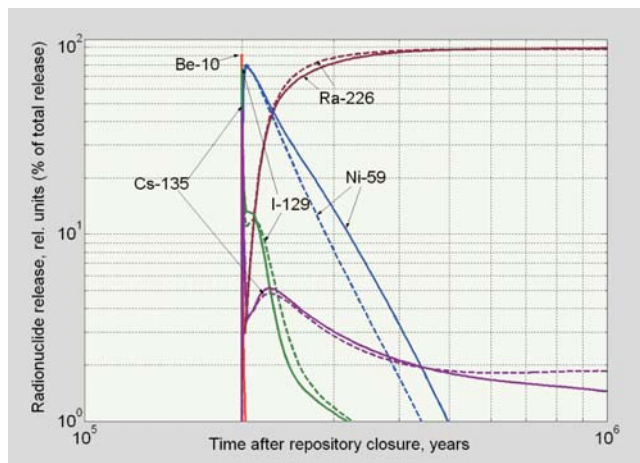
Management of spent nuclear fuel (SNF)

Specialists of the Laboratory for a number of years have been performing scientific research related with management and disposal of spent nuclear fuel. The dry interim storage facility for SNF at Ignalina NPP with CASTOR RBMK-1500 and CONSTOR RBMK-1500 type casks was commissioned in 1999. The Laboratory has been performing studies related to the safety assessment of SNF storage and disposal. The Laboratory carried out criticality assessments for the casks of normal and extended capacity with fresh and burned-up nuclear fuel under normal operational and accident conditions, variation of radioactive nuclides activity during the interim storage period, radiation doses on the cask surface and at the specific distance from it, and temperatures of the cask.

Implementing research on SNF disposal in Lithuania (***The Assessment Programme of the Possibility of Spent Nuclear Fuel and Long-lived Radioactive Waste Disposal in Lithuania (2003–2007)***), the Laboratory experts with the assistance of Swedish experts, proposed the generic concepts of deep geological repository in clay and in crystal rocks in Lithuania, performed assessment of geological repository costs and initiated the generic repository safety assessment. Concepts are constantly revised and optimised taking into account international experience and physical, chemical, thermal and mechanical properties of a specific repository site. While analyzing possibilities of SNF disposal in Lithuania, the costs assessment of geological repository installation was carried out and generic repository safety assessment was initiated, various scenarios of repository evolution were analysed: supposing the present conditions remain in the repository environment, one container happens to be leaky, climate conditions change.

In 2007 research related to radionuclides dispersion and processes influencing it in the far field of the repository (geosphere) were continued aiming to more optimally evaluate the impact of geosphere on the safety of SNF repository. Research was carried out with the researchers from other countries (the coordinator – IAEA). Data of Veresnia site (Ukraine) were used. Evaluating different flow conditions of underground water in different geological formations, the geofiltration nature of underground water under respective conditions was determined. Preliminary results of numerical evaluation revealed that if radionuclides (in this case unsorbed long-lived iodine isotope ^{129}I) were dispersed from one repository container with defect (which becomes larger 200 thousand years after repository's closure) they would not reach the river present near the repository at 5 km distance during the analysed period of one million years.

If there is larger flow of radionuclides from the repository, part of them reaches the river water, however the biggest flow from geosphere value is not determined by the part of radionuclides dissolving immediately in the water under analysed geological conditions. The biggest value of iodine isotope flow to river water is approximately 5 times lower in comparison to the biggest value of flow via engineering barriers, whereas the biggest flow values achievement times differ almost twice. Complex researches of the impact of heat and gas dispersion on radionuclides transfer were started. COMPULINK, CHAN3D, PREBAT-BATEMAN (Sweden), AMBER (UK), and TOUGH2 (USA) codes were applied for the assessment of radionuclides dispersion.



Specific radionuclide's flux in near field of possible RBMK-1500 SNF repository in crystal rocks in Lithuania, when SNF container is placed vertically (solid lines) and horizontally (dashed lines)

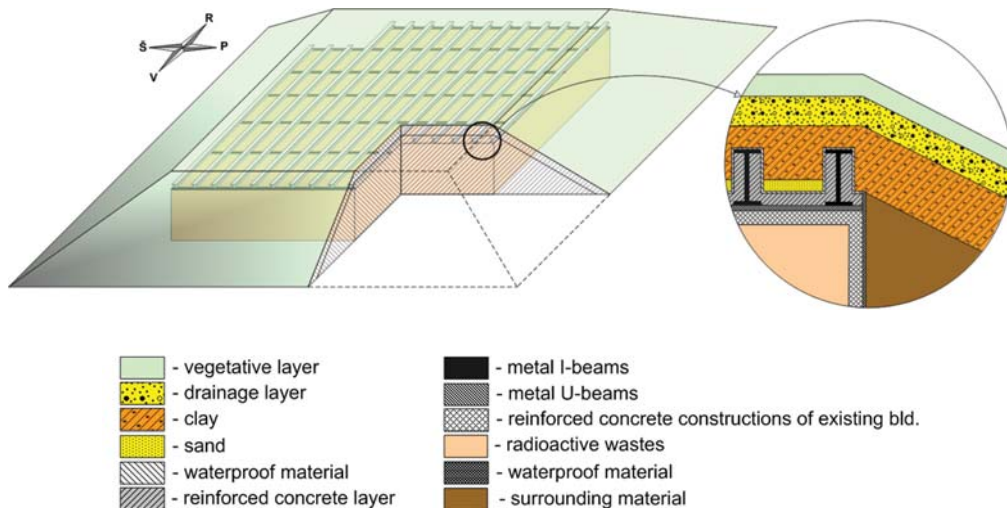
In 2007 the Laboratory together with GNS-RWE NUKEM GmbH (Germany) consortium continued the project – ***The Interim Storage Facility for RBMK Spent Nuclear Fuel Assemblies from Ignalina NPP Units 1 and 2 Supply and Installation (2005–2009)***. The Laboratory prepares environmental impact assessment and 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 and ***Preliminary Safety Analysis Report*** was submitted to relevant parties for assessment.

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, including safety evaluation of existing waste storage facilities. Long-term safety assessment of existing radioactive waste storage facilities at Ignalina NPP and Maišiagala was performed, and the possibilities to transform these storage facilities into repositories were analysed. The Laboratory together with *Framatome ANP GmbH* (Germany) participated in environmental impact and safety assessments for Ignalina NPP cement solidification facility and a temporary solidified radioactive waste storage facility. The Laboratory constantly participates in IAEA coordinated research programmes, among them ***Application of Safety Assessment Methodologies for near Surface Waste Disposal Facilities (ASAM) (2002–2007)***.

In the recent years a lot of attention was paid to site selection for a radioactive waste near surface repository in Lithuania, also to scientific research related with radionuclides dispersion from radioactive waste repositories and their influence on safety. The Laboratory specialists with the assistance of Swedish experts prepared the set of criteria for choosing a near surface repository site, improved the concept of a near surface repository project, and prepared the implementation programme.

Together with French companies *Thales Engineering and Consulting* and *ANDRA* as well as Institute of Physics PHARE



Conceptual scheme of engineering barriers for bitumen radioactive waste storage facility

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 all information on the radioactive waste inventory, which is being stored in the Maišiagala storage facility, and performed a comprehensive nuclide composition analysis.

Implementing the research funded by Science and Study fund the Laboratory specialists together with the Institute of Physics prepared report **Research and application of radioactive waste formation, its dispersion and impact on the environment and man**. DUST, GENII, GWSCREEN (USA), AMBER codes were used for the research.

In 2006 the Laboratory specialists started to implement the project – **Reconstruction of Ignalina NPP bitumen radioactive waste storage facility (building 158) into repository**. In 2007 long-term safety assessment of the planned repository was performed. In the research possible engineering solutions of storage

facility reconstruction into repository, components of disposal system, i.e. radioactive waste, storage facility and surface engineering barriers planned to be installed over storage facilities and site characteristics were considered. ISAM safety analysis method, AMBER and DUST codes were used in the assessment. Prepared documents were submitted to regulatory institutions.

In 2007 the Laboratory together with NUKEM GmbH (Germany) continued the project **New Ignalina NPP solid waste management and storage complex (2006–2009)**. The Laboratory prepares environmental impact and safety analysis reports for this complex. In 2007 **Environmental Impact Assessment Report** was submitted to the Ministry of Environment. **Preliminary safety analysis report for Ignalina NPP new solid waste management and storage complex** was prepared.

Evaluation of different factors related to decommissioning of nuclear power plants

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



Discussion while preparing environmental impact assessment programme for new nuclear power plant in Lithuania (Dr. V. Ragaišis (left) and Dr. E. Adomaitis)

2004 the Laboratory specialists for the Ministry of Economy prepared the drafts on ***The Ignalina NPP Decommissioning Programme and the Plan of Means of its Implementation for the period 2005–2009.***

In 2002–2004 the fire hazard analysis for Ignalina NPP Unit 1 and Unit 2 was carried out together with Swedish experts. In 2005–2006 fire hazard assessment of some renewed Ignalina NPP rooms was carried out. Fire hazard assessment of newly designed Ignalina NPP SNF storage facility was carried out as well. In 2006–2007 the external fire impact on the new Ignalina NPP solid waste management and storage complex was assessed. Internal fire risk in the most hazardous compartments in case of fire was also carried out.



Prof. S. Šinkūnas from Kaunas University of Technology (stand) starts the public session of the Council for A. Sirvydas (sits right) dissertation defence on December 27, 2007

Since 2002 the Laboratory has been participating in IAEA coordinated research project ***Disposal Aspects of Low and Intermediate Level Decommissioning Waste.*** The Laboratory performed radioactive deposits formation analysis, also analysed the expected amounts of the radioactive waste at final INPP shutdown. Radioactive residue composition and their activity assessment methodology during the final reactor shutdown was prepared, forecasted quantities of radioactive waste were estimated, preliminary specific activity values for radioactive waste packages with activated reactor components were calculated.

In 2007 research concerning neutron activation of reactor constructions was continued, most of attention giving to reactor constructional elements, situated remotely from graphite stack boundary. In order to evaluate the activation of such elements, neutron fluxes should be simulated using numerical method in the constructions since in RBMK reactors neutron fluxes are measured only in the boundaries of reactor graphite stack. Thus the methodology is developed, which enables to estimate neutron fluxes in the analysed reactor constructions. MCNP-5, SCALE (USA) codes were used for the modelling of neutron fluxes.

Together with Institute of Physics the Laboratory completed the project ***Development of radiological characterization programme for equipment and installations at INPP. General Programme of Radiological Survey*** was prepared and approved by regulatory institutions. ***Historical Assessment Report of Radiological Situation at INPP*** and ***Programmes of detail radiological characterization*** of individual Ignalina NPP blocks (V1, G1, 117/1) were prepared as well.

In 2007 new project – ***Preparation of detail radiological survey programmes for Ignalina NPP blocks B1, D0, D1 and building No. 119 facilities*** has been started. Microsoft Access

database was developed, where all data, necessary for describing equipment and schemes with planned positions of radioactivity measurement and sample taking, will be accumulated. Developed codes and collected and analysed data regarding radiological situation at Ignalina NPP are necessary for preparation of the Ignalina NPP Unit 1 dismantling projects.

In 2007 Lithuanian Energy Institute, as a partner of consortium BNG (UK)-LEI-NUKEM (Germany), participated in the new project – ***Decontamination and dismantling of facilities of Ignalina NPP building No. 117/1.*** CORA/CALCOM (Germany) code designed for the calculation of prices of power plant's decommissioning and for planning activities was mastered. Software VISIPLAN 3D ALARA (Belgium) is used to evaluate emission doses.

In 2007 researchers of the Laboratory started the activities related with the implementation of new nuclear power plant in Lithuania. In accordance with the order of SC „*Lietuvos energija*“, consortium Pöyry (Finland)-LEI (Lithuania) completed important project – ***Preparation environmental impact assessment programme for new nuclear power plant***, where the scope of new nuclear power plant environmental impact assessment report was determined.

In 2007 the Laboratory continued 2 state funded research works, carried out 10 applied research works and earned over 1.9 million Litass. In Laboratory one PhD thesis was defended. Currently there are 5 PhD Students in the Laboratory. Researchers of the Laboratory actively participated in different training programs, coordinating meetings, presented 11 papers at international conferences (United Kingdom, Belgium, South Africa, Russia and Lithuania), and published 14 scientific articles in Lithuanian and international journals.

LABORATORY OF NUCLEAR INSTALLATION SAFETY

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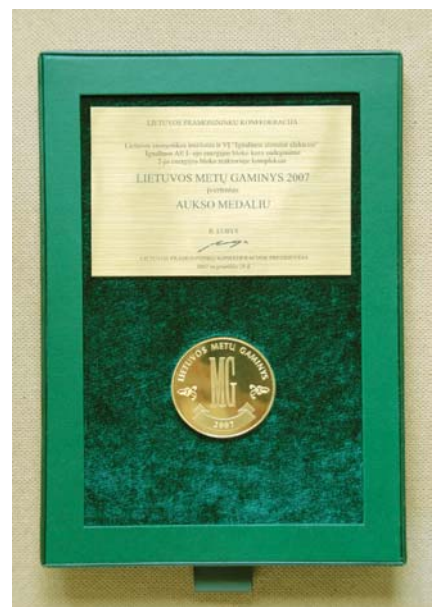
Main research areas of the Laboratory:

- justification of nuclear facilities safety;
- thermal-hydraulic analysis of accidents and operational transients;
- assessment of reactor core modifications and analysis of reactivity initiated processes;
- thermal-hydraulic assessment of Accident Localization System, containments, and other compartments;
- simulation of radionuclides and aerosols transport in the compartments;
- Level 1 and Level 2 Probabilistic Safety Assessment of nuclear power plants;
- assessment and prognosis of the graphite stack-fuel channel gap closure dynamics;
- analysis of new generation nuclear reactors;
- safety analysis of fusion reactors;
- structural analysis of complex technical systems;
- single failure analysis and engineering assessment for complex technical systems;
- risk and hazard analysis of industrial sites;
- assessment of energy resources and security of energy supply;
- modelling and reliability assessment analysis of net systems (pipes, electricity networks, transport networks, etc.)
- sensitivity and uncertainty analysis of modelling parameters and results;
- fundamental research of thermal physics.



In 2006 the project for development and implementation of technology and equipment for nuclear fuel transportation from Ignalina NPP Unit 1 to Unit 2 for fuel reuse was completed. This equipment set, which has been operating for one and a half years, will enable to save hundreds of millions of Lit

and reduce the amount of nuclear fuel, imported to Lithuania and stored in Lithuania after NPP decommissioning. In December 2007 the developed technology was granted a golden medal of Lithuanian Industrialist Confederation competition “*Lithuanian product of the year*”.





In 2007 researchers of the Laboratory together with Lithuanian and international partners implemented 31 projects: 3 state funded scientific research projects, 14 international projects (among them five EU Sixth Framework Programme projects, 2 international scientific research programmes financed from own resources) and 14 projects with Lithuanian industry partners.

Researchers of the Laboratory actively participated in activities related with the most acute issue in Lithuania – the construction of new nuclear power plant and assessment of Lithuanian energy security. Researchers of the Laboratory started participation in Ignalina NPP Unit 1 dismantling and decontamination projects, which are important also for construction of new NPP since they will be carried out at the same site chosen for new nuclear power plant simultaneously with decommissioning activities at shutdown power plant, and construction of new related facilities (storages of different radioactivity level). It has to be justified and ensured that the facilities of new and shutdown nuclear power plants will not have negative impact on each other during construction / dismantling and operation, and during the whole time the safety of the complex consisting of new and shutdown nuclear power plants is ensured.

Assessment of energy security

The aim of a three year (2006–2008) state funded project **Development of methodologies for security and reliability assessment of energy supply to Lithuania** is to create an instrument, which would enable identification of the most vulnerable branches of energy supply and most hazardous disturbance scenarios, and evaluation of the probabilities of its occurrence. In accordance with the methodology developed in 2006, the scenarios of energy accidents, disturbances of energy raw materials supply, economic blockades, price crises and other energy supply disturbances are further investigated. Probabilities and frequencies of scenarios are evaluated using the probabilistic model. Modelling of possible energy supply scenarios is carried out using economical and reliability and risk models. Construction of new power plant with installed capacity of 1600 MW (start of operation in 2019) was one of the analysed scenarios. In accordance with the energy security assessment system, developed in the methodology, modelling results of each scenario are evaluated with safety points. The most hazard scenarios of energy supply disturbances were compared and chosen according to the safety points. In the prepared interim report a great deal of attention is given to geopolitical aspects of security of energy supply, the issues of national energy security, analysed in Lithuanian energy strategy, are presented, the progress of annual Lithuanian national Lisbon strategy implementation program is reviewed,

energy security aspects, presented in the Green book of European Commission, are analysed.

UNDERSTAND project is similar to the latter work. The objective of **UNDERSTAND** is to present a training package to system operators concerning crises management and intersystem cooperation. The aim of the project is to develop and justify a training concept, which could be expanded in further projects striving to retain undisrupted electricity supply in European electric systems. In this project, which is part of **Leonardo da Vinci** programme, besides Lithuanian Energy Institute, participate 9 partners from 8 European countries: the leading partner – **Swedish Energy Agency**, SC SecLink (Sweden), Ostrav Technological University VSB (Czech Republic), ABC Dialog (Denmark), national Emergency Supply Agency (Finland), Link Consulting sas (Italy), KCEM (Sweden), Žilina University (Slovakia), and University of Cranford (UK). The project is to be continued till September 2008.

A two-year project **Reliability and safety assessment and improvement of electricity transmission grid**, signed with SC *Lietuvos energija*, was completed in 2007. Software NETRPAS, designed for the assessment of reliability level of electricity transmission grid, planning of reconstructions and calculation of possible losses, was further improved. Consumer connection of substations' collection, reliability of transmission grid's computation algorithm as well as data base structure were improved.

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

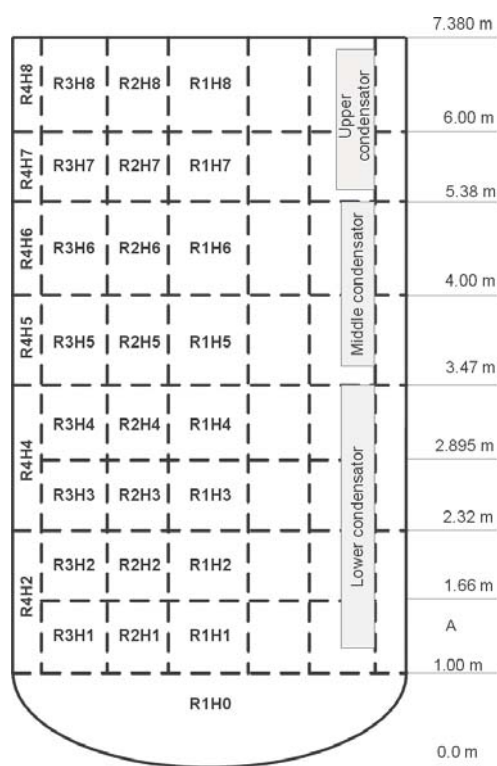


In 2007 Lithuanian Energy Institute continued work for project **IRIS** (International Reactor Innovative and Secure) signed the joint agreement of participants with Westinghouse Electric Company LLC, where new bilateral agreements are forecasted. Conceptual IRIS project is already finished and at present works of reactor technical systems testing and preparation of reactor project for licensing are carried out (till year 2010). In this stage researchers of the Institute started to prepare inter-comparison methods of new reactors and implement works, related to reactor structural, economical, security and safety assessment. Scientific research in this field is relevant for the study of construction of new reactors 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. In the recent years specialists of the Laboratory of Nuclear Installation Safety have participated in performing IRIS probabilistic safety and economical efficiency analysis and research, devoted to reduction of the risk of different external hazards and the uncertainty of obtained results.

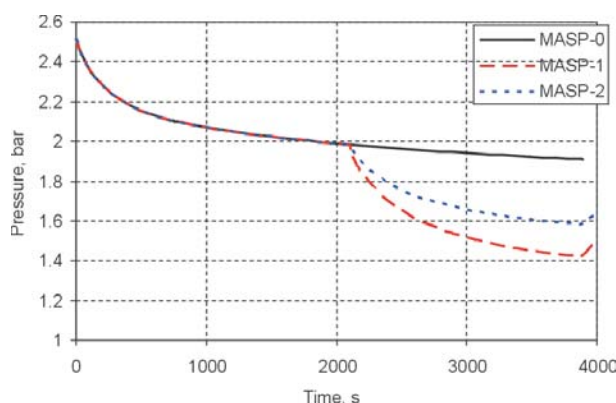
New generation reactor development and analysis works, related to IAEA coordinated research programs, are carried out in the Laboratory. One of such programmes is **Review of economic benefit of evacuation zone and safety measures around**

nuclear power plants with innovative small and medium capacity reactors in the regions, where reactors are used for electricity and heat generation. The objective of this project is the assessment of evacuation zone and safety measures of nuclear power plants and for the analysis of perspectives of secure and efficient small and medium power reactors. Performing research there is an attempt to develop an economic efficiency study, where the possibilities of new nuclear power plant use for district heating are analysed. In the work it is analysed what the economic effect would be if nuclear power plant of several units was used for electricity production as well as district heating. Performed research clearly shows that in such case the efficiency of new nuclear power plant increases.

Network of Excellence of Severe Accident Research of Nuclear Power Plants SARNET. Contract on Network of Excellence for severe accident research and management (SARNET)



Scheme of MISTRA experiment facility for COCOSYS code



Evaluated pressure change during MASP-0, MASP-1 and MASP-2



was continued in 2007. 49 European R&D organizations, including Lithuanian Energy Institute, have participated in this project. In 2007 the Laboratory personnel participated in the activities of three working groups:

- **ASTEC** – adaptation and verification of integral code ASTEC designed for modeling of severe accidents in nuclear power plants;
- **CONTAINMENT** – analysis of processes occurring in containments of nuclear power plants;
- **PSA-2** – application of Level 2 probabilistic safety analysis for various nuclear power plants, risk assessment and method development of its reduction.

During 2007 the models of RBMK-1500 reactor cooling circuit and confinement were developed for ASTEC and COCOSYS codes. These codes were used for simulation of the processes that occur in the Ignalina NPP reactor core, reactor cooling circuit, and confinement. Analyzing hydrogen generation due to steam-zirconium reaction in the reactor core the benchmark calculations were carried out using ASTEC and RELAP/SCDAPSIM codes. Such benchmarking enables assessment of capabilities of the codes in simulation of specific processes in nuclear power plants and it increases the reliability of obtained results. In the CONTAINMENT work package the benchmark of the computer codes is performed in order to investigate the influence of the sprays on the destruction of the atmosphere stratification in the containments. The analysis is performed by different organizations, taking part in SARNET Network of Excellence, using chosen codes. The obtained results are compared with the parameters measured in TOSQAN and MISTRA experimental facilities. Using COCOSYS code LEI representatives carry out analysis of M5 and MASPN tests performed in MISTRA test facility

Another part of SARNET project is probabilistic safety assessment in analyzing potential severe accident scenarios. Improving methods necessary for this assessment scientific research by Lithuanian Energy Institute researchers were carried out in the field of system probabilistic dynamic modeling and analysis. Applying probabilistic dynamics theory, the methods of level-2 probabilistic safety analysis were improved. Development of new method to perform estimation of safety systems reliability parameters (employing quantitative expert assessment and developed program REPEAT) was initiated. Pilot model of severe accident (hydrogen explosion and reactor containment rupture) was analysed together with another participants of the project (close cooperation with scientists from Consejo de Seguridad Nuclear and Universite Libre de Bruxelles). Further improvement of developed software and model was carried out. Sensitivity analysis software (SUSA and SIMLAB) was applied for the analysis and comparison of results.

Network of Excellence of Nuclear Plant Life Prediction NULIFE. In 2007 Lithuanian Energy Institute together with partners continued works in Network of Excellence **NULIFE**. One of the main tasks is to establish an integral organizational structure – virtual institute capable of performing scientific research of lifetime assessment in European nuclear facilities industry. Network



of Excellence **NULIFE** will enable coordination of scientific research, carried out in Europe, in the fields which require the interaction among different

ageing processes, environmental impacts and loadings, taking into account safety level of different nuclear facilities. The project consortium is comprised of Contractors from 10 organizations and Associated Contributors from 27 organisations, whereas the project coordinator is – VTT Technical Research Centre of Finland.

In 2007 researchers of the Laboratory participated in the following working groups:

- *A-1 – assessment of experience and competence of partners* (analysing power issues of nuclear plant).
- *IA-2-2 – assessment of structural integrity* (report was prepared on RBMK-1500 reactor fuel channel ageing).
- *IA-2-4 – safety, risk and reliability* (researchers presented their experience in the works on safety, risk and reliability assessment of nuclear power plants).

In 2007 scientists of the Laboratory continued research in **PHEBUS-FP** programme. Phébus-FP programme comprises five integral experiments on reactor severe accidents dealing with fuel degradation, hydrogen generation, fission product release, transport and deposition in the containment. In 1988 the programme was initiated and now is coordinated by IRSN. Representatives from the EU countries, USA, Japan, and South Korea participate in its activity. Lithuanian Energy Institute performs modeling of fuel degradation processes in PHEBUS experiments using RELAP/SCDAPSIM code. Phenomena occurring in PHEBUS containment are modeled using COCOSYS code.

International research network **Use of Probabilistic Safety Assessment for Evaluation of Ageing Effects to the Safety of Energy Facilities (APSA)**.

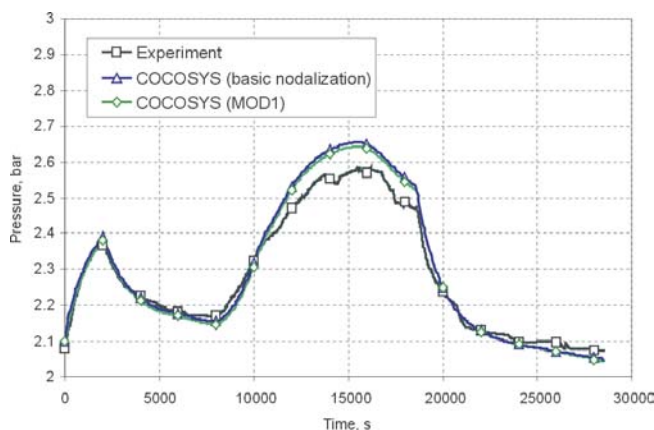
APSA research network is devoted to the extension of classical Probabilistic Safety Analysis (PSA) by incorporating of ageing effects into reliability models. In classical PSA constant

failure rate assumption is used. However, this assumption can lead to inadequate safety assessment results. Ageing PSA requires much more statistical data, operational control and more detailed models.

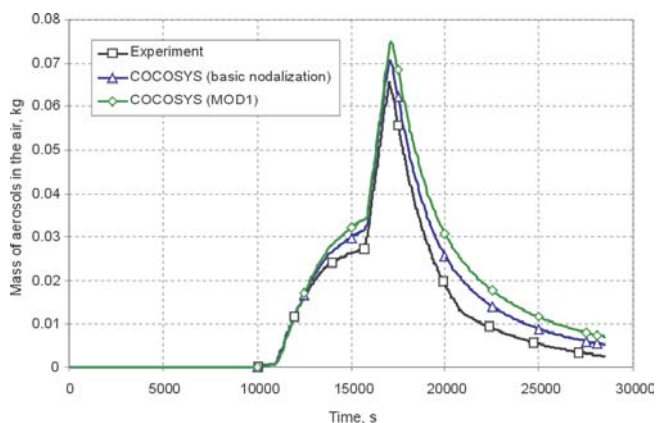
In 2007 Lithuanian Energy Institute was involved into activities related to methods for data analysis of active components, time dependent failure rate assessment and investigation of other methods and estimates that potentially can be used in PSA models.

In 2007 contract signed with Inspecta Nuclear AB (Sweden) **LEI assistance in review of PULS O3 and GREAT documentation** was continued. At present 10 nuclear power reactors are operated in Sweden, which produce approximately 50% of electricity consumed in Sweden. In 1980 Sweden in accordance with referendum results made a decision not to construct new and shutdown the operating nuclear power plants. It was forecasted to shutdown the operation of all Sweden nuclear power plants till 2010, however, after shutdown of two reactors of the Barsebäck nuclear power plant in 1999 and 2005, the decision regarding shutdown of other nuclear power plants was suspended. Currently programme of power uprate in operated power plants is carried out, to compensate loss of shutdown reactors. The experts of the Laboratory participate in review of documentation of PULS O3 and GREAT projects, which are related with the power uprate of Oskarshamn (BWR type reactor) and Ringhals 3 (PWR type reactor) nuclear power plants. The main task of our experts is to review the thermal hydraulic and structural integrity calculations, given in PULS O3 and GREAT projects. Power uprate is taken into account in the calculations and the loadings, to the pipes and other components in case of postulated accidents are determined and evaluated. Participation in these projects is an excellent possibility to get to know the specifics of different type reactors, the national Sweden and international requirements for documentation of different type reactors design and safety justification. The experience gained in this project will be employed in constructing new power plant in Lithuania.

B9-0- Development of documentation for Ignalina NPP 117/1 building decontamination and dismantling was begun in 2007. This is the first project in Lithuania for the decontamination and dismantling of nuclear power plant. After conquering strong competitors from Spain and Italy, the winner became the consortium, consisting of BNG Project Services (United Kingdom), Nukem



Pressure change in PHEBUS protective shield during FPT-1 experiment



Aerosol deposition in PHEBUS protective shield during FPT-1 experiment

Technologies GmbH (Germany) and Lithuanian Energy Institute. The objective of the project is to perform decontamination and dismantling of the emergency cooling system of RBMK-1500 reactor installed in Ignalina NPP building No 117/1. General decontamination and dismantling strategy, design documents, safety justification, waste storage plan will be prepared, and the program for transferring experience and knowledge to Ignalina NPP personnel will be developed and implemented. Experts of Laboratory participate in the development of the strategy, basic design and safety justification report. The projects for decontamination and dismantling are important for the construction of new nuclear power plant as well since they will be performed on the same site. Therefore it will be necessary to investigate the interaction between facilities of new and shutdown NPPs and its influence on safety and to justify the safety of the complex, consisting of new and shutdown nuclear power plants during construction / dismantling and operation.

Application of best estimate methodology

In 2007 a three year state funded project *Best estimate methodology application simulating processes in technical, natural and social systems*, which continues the previous work *Uncertainty analysis of modelling results of technical, natural and social systems*, was started. Researchers from the Laboratory of Hydrology and from the Laboratory of Energy Systems Research also take part in this project. The aim of the work is application of uncertainty analysis methodology in the field of social sciences and performing modelling of hydrological processes. In 2007 the origin of the uncertainties in the analysis of thermalhydraulic accident processes in the reactors and their evaluation methods were investigated, the refined forecast of electricity demands for different branches of Lithuanian economy was performed, the modelling methodology of Kaunas Hydropower Plant reservoir under different natural conditions and according forecasted climate change scenarios is developed. Application of best estimate methodology, including the uncertainty analysis, is relevant in

performing assessment of energy security and other works related with the construction of new nuclear power plant in Lithuania.

Research of condensation implosion

State funded work *Research of condensation impact on the gas/liquid interface stability* was continued in 2007. In the first stage, numerical research of two-phase (air/water) flow in the inclined channel was carried out, modelling results were compared with experimental data, single-phase flow velocity profile variation at different roughness of the wall was determined, pressure loss in single-phase and two-phase flow was compared. The analysis of obtained results revealed the drawbacks of the experimental facility, helped to make decision on the constructions of experimental facility, further improvements of measurement equipment and methodology. In the second stage, a new improved experimental facility was developed, numerical and experimental research was initiated in the condensed media.

Safety analysis of thermonuclear synthesis reactors

Research in thermonuclear synthesis energy (FUSION) development is one of priority research fields in EU's Seventh Framework Programme. In the beginning of 2008 the revision of the design of ITER (International Thermonuclear Experimental Reactor) is coming to an end. ITER reactor will demonstrate scientific and technical possibilities of thermonuclear energy use for peaceful purposes. It will be the first thermonuclear fusion facility, which will generate 500 MW power. This reactor will be constructed in Cadarache (France), approximately 100 km from Marseille.

Scientists of the Laboratory become more actively involved in 7th Framework Programme projects, which are related to fusion research activities connected not only to ITER but to the development of other thermonuclear fusion facilities and solution of related scientific problems.



Experimental facility of interphasic friction

In the beginning of 2007 works were completed in EURATOM project Cost-Sharing action: Hydrogen deflagration/detonation analyses in ITER HNB- and DNB-boxes and cryopumps following a loss of vacuum accident. This was the first project in Lithuania, designed for thermonuclear synthesis research. Main objectives of the project were to evaluate gas concentration distribution in compartments, to determine possible hydrogen accumulation areas and evaluate whether burnable hydrogen-air mixture could develop in the analysed accident case. Information concerning ITER components, their volumes, surface areas, hydrogen amounts, etc. was collected, models of these compartments were developed and calculations were carried out, which determined not only gas distribution but pressures that could be reached in case of hydrogen detonation. Performed calculations revealed that in order to prevent hydrogen detonation during the considered events, the ITER design safety systems should be improved.

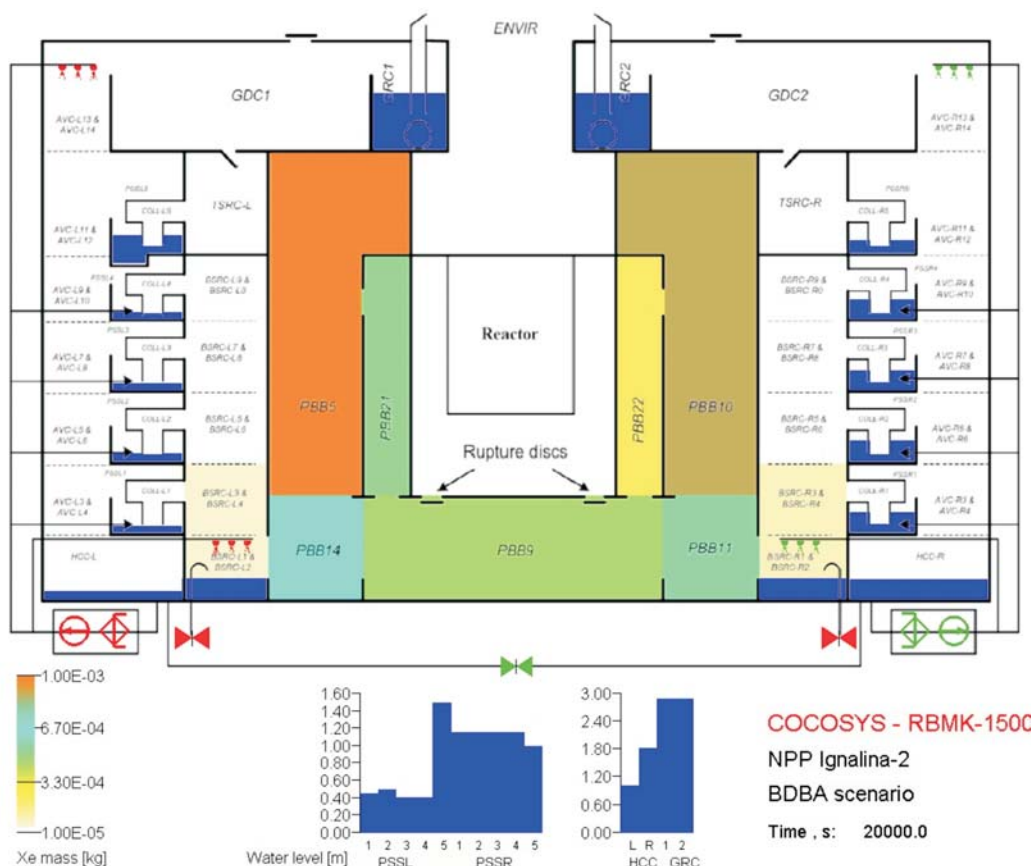
On the 1st of January 2007 the **Contract of Association concerning the cooperation in the field of scientific research of thermonuclear synthesis** between Lithuanian Energy Institute and European Commission came into force. Together with Max-Plank-Institut für Plasmaphysik (Germany) the cooperation was begun, the aim of which is to perform the analysis of stellarator type thermonuclear synthesis experimental equipment W7-X. Three scientists from LEI visited Germany to get acquainted with the design of facility and to discuss the cooperation program between our institutes. At the moment, the information on W7-X is collected and component models for ASTEC, PepS, BRIGADE/Plus codes are developed. Main analysis works will be carried out in 2008.

International Ignalina NPP safety projects

Activities in PHARE project **Support to VATESI in solving significant Ignalina NPP licensing tasks**, the objective of which is to provide support and its TSOs in assessment of beyond design basis accidents for RBMK-1500 reactors, were continued. This project is carried out together with Institute of Physics, GRS mbH (Germany) and IRSN (France).

The analysis of the largest diameter pipe rupture accident, during which emergency cooling system does not operate, was carried out. Using SCALE and TESPA-ROD codes processes were modelled in nuclear fuel rods, using RELAP/SCDAPSIM and ASTEC codes – in reactor cooling contour, whereas using COCOSYS software – thermal hydraulic and hydrogen and radioactive material transfer processes in accident localization system compartments. Processes, which occur after losing water in spent fuel pools, were modelled using ATHLET-CD code. The project was successfully completed at the end of 2007.

In 2007 a new project with GRS mbH **Performance of confinement analysis** was started. The objective of this project is to perform analysis of processes that occur in the confinement of Ignalina NPP. In this project GRS mbH transferred ATLAS visualisation tool to facilitate the analysis of calculation results. In the first step of the project LEI representatives were trained to use the software and the first visualisation scheme of Ignalina NPP accident localization system was developed for ATLAS. The scheme is developed for the analysis of results, obtained applying



Visualization scheme of Ignalina NPP accident localization system

COCOSYS code. In the next step it is planned to perform an analysis of the selected beyond design basis event and evaluate the impact of the modeling parameters on calculation results (e.g. initial gas and water temperatures in confinement).

After performing study ***The overview of improvements and modifications of the power plant with RBMK reactors, and the analysis of operation experience and selected accident scenarios***, information concerning nuclear power plants operating RBMK reactors, performed modifications and work experience, was collected and systematized. Numerical investigation, during which the capability of RBMK-1500 reactor protective system to shut-down the reactor during selected (most severe) accident in case of 25 AZ/BSM rods fail, was carried out.

Other activities for the assessment and improvement of Ignalina NPP safety

In 2007 two new interrelated contracts ***Research of the impact of linear load criteria violation on fuel element during transients in the reactor core*** and ***Analysis of the impact of uncertainty and sensitivity parameters on the modelling results of transients*** were concluded. The objective of the first project was to assess the impact of linear load criteria overrun on further operation of fuel elements. In the first stage, employing QUABOX/CUBBOX – HYCA code numerical model of RBMK-1500 reactor and its engineering manual were prepared, and verification of numerical model was carried out. Using FEMAXI code, the analysis of processes, occurring in fuel rods, was carried out. In the second project modelling of continuous withdrawal a group of rods, erroneous fuel assembly reloading and control and protection system circuit drainage were performed. For each of the investigated accidents the uncertainty and sensitivity analysis was carried out, taking into account the impact of variation of physical properties of materials and deviation of physical values, used in modelling, on the calculation results. Recommendations were given to improve the methodology of reactivity accident analysis. After the implementation of projects, final reports were published.

The contract concerning procedure ***The hot shutdown in case of station blackout at Ignalina NPP*** justification performance was signed with the Ignalina NPP. The analysis of processes, occurring in the reactor cooling circuit in case of station blackout was carried out. The analysis was carried out employing systemic thermohydraulic analysis code RELAP5. This project will be continued in 2008, when performed works will enable to improve of Ignalina NPP “hot shutdown” procedure in such way that operators of power plant could successfully control such beyond design basis accident as station blackout.

After the completion of project ***Technical assistance in licensing Ignalina NPP operation***, Lithuanian Energy Institute together with Institute of Physics under the supervision of Serco Assurance specialists developed the state-of-the-art method for the development of macroscopic cross-sections of 2 group materials of RBMK-1500 reactor. Results of the calculations, carried out employing QUABOX/CUBBOX code and revealed that employing this methodology the change of reactor parameters may be forecasted more accurately during its operation and while analyzing emergency processes.

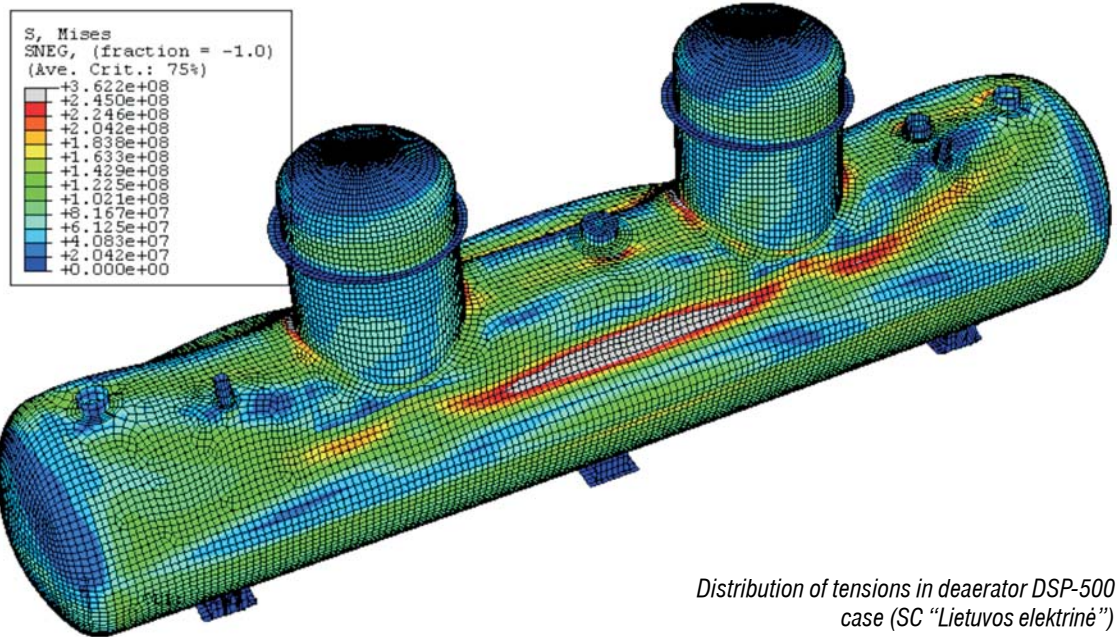
In Ignalina NPP project ***Replacement of flow meters due to the diagnostic results in Unit 2 in 2007*** was completed. In each technological channel of RBMK-1500 reactor coolant flow meters are installed. When the flow meter fails, the operation of appropriate technological channel is interrupted until the next shutdown of the reactor, when the broken flow meter is replaced with a new one. Flowmeter diagnostics is being carried out before annual maintenance in order to avoid failures. In 2007 in the continued work analysis of diagnostic measures results was carried out and it was determined that 410 flow meters had to be replaced in Ignalina NPP Unit 2 in order to guarantee a reliable operation of Unit 2 until the next planned maintenance. The most failed flow meters were selected during the analysis, and in case of changing them the reliability of all flow measuring system would improve.

The residual graphite-fuel channel gas gap probabilistic analysis and forecast at Ignalina NPP Unit 2 was carried out in 2007. The methodology, developed in previous works, was applied in the project to forecast the gas gap of Ignalina NPP Unit 2 and assess the probability of residual gap. Statistical analysis of measurements of fuel channels of Unit 2 was carried out using measuring data till year 2007, the probability of gas gap disappearance was evaluated and forecast of its change was carried out till the planned maintenance in year 2008. Calculations revealed that the forecasts of disappearance probability of the gas gap in Unit 2 till year 2008 comply with the requirements of VATESI. In the work 30 technological channels were indicated for which gap calculations should be carried out during planned maintenance in 2008.

In 2007 after completing project ***Improvement of RBMK-1500 reactor fuel channel linear load coefficient computational algorithm*** the linear load coefficient fluctuation elimination method was developed and respective recommendations were prepared. Developed improved algorithm was verified at the Ignalina NPP and after performing the analysis of obtained research results it was forecasted to use it in the power plant during operation in the beginning of 2008.

In 2007 project ***Development of set of equipment designed for picking spent fuel fallings in the hot cells of Ignalina NPP*** was completed. Developed equipment set was installed in the power plant, all the necessary tests and personnel training were carried out. The complex is comprehensively prepared for operation. Equipment testing, carried out in 2007, confirmed the validity of technical decisions, presented in design documentation of 2006, and compliance of calculations, carried out in technical safety substantiation report, with the parameters measured during testing.

In 2007 works were carried out in accordance with the contract Ignalina NPP probabilistic safety analysis. In the first stage of the project the probabilistic analysis of personnel errors was carried out. Works of this stage cover the preparation of method, performance of primary analysis and preparation of interim report. In the second stage, the renewal of probabilistic analysis of personnel errors, update of probabilistic safety analysis model and analysis of initiating events, renewal of probabilistic safety analysis and uncertainty analysis were carried out.



Distribution of tensions in deaerator DSP-500 case (SC "Lietuvos elektrinė")

Contract **Preparation of safety justification of Ignalina NPP Unit 2 diverse shutdown system servodrives** was concluded in 2007. Final safety justification of Ignalina NPP second diverse shutdown system servodrives was completed and it was submitted to VATESI experts for assessment.

Laboratory of Nuclear Installation Safety is one of the technical support organizations, which for a number of years has been closely cooperating with VATESI. Performing agreement **Expertise of INPP documents, submitted to VATESI, related with changes of reactor core zone configuration, physical characteristics and control, and other issues of reactor physics and nuclear fuel storage and management**, Ignalina NPP documents were analyzed in order to justify modifications of composition of RBMK-1500 reactor cores (mastering uranium-erbium fuel, rods of new construction), control of compliance of reactor passport characteristics for the determined limits. Independent calculations were carried out, on the basis of which conclusion were drawn on the reliability and expedience of presented safety justifications.

Safety and reliability assessment of other industrial objects

In 2007 contract **Assessment of the impact of Unit No 6 deaerator DSP-500 case shape on the vessel strength** was signed with SC *Lietuvos elektrinė*. The analysis of case strength of Unit No 6 deaerator DSP-500 (operated since 1968) at operational loads and in case of increased vessel oval form was carried out. Using finite element software BRIGADE/Plus the

analysis was carried out and it was determined that at deaerator oval size (as estimated in 2007) average stresses through deaerator vessel wall thickness do not exceed permissible nominal stresses thus deaerator can be operated. Average stresses through case wall thickness reach the permissible nominal stresses only when oval shape reaches 8%. Obtained stresses are not local, but they are distributed in a large area of case (dotted gray in the picture), which may cause a plastic deformation of the case and due to this reason gaps may be formed in the case and thus the structural integrity may be damaged. Thus the deaerator vessel, the average oval shape of which reaches 8%, is not recommended to be operated.

Other activities

In 2007 Mr. M. Vaišnoras defended Doctoral dissertation **Analysis of water hammer phenomena using RELAP5 code**. Results of Laboratory researchers are presented in work reports, a monograph (S. Rimkevičius, E. Ušpuras **Modelling of Thermal, Hydraulic Transient Processes in Nuclear Power Plants: Ignalina Compartments**) and 60 scientific articles (among them, 8 in publications, included in the list of Institute of Scientific Information), 39 papers were presented at scientific conferences. It should be noted that researchers of the Laboratory participated and presented papers in all main international conferences, where safe operation of nuclear power plants and physical phenomena in them were analyzed. They also participated in different training programmes, many IAEA technical committees meetings, and coordination meetings.

LABORATORY OF ENERGY SYSTEMS RESEARCH

Head of the Laboratory –
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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;
- 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.

Laboratory carries out scientific research, important for the analysis of the Lithuanian energy sector and different energy systems development, forecasting of energy demand and formation of the methodology and software for the energy sector development optimisation and for updating necessary statistical database.

State funded research projects ***Investigation of Distributed Energy Generation Development and Development of Methodology for the Evaluation of Safety and Reliability of Energy Supply to Lithuania*** were further continued. In the first project, a general overview as well as advantages and disadvantages of the distributed energy production are presented, the role of this production in the EU member states is assessed, the possibilities to develop it in Lithuania are analysed. This project also deals with the problems of entering the market and joining the distribution network. In the second project, methodology for safety evaluation of Lithuanian energy supply systems is further developed, geopolitical aspects of energy safety and energy supply interruption scenarios are discussed.

State funded scientific research work ***Application of Best-estimate Methodology for Process Modelling of Technical, Natural and Social Systems*** has been launched together with partners from the Laboratory of Nuclear Installation Safety and the Laboratory of Hydrology. In this project, the principles of best-estimate methodology application when solving the problems of energy economics are discussed and the revised forecasts for electricity demand in different branches of the Lithuanian economy are presented.

Scientific research works for the national economy

The Laboratory continues its successful cooperation with Lithuanian Ministry of Economy. The Laboratory won the tender and carried out three applied research projects:

- ***Analysis of Technical and Economic Indicators of the Lithuanian Energy Sector during the Period of 2000–***

2006, Comparison to the Respective Indicators of the EU Member States and their Publication. In this work, the development trends of the Lithuanian energy sector and its branches in 2000–2006 were analysed, a comparative analysis of major economic and energy indicators of other EU members was carried out, general production and consumption balance of different fuel and energy forms in Lithuania in 2000–2006 was presented. The indicators that define the Lithuanian energy sector development were compared to the respective indicators in Latvia and Estonia, the publication ***Energy in Lithuania 2006*** was prepared.

- ***Preparation of Comments on National Energy Strategy***. In this work, text of National Energy Strategy (NES), approved by the Seimas of the Republic of Lithuania, was supplemented with comments, illustrations and definitions of specific terminology in Lithuanian and English. NES was supplemented with basic indicators of the Lithuanian energy sector that were compared to the corresponding indicators of the other EU member states and with the results of the forecasts and optimisation calculation, prepared by LEI. Comments could be useful for Lithuanian society, the employees of energy enterprises and ministries, political parties, the media, the specialists of foreign energy companies, the representatives of the European Parliament, students and anyone who is interested in the development trends of the energy sector, seeks for better understanding of the strategic provisions, anticipated or planned measures of NES implementation.
- ***Analysis of Energy Sector Development Scenarios and Preparation of Project for NES Implementation Measures for the Period 2007–2012***. According to this project, measures of NES implementation for individual energy sectors are analysed. Measures, which were submitted by the Lithuanian energy industries, ministries, departments and municipalities to the Ministry of

Economy, were generalized. Extra measures, which should be implemented aiming at preparing capacities, that will substitute Ignalina NPP units, avoiding the violation of the fulfillment of strict environmental protection requirements, enhancing energy efficiency, promoting usage of renewable energy resources, etc., are evaluated in this work. Strategic assessment of environmental consequences of NES implementation plan focuses on such aspects as determination of influence that various measures have on the environmental protection and sustainable development.

Following European Union's objective to mitigate the climate change process, Lithuania must analyse trends of the greenhouse gas emissions and undertake definite obligations with regard to reduction of greenhouse gas emissions by the year 2020. Scientific research work **Forecast of greenhouse gas emissions trends by 2020, evaluation of possibilities and preparation of recommendations for Lithuania to fulfil its obligations to reduce greenhouse gas emissions by 20% till 2020** was submitted to the Ministry of Environment of the Republic of Lithuania. In this project, generalization of current situation and trends of greenhouse gas emissions during the period 1999–2005 are presented, rational energy development scenarios and relevant greenhouse gas trends are analysed, principles of the energy sector modelling methodology are submitted, forecast of greenhouse gas volumes, produced by other sectors of economy, and the overall emissions of greenhouse gas due to the activities in all sectors of the Lithuanian economy by 2020, is presented. Inventory of Lithuanian greenhouse gas was carried out and its report of 2006 for the United Nations Framework Convention on Climate Change on greenhouse emission in the energy sector was prepared.

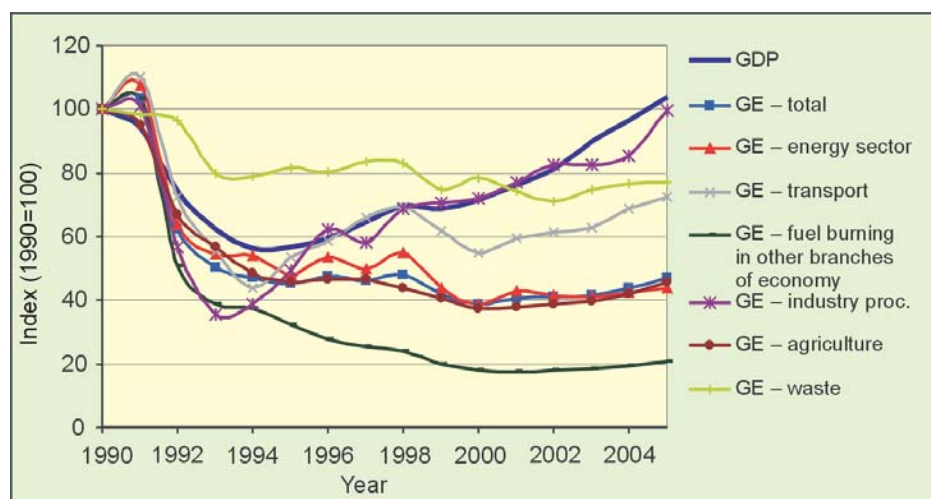
Continuing cooperation with JSC Lietuvos energija, a package of scientific research projects **Long-term Tower System Development in Conformity with National Energy Strategy** was carried out. In the initial stage of this project, analysis of Lithuanian economy growth and energy consumption variation was presented, trends of electricity consumption were analysed, and energy demand forecasting methodology and forecast of electricity demand was presented. In the second stage of the project, analysis of the legal and economic circumstances related to the closure of Ignalina NPP Unit 2 was presented. In the third stage, different possible ways for interconnection of power systems of Lithuania

and Baltic States and UTCE were discussed, their advantages and drawbacks were emphasized and preliminary investment was identified. A detailed implementation plan, which has to be fulfilled in the Lithuanian power system in order to meet the requirements for synchronous operation of the common Baltic States' power systems and UTCE was submitted. In the fourth and fifth stages, technical and economic possibilities of supplying Lithuanian consumers with electricity during the period 2010–2015 were studied, options of natural gas supply to Lithuania were analysed, and the plan of measures for the reduction of Lithuanian vulnerability in gas sector and security of electricity supply during the period 2010–2015 were presented. In the sixth stage, implementation of National Energy Strategy, approved by the Seimas of the Republic of Lithuania in 2002, was assessed by defining the level of implementation of strategic tasks and current status of different energy sectors, changes in the sectors of electricity, district heat, natural gas, oil products and renewable energy resources, in the spheres of environmental protection, energy efficiency, market liberalization and management enhancement were discussed.

Changes which take place in the European energy markets and the environmental requirements that become stricter for the energy sector prompted to carry out an investigation **Identification System of Electricity Origin in Lithuania**. After analysing implemented systems of energy origin identification, the requirements for identification system, that are defined by legal acts and system functioning conditions, were analysed and generalized. Possible scenarios of practical application of identification system were formulated, technical conditions and structural aspects for implementation of the system were analysed. Generalized recommendations for the implementation of electricity origin identification system were proposed.

Participation in the international programmes

Experience accumulated in preparing the following EU Sixth Framework Programme projects was very valuable for raising the qualification of laboratory personnel: **New Energy Externalities Development for Sustainability (NEEDS)**, **Coordination Action to Consolidate RTD Activities for Large-scale Integration of DER into the European Electricity Market (SOLID-DER)** and **Cost Assessment of Sustainable Energy Systems (CASES)**.



Indexes of change of Lithuanian GDP and the amount of greenhouse emissions in separate branches of economy

Relevant questions regarding the Lithuanian energy sector development, including aspects of wider use of renewable energy sources, are analysed in the following international projects of *Intelligent Energy – Europe*: **European Tracking System for Electricity (E-TRACK)**, **Determination of Milestones of European Policy Future of Electricity Energy Production Using Renewable Energy Sources (FUTURES-e)**, **Sustainable Energy Projects for the Local Economic Development (SEIPLED)**, **Analysis of Achieving National and Community Objectives for Year 2010 of Directive 2001/77/EC (PROGRESS)**. Successful cooperation with the EU partners and relevance of electricity tracking system enabled the researchers of the Laboratory to continue their work in this field. Since the 1st of October 2007, investigation that started two years ago has been renewed in a new project **E – TRACK – II**, the main purpose of which is to prepare and implement a common European electricity tracking standard.

International climate change regimes after the Kyoto protocol were analysed in the project **Strategies of Greenhouse Gas Reduction and Scenarios of Energy Development** coordinated by IAEA.

When implementing INTERREG-IIIC project **Redirecting Urban Areas Development towards Sustainable Energy (RUSE)** the possibility analysis of EU structural funds' employment for sustainable energy projects was carried out.

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

- Power sector models of Sudan and Nigeria, and performing analysis of their development scenarios (Dr. A. Galinis);
- Intergovernmental panel on climate change report **Climate Change 2007: Climate Change Mitigation** (Dr. I. Konstantinavičiūtė has significantly contributed to preparing section *Energy supply*); the Intergovernmental Panel on Climate Change together with Albert Arnold (Al) Gore was rewarded with the Nobel Peace Prize for the efforts to build up and disseminate greater knowl-

edge about man-made climate change;

- Implementing strategy of sustainable development for Kazakhstan (Dr. D. Štreimikienė was responsible for selecting measures for sustainable development strategy);
- Evaluation of Australian, Croatian, Turkish, USA and Latvian greenhouse gas inventories (Dr. I. Konstantinavičiūtė);
- Dr. A. Galinis participated in training courses in the Republic of South Africa and Nigeria organized by IAEA (as an expert delegated by this agency) and was responsible for MESSAGE model application when solving the issues of long-term energy planning.

On the 6th of March 2007, Laboratory at premises of JSC *Lietuvos energija* organized National seminar **The role of distributed energy generation in the European Union and Baltic States**, which was attended by the specialists from Estonia, Czech Republic, Spain, Latvia, Germany and by more than 40 representatives from Lithuanian energy companies and organizations. This seminar was organized in the frame of Sixth Framework Programme project **Coordination Action to Consolidate RTD Activities for Large-scale Integration of DER into the European Electricity Market (SOLID-DER)**. The participants of the seminar had a possibility to share the experience that EU-15 countries have accumulated in this field and discuss the problems and perspectives of efficient integration of small generation sources that are connected to the distributed electric networks into Lithuanian energy market.

In 2007 researchers of the laboratory participated in the conferences in Kazakhstan, Australia, Germany, Italy, Estonia, Latvia, Poland, and Russia, where 24 papers were presented. Researchers of the Laboratory published 2 monographs, 20 scientific articles in Lithuanian and international journals and proceedings of international conferences (6 of them in publications that are included into the list of Information Sciences Institute).



Seminar "The role of distributed energy production in the EU and Baltic countries" is opened by academician J. Vilemas

LABORATORY OF REGIONAL ENERGY DEVELOPMENT

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Main research areas of the Laboratory:

- analysis and modelling of energy sector development of municipalities, which enable forecasting in short and medium periods;
- analysis of activity indicators of heat sector companies, taking into account economical and social factors and impact of regulation measures;
- integration of indigenous 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.

Research of regional energy issues

Research work ***Investigation and mathematical modelling of factors, which determine activity of municipal heat sector and impact of regulation measures*** was completed in 2007. It enabled to develop the heating sector monitoring and regular development forecasting system of municipalities. Results of this work, which enable to model the activity of heat sector at macroeconomic level, as well as activity indicators of heat supply enterprises, taking into account the impact of various factors and regulatory measures, are particularly relevant today, when the import prices of the main consumed fuel – natural gas and people's expenditure for heating household are rapidly increasing.

Heat sector model simulates the impact of different economical policy tools in the past and may be used in forecasting the interim and final heat consumption in the nearest and medium period.

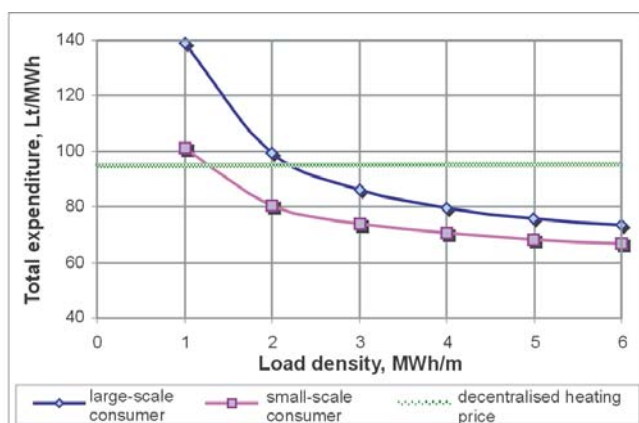
Final heat consumption and district heating market research in household sector supplements the macroeconomic model of heat sector and are further continued while implementing international projects.

Current and potential biomass reserve research are further developed, bio-energy investment planning tools enable to estimate the economical possibilities of indigenous fuel use in heat sector, with biomass accessibility, extraction methods, logistics possibilities, determining raw material costs and demonstrating the impact on the structures of biomass use.

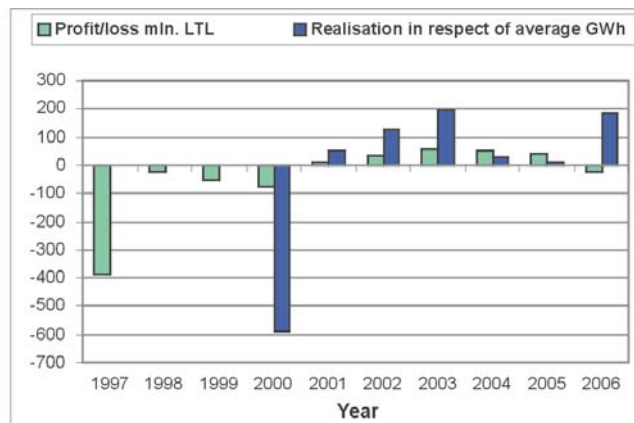
Developed macroeconomic model enables to analyse heat sector issues and apply it for the numerical research of dependence of heat sector development indicators on various influencing factors and economy policy measures on national and municipal levels.

Expanded competitive ability in heat supply network enables to evaluate alternatives of efficiency improvement of non-economic district heating network systems (optimization and refurbishment of some segments of pipeline, disconnection of detrimental consumers or their groups, changes of network scheme configuration, decomposition of supply systems into smaller ones, etc.).

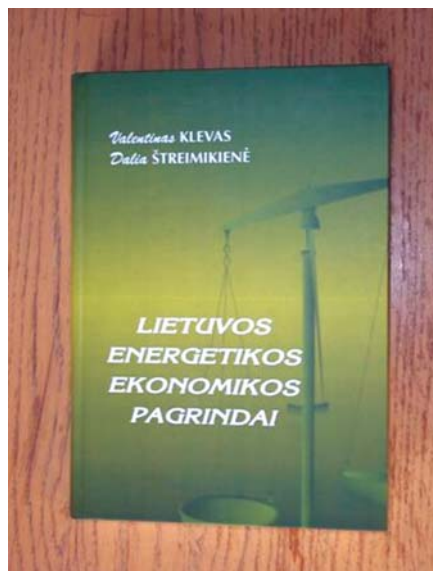
The analysis of heat sector reform sequence and consequences, carried out in Lithuania, was updated and supplemented. With drastic increase of natural gas prices, the analysis could be of great interest to researchers of other countries as well, which transfer from the planned to market economy.



DH competitiveness in respect of decentralized heating



Heat realization and net profit of enterprises



Research trend **Sustainable energy development methodology** is performed integrally, covering scientific research and applied research works in the field of sustainable energy development in Lithuanian and international programs. The objective of all performed activities – the development of Lithuanian energy economics branch on the basis of integral fundamental economic theory applied for energy.

Research is comprised of three interrelated systems:

- a) development of energy economics theory;
- b) research in accordance with budget theme **Development of assessment methodology of sustainable aspects of energy resources' utilization**;
- c) implementation of international projects related to sustainable energy issues.

Summarizing performed research, the monograph **Basics of Lithuanian Energy Economics** by V. Klevas and D. Štreimikienė, where the content, issues and research trends are formulated, was published.

State funded work **Development of assessment methodology of sustainable aspects of energy resources' utilization** was initiated in 2007. The objective is to develop the methodology of economic, social, environmental, reliability aspects of energy sources to justify and evaluate the perspective of sustainable energy development.

Besides technical issues, a great deal of attention and financing is given to the research of economical, social, environmental issues and innovative solutions, which define competitive possibilities of new technologies in energy sector.

International projects

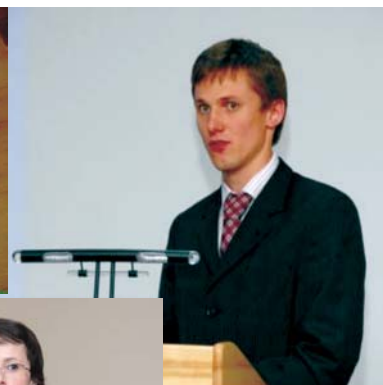
Successfully completed INTERREG III B programme – **Baltic Biomass Network** project, partially financed by the European Commission. The objective of the project is to contribute to implementing the EU objectives in energy sector pursuing that share of renewable energy sources in the region and total EU energy balance would satisfy the tasks, which are foreseen in the directives and other regulating documents. Estonia, Germany, Finland, Latvia, Lithuania and Poland take part in the project.

The assessment of potential of biomass production and use in future biomass energy technologies at regional level was completed in 2007. Modelling maps of resources of current boiler houses, woods and farming biomass were developed, the strategy of biomass energy development for Kaunas county was produced. In the common English manual, prepared by all countries participants, strategic planning indicators of biomass energy development planning system, strengths, weakness, opportunities and threats analysis project for investigated

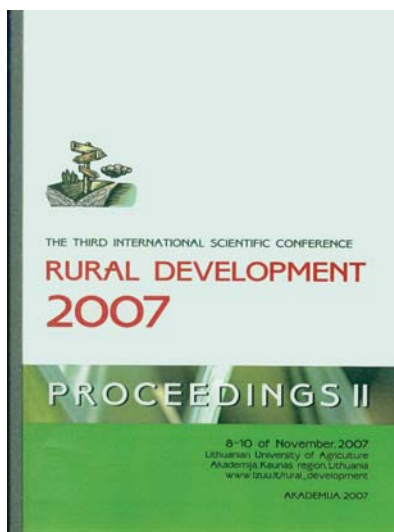
regions are presented, as well as GIS methodologies and maps and recommendations concerning biomass production and utilization for the investors from 6 countries and the Baltic sea region. Two seminars were organized, where participants presented their presentations on biomass fuel production and utilization, possibilities of implementation of new innovative biomass technologies.



BBN project publications – Biomass energy strategy, maps and manual of biomass resources for Kaunas county



Speeches made by representatives from Ūkio bankas, Forest department under the Ministry of Environment



Publications of conference “Rural development 2007” where proceedings of BBN project participants are included



Moments of final project conference in Potsdam (Germany)

During the project there was a close cooperation with organizers of international scientific conference “*Rural development 2007*”, which took place at Lithuanian University of Agriculture.

The project was completed in Potsdam (Germany), where each country – project participant submitted their results – the

situation of the country, its input to biomass energy development. Possibilities of project continuation were discussed, promoting the development of biomass energy business, inviting more countries from the Baltic Sea region to take part in the project.



6 Framework Programme project **Energy Innovation Financing Network (EIFN)** in the framework of INNOVA programme was continued. A wide network of energy companies and institutions as well as financial agencies, which will

help to implement the EU innovations and energy policy, offering financial services in energy sector, making practical and effective decisions, which would enable the access of innovation agencies to financing sources in energy sector, is to be created. During the project LEI participants presented the possibilities of the project and INNOVA network to the participants of Kaunas University of Technology conference *Heat energy and technologies – 2007*. Project activity and possibilities of the network were also presented in several other project seminars, where representatives of banks, investment funds, and renewable energy sources manufacturers participated.



EIFN Project seminar



Intelligent Energy – Europe programme project **Improvement of Social Dialogue Seeking for Energy Efficiency in Social Dwelling-houses (ISEES)** is designed for the improvement of energy

efficiency of social residential houses. It is expected that the project will enable to show possibilities and disclose problems of efficient energy consumption and start dialogue with tenants seeking

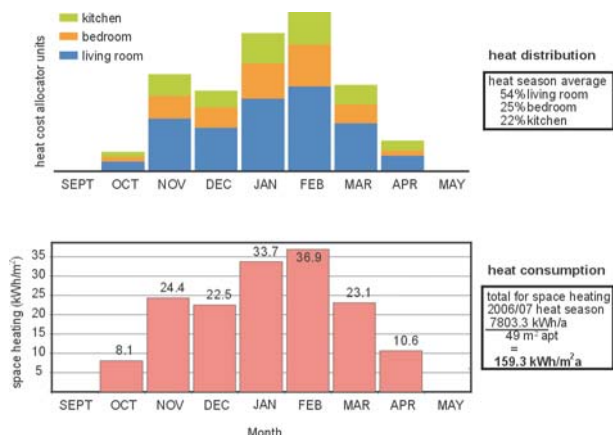


to improve the efficiency of energy consumption. With the assistance of ISEES project there is a need to initiate *social dialogue* among resident housing associations, energy companies (DH companies and electricity supply companies) and municipalities, seeking to determine issues, related with energy consumption in social buildings, present technical solutions, which would enable to optimize energy consumption, evaluate the quality of services supplied by municipal enterprises and heat companies. Austria

(coordinator), United Kingdom, Czech Republic, Slovakia, Bulgaria and Lithuania take part in the project.

Last year was particularly important since measurements of heating season 2006/2007 were carried out, questionnaires gathered from habitants and heat suppliers were overviewed, economical and financial situation was compared in five participating countries. This material enabled to identify problems and evaluate possibilities of more efficient energy consumption in residential houses.

The main conclusion of performed measurement (not only in Lithuania, but also in Bulgaria, Czech Republic, Slovakia and United Kingdom) is that rational heat consumption, efficient energy use in apartments is possible only after implementing these measures in buildings – after buildings' renovation and implementing basic efficient energy supply measures on the heat supplier side.



Heat distribution in apartments according to heat indicators during heating season in 2006/2007



Booklets prepared for habitants and heat suppliers according to project results

Kauno diena

2007.03.27, Nr. 70 (18133)

Lietuviai nemėgsta šalčio

Mantas TOMKŪNAS

Tyrimai atskleidžia, kad gyventojai taupyti šilumą linkę tik žodžiais

Lietuvoje nuolat brangstantis centralizuotas šildymas daugeliui kelia pasipiktinimą, tačiau atlikti šilumos vartojimo tyrimai leidžia teigti, kad turintys galimybę reguliuoti šildymą namuose gyventojai nemoka ir nėra linkę šilumos taupyti.

Stebėtojų įpročiai

Nuolat brangstanti elektra, dujos bei šildymas šalies gyventojams jau seniai yra tapę įprastiniu galvos skausmu, dėl kurio dažniausiai kaltinama valdžia. Tačiau pagal Europos komisijos projektą „Pažangli energetika Europai“ atlikti energijos taupymo tyrimai penkiose Europos Sąjungos valstybėse atskleidžia, kad lietuviai mažiausiai linkę taupyti. Be Lietuvos, projekte dalyvavo Didžioji Britanija, Čekija, Slovakija bei Bulgarija.

Lietuvos energetikos institutas per šildymo sezoną atliko matavimus Kaune, viename šiluminių mikrorajonų daugiabučiams namams, kurio butuose įrengti šilumos reguliatoriai. Dešimties butų sudėti šilumos davikliai padėjo sužinoti namo gyventojų šildymo įpročius. Gauta informacija atskleidė, kad lietuviai savo butuose, skirtingai nei gyventojai kitose keturiuose valstybėse, labiau mėgsta šilumą, be to, nelabai žino, kada geriausia sumažinti ar padidinti temperatūrą kambariuose. Dėl to prarandama galimybė sutaupyti.

Temperatūros nemažina

Lietuvos energetikos instituto laboratorijos vadovas Vaclovas Kveselis sako, kad butuose, kuriuose gyventojai patys reguliuoja temperatūrą, taupymo galimybės priklauso nuo to, kaip intensyviai kambariai yra vėdinami, kokia temperatūra viduje palaikoma ir kiek suvartojama šilumos.

„Tokių butų gyventojai dalį šilumos mokesčio moka pagal suvartotą šilumos kiekį butuose. Pirmas įspūdis atlikus tyrimą – gyventojai šilumą išleidžia per langus, tokiu būdu atšalę butų sienos, o įiems susidūsi reikia daugiau šilumos. Buvo butų, kuriuose atviri langai vėdinavo patalpas visą dieną. Norint, kad tokiam bute būtų šilta, reikia suvartoti ir daugiau šilumos, o tai didina mokesčius už šildymą. Iš penkių valstybių, kuriose buvo atlikti tyrimai gyventojų butuose, Lietuvoje žmonės butuose mėgsta palaikyti didžiausią šilumą, kai kurių lietuvių butuose temperatūra siekė net 24 laipsnius šilumos, žemiau 21 laipsnio nemokėdavo. Be to, ir naktimis gyventojai nebūna linkę mažinti šilumos. Kitų valstybių butuose temperatūra buvo apie 20-21 laipsnis šilumos, o naktimis – 16-18 laipsnių šilumos. Žinoma, jei žmogus jaučiasi gerai šiltoje aplinkoje, tai jam ir gerai, kokia temperatūra turi būti namuose, tačiau taip prarandama galimybė sutaupyti nuo 10 iki 20 procentų mokesčio už šildymą“, – sako V. Kveselis.

Britai gauna daugiau kompensacijų

Kartu su tyrimais atlikta ir sociologinė apklausa, ar gyventojai yra patenkinti energijos vartojimu butuose. Lietuvoje apklaustųjų 54 butų gyventojų nuomone atskleidė, kad lietuviai labiau linkę kalbėti apie energijos taupymą, nei iš tikrųjų taupyti.

„Gyventojai patenkė savo vertinimus, kurie gal subjektiviūs, bet atspindi

tam tikras nuotaikas. Išaiškėjo, kad už butą mokame tiek pat procentų nuo pajamų kiek ir anglai ar slovakai, bet šiek tiek daugiau nei čekai ar bulgarai, kurie dėl šiltesnio klimato moka mažiau.

Tačiau net 50 procentų britų gauna kompensacijas už šildymą, o Lietuvoje tik – 17 procentų. Visose šalyse žmonijai netenka namų izoliacija. Lietuviai yra patenkinti šilumos tiekimo kokybe, o nepatenkinamą dažniausiai išreiškia dėl didelių šildymo kainų: sezono metu net pusė mokesčių už butą tenka šildymui.

Apie 20 procentų apklaustųjų Lietuvoje teigė, kad stengiasi taupyti elektros energiją ir šilumą, tačiau šilumos vartojimo tyrimas parodė, kad dėl komforto lietuviai taupyti nelingę“, – teigė V. Kveselis.

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Article in Lithuanian daily newspaper „Kauno diena“

Extracts from
Lithuanian TV
show
„Pinigų karta“



INTERREG-III C programme project **Redirecting Urban Areas Development towards Sustainable Energy (RUSE)** was completed. The aim of the project is to support new EU countries in directing energy policy towards sustainable development, using Structural Funds. This support is provided at municipal development level, by summarizing the experience of 15 old EU members in various aspects of energy sector. Collected material is analysed, summarized and published at www.ruse-europe.org, used in publications and submitted to new EU member states.

Researchers of the Laboratory participate in much promising project concerning application of hydrogen technologies in transport sector **Roads2HyCOM**, the objective of which is to prepare primary indications how to use hydrogen-energy source in EU countries.

Intelligent Energy – Europe programme project **Sustainable Energy Investments for Consistent Urban Environmental Management (SEIPLED)**, with seven participants from seven countries, was continued in 2007. The objective of the project - theoretically and practically demonstrate the impact of sustainable energy projects' implementation on social, economical and environmental urban development.

7 Framework Programme project **PLANETS (Probabilistic Long-term Assessment of New Energy Technologies)**, the objective of which is to determine optimal scenarios of energy development for the 50-year perspective, was initiated in 2007. This will be carried out due to quantitative and analytic tools, which will enable to determine best future technologies, able to implement EU future environmental and energy policies. Sustainability assessment of technologies performed during the project will enable to determine the competitiveness of future energy production technologies. This work trend is directly related to Sixth Framework Programme theme according to 6.1.3.2.5 trend – (Social-economical tools and conceptions in energy development) – Sixth Framework Programme project **Expenditure assessment in sustainable energy systems**, supervised by D. Štreimikienė. Cooperation will also be carried out in International Atomic Energy Agency project **Strategies of greenhouse gas emissions reduction in energy sector**.



Gaseous Fuels Produced Decentralised from Renewable Energy Sources) is implemented in the framework of *Intelligent Energy –*



Meeting of SEIPLED project executers in Sofia

Europe programme. Coordinator of the project – Gas-und Umwelt-technik GmbH (DBI), one of the largest German gas institutes.

At present, in Western Europe biogas is usually used in the place of its production for generating electricity energy, whereas heat obtained in the production process remains unused. This project has been initiated aiming for higher energy efficiency in biogas utilization. The objective of the project is to analyse and give recommendations while eliminating administrative and technological barriers, development of legal tools while using biogas for heating, cooling and electricity production purposes.

Predictable project results:

- the analysis of countries and participants' legislation, which enables to evaluate the lack of legal tools in EU and Lithuania aiming to utilize biogas for heating, cooling and electricity production purposes;
- development of technologies, designed for biogas cleaning, aiming to transmit the obtained product via natural gas pipelines;
- development of biogas standards aiming to supply them to consumers by natural gas networks;
- analysis and dissemination of information concerning successfully operating biogas power plants in Europe.

Researchers of the Laboratory perform scientific research and consulting works and provide services according to contracts with Lithuanian institutions, companies and organizations.

In 2007 monograph **Basics of Lithuanian Energy Economics** by V. Klevas and D. Štreimikienė was published in the Laboratory, 4 articles were published in ISI journals (2 Energy Policy and 2 Renewable and Sustainable Energy Reviews). Researchers of the Laboratory presented 4 papers in Lithuanian and 2 in international conferences.

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

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Main research areas of the Laboratory:

- research of solid biomass use for energy production;
- analysis of RES use for energy production and assessment of utilization development for 2008 – 2025 in accordance with EU requirements;
- research, modelling and forecast of wind flow variation on the Baltic seashore in Lithuania;
- analysis of RES use for electricity energy production in Lithuania and research of development possibilities;
- economical and environmental efficiency research of biogas and biofuel production and use;
- promotion of state-of-the-art technologies using local and renewable energy sources, research of environmental issues;
- organization of accredited training courses, development of RES database, services and consultations for users.

Research of solid biomass use for energy production

At the Laboratory research related to rational use of biomass resources in biofuel production and solid biofuel use to produce heat and electricity energy is carried out. Data on biomass sources and their use in biofuel production, covering all cycle from raw material collection, preparation, and reproduction into solid biofuel and burning in different types of boilers, are accumulated and analysed.

In 2007 INTERREG IIIB programme project **Baltic Biomass Network**, implemented by 12 organizations from six EU countries was completed. One of the main objectives of the project is at the regional level to integrate biomass use for energy production into the common planning process. During the project the strategy of biomass use in energy sector designed for Kaunas district, Lithuania, was prepared, and model and software, designed for calculating the output of deforestation waste and wood fuel, were developed.

In 2007 Sixth Framework Programme project **Co-firing – from Research to Practice: Technology and Biomass Supply Know-how Promotion in Central and Eastern Europe (COFITECK)** was started. In EU countries the scope of firing fuel and biomass and every kind of biomass fuel mixtures is increasing, employing different firing technologies for this purpose. In Lithuania, fuel mixtures (e.g. turf and wood) are burnt more often. Thus, the aim of the project is support the optimization of chains of fuel mixtures firing technologies and biomass fuel supply. It is forecasted to give possibilities for interested employees of heat and electricity production enterprises to get acquainted with up-to-date technologies in the field of fuel mixture firing in EU countries and share experience, gained in different Lithuanian enterprises.

With the increase of boiler houses, using wood fuel, and thermal power plants the demand for wood fuel increases and its lack may become the main factor, limiting the development of

energy sector. Due to this reason the cultivation of energy fuel is particularly relevant because it may increase the raw material resources of biofuel production and which also helps in dealing with environmental issues and developing economics in rural regions. Works related with the assessment of energy fuel cultivation perspectives, are continued in the laboratory. For this purpose data on osier plantations in our country is accumulated and analysed, experience of foreign countries is considered as well.

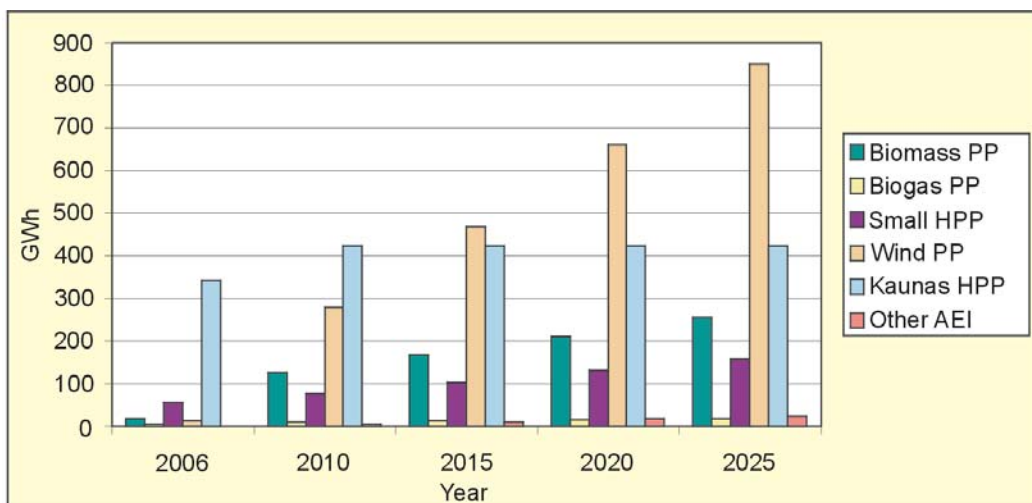
Researchers of the Laboratory continue to participate in the activity of Lithuanian Standardization department 71st technical committee **Solid biofuel and solid recovered fuel**, validating at national level standards, prepared by European standardization committee

Energy production scopes from renewable energy sources in 2008–2025

In 2007 the analysis of renewable energy sources' (RES) use in the country was carried out, their technical potential was specified according to separate types of resources, and technical, environmental and economical possibilities of RES potential's employment up to 2025 were evaluated. The forecasts of scopes of RES use for electricity, heat and biofuel production were presented, indicating assessment assumptions. The policy of mastering EU and Lithuanian RES and the overview of promoted measures were presented. Additional promoting measures necessary to increase the use of separate types of RES for energy production are prepared and recommended.

Analysis and research of development possibilities of renewable energy resources use for electricity and thermal energy production in Lithuania

Till 2004 electricity energy, using RES, was produced only in hydro power plants. Thus other RES were searched for energy production. Particular attention was given to wind energy, also



Electricity production and forecast from different types of RES. Total electricity consumption (in 2006 – 2053 GWh) and forecast (in 2010 – 12500; in 2015 – 13800; in 2020 – 15100; in 2025 – 16500 GWh)

biomass and biogas use in cogeneration facilities. Total power capacity of installed wind power plant in Lithuania – 51.95 MW. Up to year 2010 it is forecasted to build installed wind power plant with the total capacity of 200 MW. Construction of cogeneration facilities is intensively spread using biomass and biogas fuel. Vilnius TE was reconstructed – employing it for wood fuel. Electricity is produced in SC *Kauno energija* Noreikiškės boiler-house, SPUAB *Utenos vandenys* and other biogas cogeneration power plants. Aiming at implementing the requirements of Directive 2001/77/EC on the promotion of the electricity produced from renewable energy source in the internal electricity market (7% of electricity consumed in Lithuania to produce from RES), the laboratory researchers participate in the implementation of these works, i.e. they observe the operation of power plants, give recommendations concerning their efficiency, perform pre-design studies forecasting the construction of new power plants. Technical-economical analysis of installed wind power plants installation, which is important in making installed wind power plant construction plans, secure work norms and forecasting the perspectives of WP development in the country, was carried out in the laboratory. There is a constant cooperation with biogas producers to intensify biogas production, giving to them practical recommendations.

The utilization of RES in district heating sector is rapidly increasing. This is determined by rather big biofuel resources, low price of the fuel (in comparison to fossil fuel) and a small amount of emissions.

Research possibilities of solar energy use

Continuing research of solar energy use for the preparation of hot water, possible capacity of solar hot water preparation systems under Lithuanian conditions was estimated. The amounts of hot water produced in solar collectors during different periods of the year and its percentage in the annual hot water balance were analysed. Efficiency of plates and vacuum collectors was analysed, the price of hot water prepared in solar systems at different values of collector conversion and heat loss was calculated. Payback time of solar hot water preparation systems depending on the types of collectors and their surface areas was evaluated.

In 2007 research of buildings' cooling was continued. It was analysed how the form of buildings influence the cooling input, variation of cooling energy was investigated orienting buildings to different parts of the worlds, the impact of windows and walls' area ratio change on the demand of cooling energy was determined, regularities of cooling energy of buildings depending on the change of heat transfer coefficient of windows were analysed, the impact of passive measures reducing the cooling needs of buildings was evaluated.

Economical and environmental efficiency research of biogas and biofuel production and use

Biogas. Anaerobic treatment technologies are one of the most effective organic waste utilization measures, which are directly related to the reduction of environment pollution. Without these technologies it is almost impossible to implement the environment protection requirements for the manure treatment, in accordance with order No D1-367/3D-342 of the Ministry of Environment of the Republic of Lithuania, July 14, 2005. Therefore, the laboratory performs the applied research of this trend. In the Laboratory methodological recommendations are prepared for state farmers and enterprises, implementing efficient technologies of energy production from organic waste, which meet the most important environmental requirements. Thus pollutants of organic origin may at the maximum be effectively utilized and it is possible to contribute to the performance of the responsibilities of the Republic of Lithuania and the requirements of the EU Directives.

Biofuel. With the increase of the number of cars, the consumption of biofuel increases as well; as a result, pollution of the environment with hazardous combustion products, inducing greenhouse effect in the atmosphere, increases. Lithuanian transport depends on the import of raw material for fuel, therefore it is very important to use them economically or search for alternative fuel, produced from local renewable resources. Biofuel, produced from vegetable origin biomass, are most appropriate under Lithuanian conditions: rapeseeds – designed for biodiesel production and other cultures (sugar beetroots, triticale) – bioethanol production. Dehydrated ethanol and rapeseed methyl ester are already manufactured in Lithuania, however in state transport they are not widely

used since potential consumers do not have detailed information on the issues of biofuel consumption. Main characteristics of biofuel – its stability, impact on non-metal fuel supply system parts and impact on motor technical-economical characteristics are not thoroughly investigated under Lithuanian conditions. Experimental research works are carried out at the Laboratory to solve the above problems.

Research, modelling and forecast of onshore wind variations over the Baltic Sea

Data analysis of wind velocity and direction measurement is carried out in the Laboratory, forecast model of power of wind power plants (WPP) is developed, and wind energy resources in Lithuanian territory are measured. Analysis of wind energy parameters is carried out using annual observation data of Lithuanian meteorological stations and wind velocity and direction measuring data in Klaipėda region. The measurements were carried out in Giruliai town, employing state-of-the-art wind parameters measurement facility “Wicom-C”. Evaluating measuring data, the wind atlas for Lithuania territory was developed.

In order to investigate the impact of the peculiarities of constructional elements cross flow of WPP on its operation, numerical modelling of different wing profiles cross flow of WPP, employing FLUENT software, was carried out. Distribution of pressure, air flow velocity, and kinetic turbulent energy around profiles at different air flow attack angles is measured.

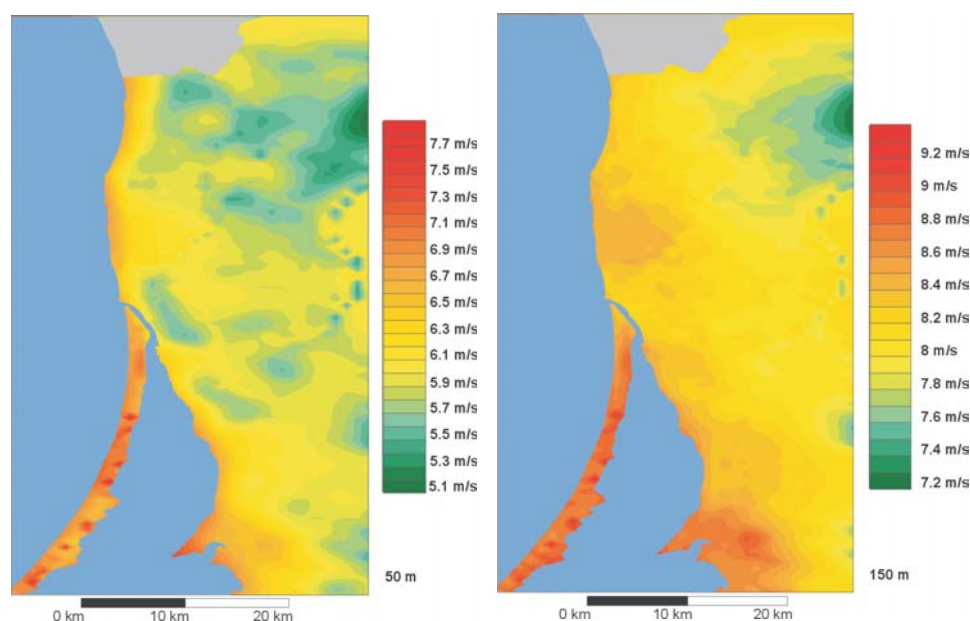
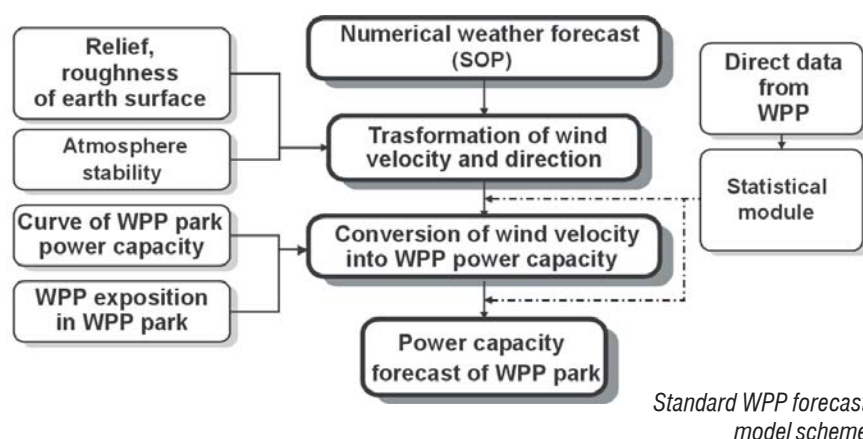
Cooperating with Wind Energy Department of Risø National Laboratory (Denmark) detailed wind resources analyses and selection meth-

odologies of WPP construction site using WASP software were mastered. Forecast methodology of WPP, based on numerical air forecast data of Lithuanian Hydrometeorology office, was analysed. According this methodology forecast model of WPP farms, which is able to forecast WPP operation two days in advance, is being developed.

It was determined that the best condition for WPP construction was the coast region. Wind resources were estimated using wind measuring data of this region, taking into account the place relief, roughness of earth surface, natural and townscape obstacles and atmosphere stability.

Other *Intelligent Energy – Europe* projects implemented in 2007:

- **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).**
- **Monitoring and Control of Energy Consumption in Municipality Public Buildings over Internet (ENER in TOWN, 2006–2008).**



Distribution of average wind velocity in Lithuanian seashore region at 50 and 150 m height

In 2007 researchers of the Laboratory published **6** articles in scientific journals and **13** articles in other reviewed scientific publications, **2** articles in popular journals. They participated in **4** international and **9** Lithuanian science conferences.

ENERGY EFFICIENCY RESEARCH AND INFORMATION CENTER

Head of the Center –
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Main research areas of the Energy Efficiency Research and Information Center:

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

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

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

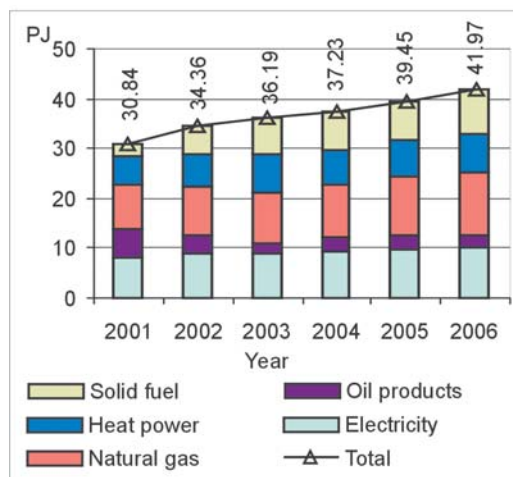
Energy saving and efficient use of energy sources, promotion of manufacturers and consumers to efficiently consume local, renewable and waste energy sources is one of the most important energy objectives, defined in main strategic documents of the Republic of Lithuania, which regulate the development and perspective of Lithuanian energy sector.

At present, in Lithuania, after the structure of final energy consumption has changed, industry and buildings cover almost two thirds of total final energy consumption. In these sectors the potential of increasing energy consumption efficiency is the biggest. It could be acquired by implementing up-to-date energy

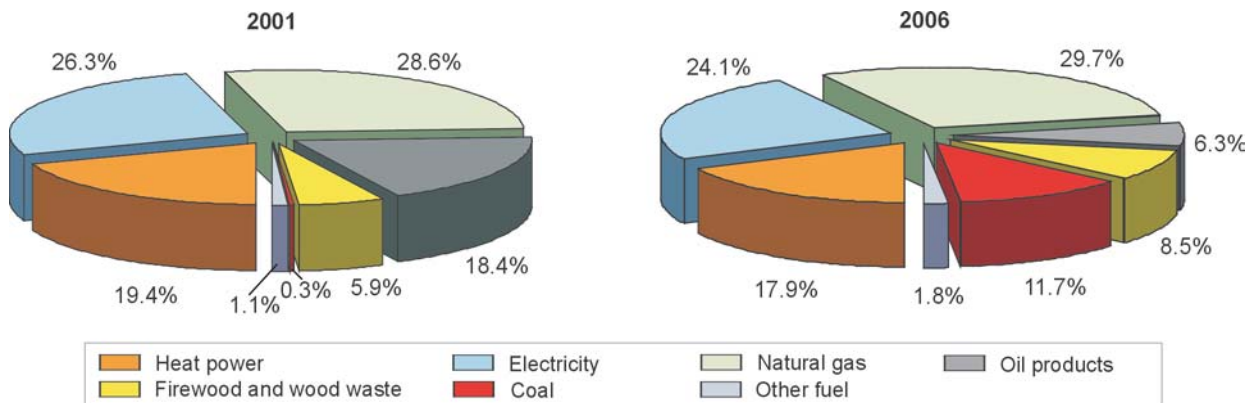
management systems, energy efficient technique and technologies, and by improving organizational legal measures.

State funded project **Research of increasing energy consumption efficiency in sectors of industry and buildings** was continued in 2007. Data on the development of Lithuanian industry sector and fuel and energy consumption for the period 2000–2006 are presented and analysed, the possibilities of employing low capacity microturbines (new cogeneration process technology) in Lithuania were investigated, data on electricity consumption in dwelling houses and domestic appliances were collected and presented.

The implementation of energy management in an enterprise is one of the measures, which enables to increase energy efficiency.



Distribution of fuel and energy final use in industry in the period of 2001–2006

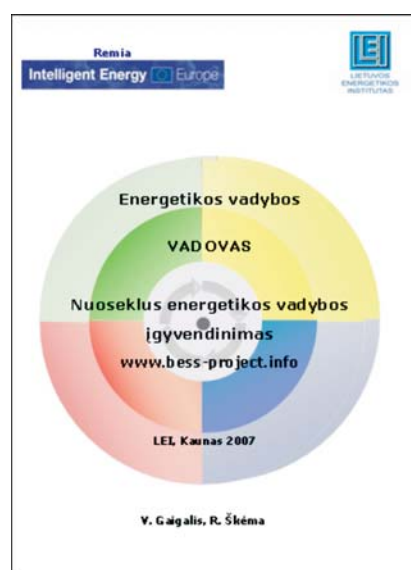


Distribution of fuel and energy final use in industry in the period of 2001–2006

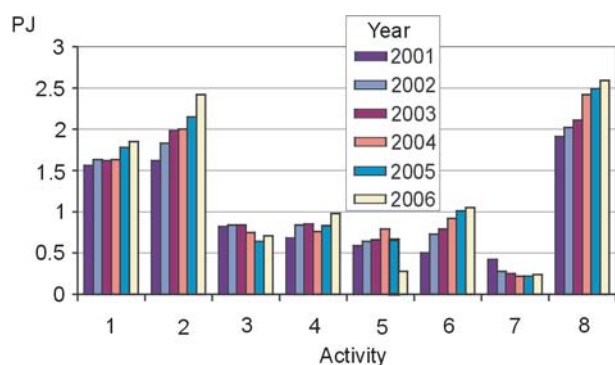
International internet site www.bess-project.info, E-learning measures (available in native language), providing main information of energy management implementation, and a handbook on step by step guidance for the implementation of energy management have been created.

The Handbook of energy management implementation is a measure, which leads small and medium enterprises towards energy management implementation process. Some measures (energy management verification sheet or description of business development) are recommended to be transferred from the internet web page directly since automatic calculations with data interpretation are introduced there.

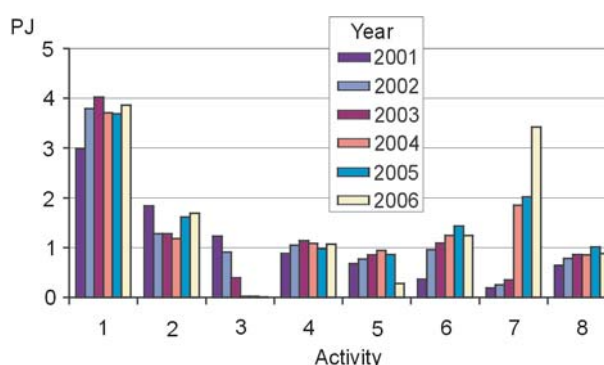
The Handbook may be used in all industrial branches and sectors. The list of horizontal efficient energy measures is beneficial for all industry branches. Specific list of efficient energy measures, divided according analysed industry divisions, is presented as a separate document. **Energy management implementation model** (EMIM) is given in the handbook, where a logic process of energy management implementation according principles plan-do-check-act is presented. EMIM comprises 19 activities and several auxiliary measures and instruments to implement them. Activity succession may differ from the order presented in the model.



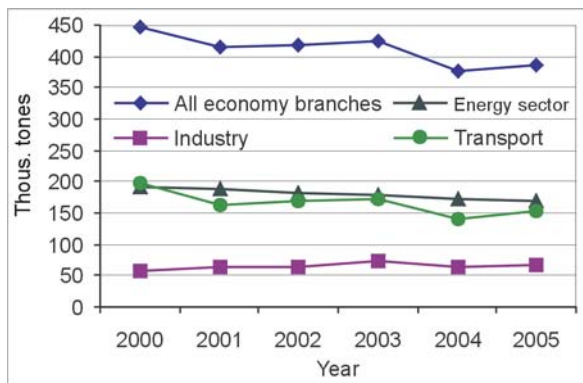
Basic energy management system requirements, which satisfy the environmental management standard ISO 14001, are presented in BESS energy management specification.



Largest natural gas consumers of the industry: 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 branches of industry



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



The emission of materials to the environment for the period 2000–2005 (thous. tonnes)

While implementing National energy consumption efficiency increase programme for the period 2006–2010 the following was performed:

- Expert assessment of possibilities of heat use of SC *Klaipėdos mediena* wood shave hothouse exhausted smoke;
- Expert assessment of boiler houses operated by JSC *Jurbarko komunalininkas* and JSC *Baisiogalos energija* for the period 2006–2007 during the heating season and estimation of the forecasted price of their supplied heat;
- Expert efficiency assessment of geothermal heating system project and installed system of judges training center of the Ministry of Justice of the Republic of Lithuania; expert note was prepared regarding defaults of technical supervision of constructional works carried out in judges training base reconstruction to judges training center in Sanklodiskiai village, Molėtai district.

The expert note concerning drawbacks of technical maintenance of construction works of the reconstruction of judges training base into judges training center in Sanklodiskiai village, Molėtai district was prepared.



In 2007 the following international projects were carried out:

- **Data comparison and Energy management schemes in small and middle size enterprises.** This *Intelligent Energy – Europe* programme project has been implemented together with partners from 11 countries (Austria, Bulgaria, Finland, Greece, Ireland, Norway, Slovenia, Spain, Sweden and The Netherlands). The main objective of the project – develop and promote energy management use in small and middle size industrial enterprises, improving energy consumption efficiency and orienting towards manufacture of food products and beverages. It is expected to form innovative decisions ensuring continuous connection of small and middle size enterprises with energy management and efficient energy consumption. It is expected that measures will help to reduce cost price of production, increase energy consumption efficiency and implement environmental obligations under the Kyoto Protocol.
- **Integration of electricity production from renewable energy sources to the EU network with least expenses.** This *Intelligent Energy – Europe* programme project has been implemented together with partners from 19 European countries. Perspective of electricity production from renewable energy sources in Lithuania up to the year 2020 was evaluated.
- **Dissemination and application of the Motor challenge programme.** This *Intelligent Energy – Europe* programme project has been implemented together with partners from 15 European countries. Efficiency of electric motors utilization in water supply enterprises was analysed. Measures were proposed for the reduction of electric energy consumption in enterprises.
- **Integration of Active Learning and Energy Monitoring with School Curriculum.** *Energy – Europe* programme project has been implemented together with partners from 15 European countries. The objective of the project is to reduce energy use in school buildings and homes, giving to schoolchildren better understanding on rational energy consumption, renewable energy sources and transport. Educational material of Active Learning and Energy Monitoring designed for schools is presented in the project. Best European examples adapted to each country's conditions and needs are reflected in the material. Collected and developed Active Learning material is presented on website www.teachers4energy.eu.

In 2007 4 seminars were organized (2 of them international), research results were presented in 13 scientific articles, 5 papers were presented in Lithuanian and international scientific conferences.

Seminar for teachers concerning the integration of Active Learning and Energy Monitoring to school programs

LABORATORY OF SYSTEMS CONTROL AND AUTOMATION

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Main research areas of the Laboratory:

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

With the rapid development of information technologies, more control and protection technical devices as well as intellectual electronic controllers are used in electric power systems (EPS). EPS control algorithms are becoming more complex, as they must regulate the work of all those devices for EPS to run in the required mode, and coordinate their actions across territories. New information and communication technologies are employed, for instance, GPS-based wide area protection system. Efforts are made to process more information (telemetry results, teleindications) from different EPS points in real time and: 1) to generate control commands that correspond adequately to the EPS status and to transmit them to remote EPS control devices; 2) to choose optimal settings of the automation devices. The target is to achieve optimal rate of the centralised and decentralised control. Flexible alternative current transmission systems (FACTS), i.e. power electronic devices are used in the EPS, increase the transferring ability of the network, and improve power system stability. The enhanced control increases economic efficiency of EPS, reduces emergency risk, allows for disturbance localization in the national system and helps to avoid its spreading into the interconnected system.

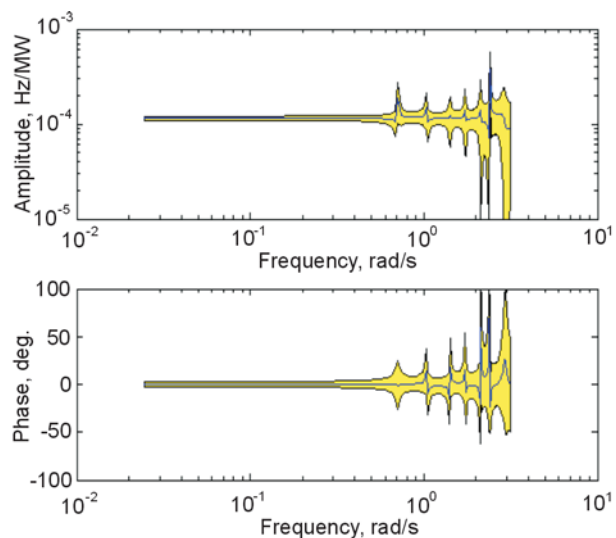
Laboratory **carries out research and offers services** in the following fields:

- evaluation and investigation of EPS parameters;
- mathematical modelling of EPS, power networks and control systems;
- investigation of advanced EPS control methods, new automatic control devices and application of information and communication technologies;
- investigation of EPS control issues and development of control algorithms (related to frequency, active and reactive power control, static and dynamic stability, loss reduction, quality of electricity, emergency prevention, aspects of electricity market);
- optimisation of EPS operation in competitive market environment, development of competitive mechanisms for balancing and ancillary services;

- EPS and network extension modelling and technical policy formulation.

In 2007 Laboratory continued its work on the on-going three-year state funded project **Efficient use of national balance control resources in Lithuanian and Baltic power systems**. This project corresponded to scientific trend **Modelling of complex systems, development of technical measures of their management methods and control**. In 2007 an interim report, a study on the evaluation of EPS parameters of dynamic frequency characteristics and a probabilistic evaluation of national balance deviations were presented.

In 2007, Laboratory carried out a number of contractual projects. Transmission operator JSC *Lietuvos energija* ordered two projects: **Revision of regulations on emergency prevention automation of Lithuanian power system** and **Evaluation of parameters of static and dynamic frequency characteristics of Lithuanian power system, investigation of their variation and**



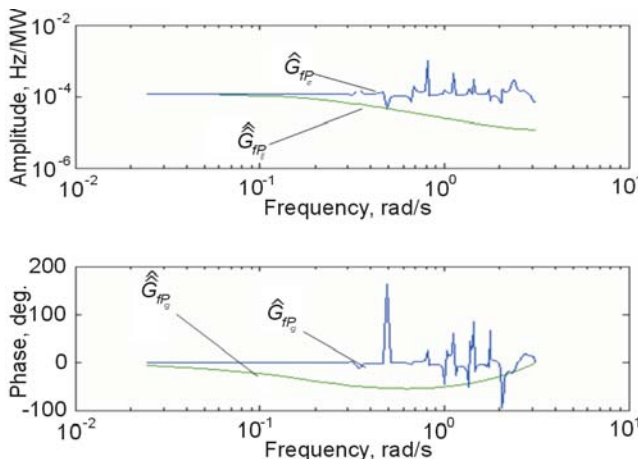
Amplitude-phase characteristics of EPS calculated when Kruonis HPP generated system is switched in. Input is generated power P_g , whereas output – frequency f



Research associates of the Laboratory (from the left) – Dr. S. Kadiša, Dr. V. Radziukynas, Dr. A. Klementavičius

influence on the operation of the system. Project **Evaluation of electrical energy loss at wind power park “Benaičiai VEP”** has been carried out for JSC Renerga.

In the first project (**on emergency prevention automation**), more accurate operation principles of emergency prevention automation (EPA) were formulated and the possibilities of EPA introduction were evaluated. A comparison of emergency prevention automation measures in UCTE and Lithuanian EPS was performed and the requirements for EPA operation were analysed. A revision of the working parameters of the main kinds of automation (emergency frequency control devices, under- and overvoltage protection devices, overload interrupting devices, and stability prevention automation, etc.) was presented. Hereby, the simulation of Baltic EPS operation modes (including perspective analysis of automatic network reserve input switch-in points) was performed. As a result, recommendations for EPA applications were submitted.



Estimates of EPS amplitude characteristics, determined within a short duration (200 s), when generation of Kruonis HPP varies, \hat{G}_{IPg} – obtained by spectral analysis method, \hat{G}_{IPg} – by identification method, using OE model

As an outcome of the second project (**on static and dynamic frequency characteristics**), evaluation methodology of static and dynamic frequency characteristics, which leads to lower errors, was developed. Parameters of frequency characteristics and their variation range for two different situations, i.e. when Lithuanian EPS works in BRELL (Belarus, Russia, Estonia, Latvia and Lithuania) ring and when it works in the isolated Baltic EPS, were identified. The influence of those parameters on the Lithuanian EPS operation modes was analysed. By means of parametric identification, a new mathematical model that allows an adequate simulation of frequency and active power regulation was developed. Frequency variation in dependence on the operation of wind power plants was analysed.

In the next project, technical and economic efficiency of connecting schemes of wind power plants to the transmission network was examined. A new efficiency evaluation methodology was developed and applied for the assessment of technical and economic efficiency on generation level (wind power plant and wind power park) and on the electrical network level outside the park.



Scientists of the Laboratory participate in the international project **UNDERSTAND**, which is a part of European Commission programme *Leonardo da Vinci*. The aims of this project are to identify the cooperation problems among the systems in crisis management process, to define the need for training and to develop an attractive training package for the European electric energy suppliers, distribution network operators, as well as the training institutions that prepare electrical engineering specialists.

Researchers of the Laboratory contribute to the training of young specialists. A student from Dublin Institute of Technology completed his bachelor thesis, other two students from Kaunas University of Technology did their internships in the Laboratory (according to student internship project, implemented by the Science Council of Lithuania and Lithuanian Ministry of Education and Science and funded from EU structural funds).

The research results were published in 2 international editions, 2 publications included into international databases recommended by the Science Council of Lithuania; researchers presented their papers at 2 international and 3 national conferences, and published 3 popular science articles.

LABORATORY OF HYDROLOGY

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Main research areas of the Laboratory:

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

In 2007, researchers of the Laboratory implemented fundamental and applied research in the field of environmental engineering.

The investigation of Lithuanian water bodies has been performed using numerous hydrographic, hydrologic, morphologic and other data, collected by the Laboratory of Hydrology since 1961. The main task of environmental protection – the assessment of impact of economical activities on the environment and justification of environmental protection measures are solved employing the state-of-the-art modules (hydrodynamic, wave, advection-dispersion and sediment transport) of modelling system MIKE 21 of Danish Hydraulic Institute.

Research objects and tasks

Most significant research objects of the Laboratory are as follows: the Baltic Sea, the Kaunas Sea, the Drūkšiai Lake, the Curonian Lagoon, the River Nemunas and other Lithuanian rivers. These water bodies are under extreme nature phenomena expressions (storms, excess rainfalls) or are affected by intensive anthropogenic activities.

Using collected data and modelling system MIKE 21 the following tasks are solved:

- environmental impact assessment of anthropogenic activities on water bodies and justification of environmental protection measures;
- hazard and risk analysis of hydrotechnical constructions;
- protection and maintenance of the Baltic Sea coasts;
- investigation of quays interaction with water flow and selection of optimal constructions;
- determination of environmental conditions using water bodies for different objectives;
- numerical assessment of mixing and dispersion of contamination under critical operation conditions in water bodies;
- exploitation of the Seaport and water ways maintaining secure depth for navigation;
- sensitivity and uncertainty analysis of two-dimensional hydrodynamic input parameters.

Research of rivers run-off variation

Since 2005, together with Nordic countries, a joint project **Climate and Energy**, funded by the Nordic Council of Ministers, has been started. 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. For the implementation of this task, research groups for climate change scenarios, statistical analysis and hydrologic modelling have been formed.

Scientists of the Laboratory participate in the activities of the research group of the statistical analysis of climate and river run-off. Global climate change will inevitably cause drastic fluctuations of hydrological regime and changes of water resources. According to climate change scenarios, rising air temperature, changes in precipitation and total evaporation will have an extraordinary effect on the annual distribution of river run-off and will cause changes of extreme run-off elements (floods and droughts). In Lithuania, as well as in other EU countries, it is necessary to properly exploit renewable energy resources, as this will allow to reduce negative consequences of the climate change (greenhouse effect). Hydroenergetic resources of rivers is one of the widely used renewable energy sources, directly depending on the parameters of river run-off. Due to climate change processes, river water resources will have the direct impact on hydroenergy production as well as on the safety of embankments during extreme natural phenomena.

Up to now Lithuanian river run-off forecasts for climate change conditions have not been made. Planning the operation of large hydropower stations, it is important to know how river water resources will change in the 21st century. Therefore, the operation of Kaunas Hydro Power Plant (HPP) under the circumstances of forecasted run-off is analysed for the first time in Lithuania, with the particular attention to the safe operation of the system in the extreme conditions. The risk analysis of the energy system will facilitate the evaluation of the system status from the point of view of climate change.

The analysis of temperature, precipitation and river run-off has revealed that the strongest relation among these parameters is during wintertime. During spring season, significant increase of temperatures is observed, whereas precipitation is insignificant. Thus snow cover melts earlier, some floods occur in wintertime. The least significant air temperature and precipitation trends are in summer and autumn, that's why river run-off does not have

many significant trends. Increase of winter run-off, decrease of spring run-off and small opposing trends of summer and autumn run-off demonstrate the levelling among the seasons during the recent decades and the situation is therefore favourable to the operation of small hydropower stations.

In 2007, database of meteorological and hydrological parameters was explored and the statistic analysis of climate and hydrologic parameters of different periods (annual, seasonal, flood and dry trends) was carried out. The database will be further analysed in order to identify the interaction between the climate change and hydro energetic potential. The obtained results have been used in the Nordic research projects **Climate and Energy** and **Climate and Energy Systems**. Doctoral student D. Meilutytė - Barauskienė working on her dissertation **Evaluation of climate change impact on Lithuanian rivers run-off** has actively participated in these projects.

Research of surface water sources

Good state of Lithuanian water bodies is closely related to hydrographic, hydrologic, water economy and environmental research. Only after evaluation of properties of water bodies in different physical geographical regions, sustainable development of water ecosystems is possible.

In accordance with the decision of the Government of the Republic of Lithuania, the Laboratory of Hydrology is confirmed to be the supplier of cadastral data of Lithuanian rivers and lakes, which is responsible for collecting data on hydrography and hydrotechnical constructions. The probability safety analysis of the Kaunas HPP water body has been carried out. Managing hydroenergetic system optimal decision is searched taking into account the assessment of run-off across embankment, inflow to water reservoir, risk related with embankment failure and useful water volume of reservoir. Results of this analysis are related with extreme, larger than millennium, floods. Created model enables to make safe decisions during floods.

Sensitivity and uncertainty analysis of input parameters of hydrodynamic model has been carried out for Kaunas HPP, which undergoes the influence of Kruonis Pumped Storage Plant, using SUSA code, created by GRS GmbH company (Germany).

Cooperation with state and scientific institutions

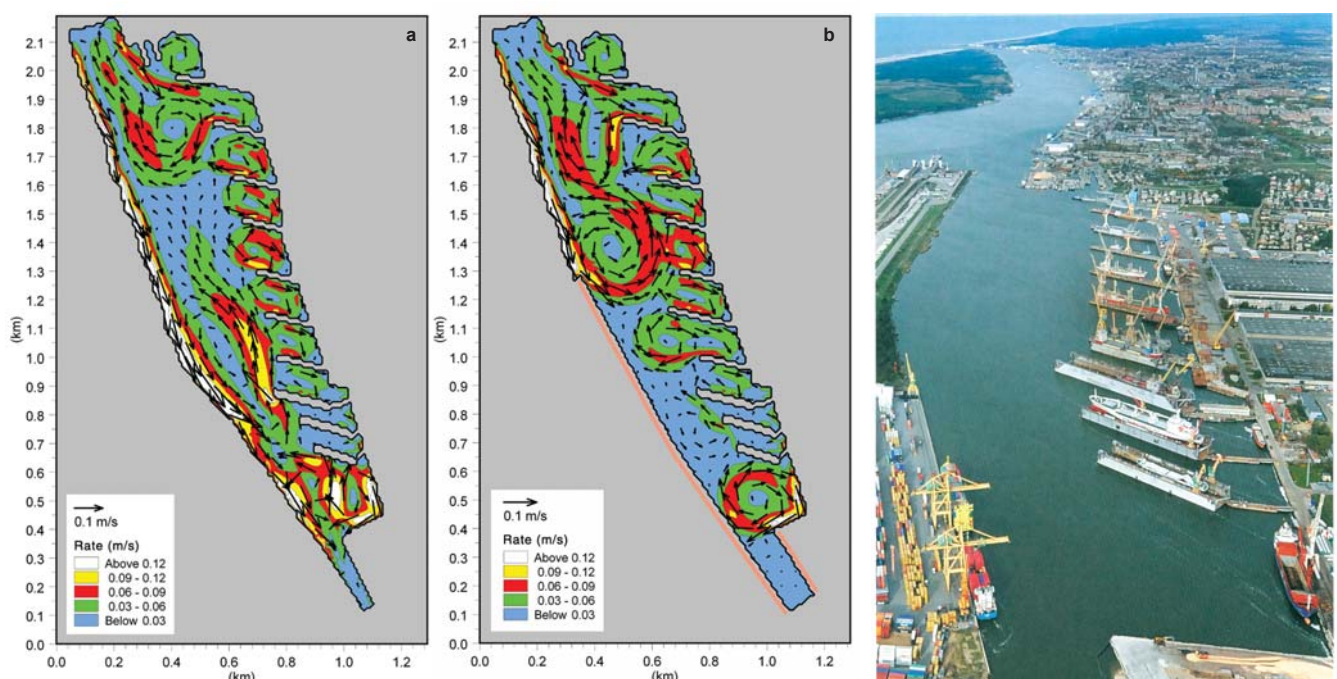
The Laboratory of Hydrology closely cooperates with the Institute of Environmental Engineering of Kaunas University of Technology, have joint doctoral studies, since 1995 have been publishing scientific journal **Environmental Research, Engineering and Management**. The Laboratory together with Institute of Geology and Geography, Institute of Botany and Institute of Ecology of Vilnius University, Vilnius Gediminas Technical University and Lithuanian University of Agriculture carry out complex environmental research. In accordance with agreements between the Ministry of Environment of the Republic of Lithuania and Lithuanian Energy Institute, expertises of plans, programmes and projects are prepared by the Laboratory.

Major applied research works

The Laboratory carries out applied research works and according to agreements with enterprises and organizations prepares projects of hydrotechnical constructions:

According to the contract with Klaipėda State Seaport Authority, environmental impact assessment reports of Malkų harbour deepening and Klaipėda harbour northern part seaway widening have been prepared, in which favourable fort environment quay variants have been identified and suggestions for their construction have been offered.

The Laboratory researchers participated in 5 international conferences and published 8 scientific articles, 2 of which in publications that are included into the list of Institute of Scientific Information.



Structure of Malkų harbour flows at North wind velocity 20 m/s: a – initial version, b – deepening and installing embankments marked in orange line

FINANCIAL HIGHLIGHTS

The financial sources of the Institute consist of:

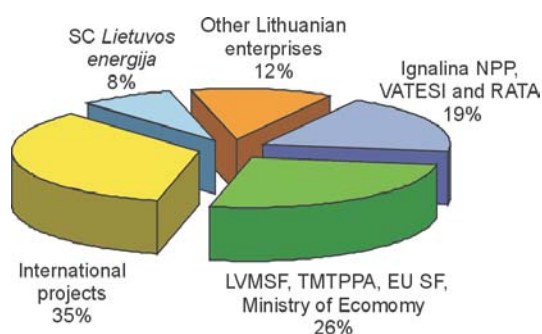
- State budget subsidies;
- financing for research programmes and education of specialists;
- financing received from Lithuanian and foreign enterprises and organizations for contract works, realization of products and services;
- funds received from various international research programmes and funding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

Structure of Income and Total Expenses (LTL'000)

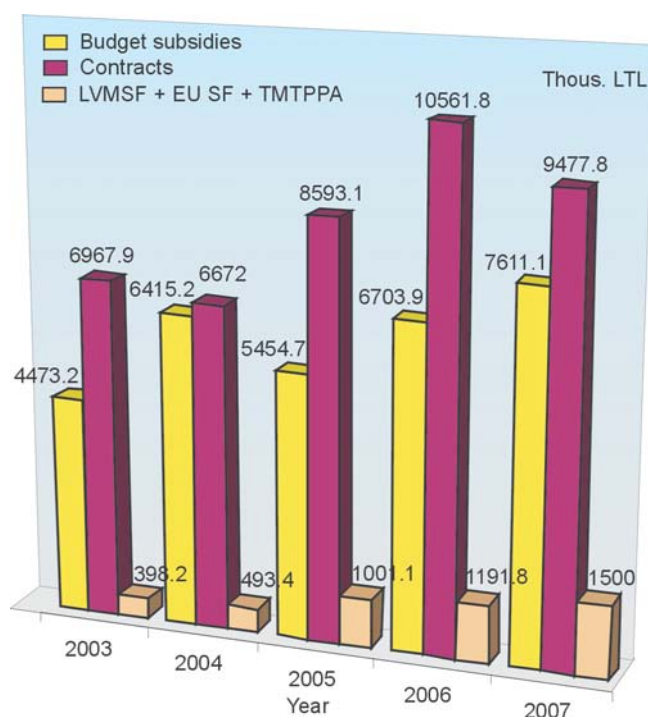
	2003	2004	2005	2006	2007
Income:					
State Budget Subsidies	4473.2	6415.2	5454.7	6703.9	7902.1
Contracts	6074.0	6833.0	8230.9	10208.6	9439.1
SF Support				225.1	1048.0
Other Income	1128.0	1356.0	1048.7	1320.4	1356.2
Total:	11675.2	14604.2	14734.3	18458.0	19745.6
Expenses:					
Salaries (soc. ins. incl.)	7783.0	8667.0	9345.5	10709.1	12919.9
Operating Expenses	3572.2	3699.7	3559.0	4696.6	4881.8
Capital Funds	571.0	1564.3	1548.4	1185.5	2010.4
Total:	11926.2	13931.0	14452.9	16591.2	19812.1
Long-term Projects Assets	1705.0	2378.2	2878.0	4744.8	4678.1

Variation of Financial Structure

Income of 2007 from local and international projects



LVMSF – Lithuanian State Science and Studies Foundation
 VATESI – State Nuclear Power Safety Inspectorate
 RATA – Radioactive Waste Management Agency
 TMTPPA – Agency for International Science and Technology Development Programmes in Lithuania



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Lithuanian Energy Institute in 2007

2 January.
Head of DG RTD
signed EURATOM-LEI
association contract

8 January. Signed agreement
concerning scientific collaboration
between Università degli Studi di
Milano-Bicocca (Italy) and
Lithuanian Energy Institute

2 February.
Signed collaboration
memorandum with
American Nuclear
Society



15 February. Certificates ISO 9001 and ISO 14000
were issued to the Institute



15 February.
Expanded
session of
Lithuanian
Industrialists
Confederation
at the Institute



22 February. Meeting with Kaunas
town mayor A. Garbaravičius



2 March 2006 Lithuanian Science awards
granted to B. Čėsna, P. Vaitiekūnas and
L. V. Ašmantas for the cycle of works
“Intensification of heat and mass transfer
and determination of regularities in power
devices (1975–2005)”



6 March. LEI organized seminar in SC “Lietuvos energija”,
Vilnius



14 March. LEI successfully participates in Career
days 2007 organized by Kaunas University of
Technology



11 April. Conference “Nuclear
energy: present and perspectives”
organized by LEI young scientists
union



24 April. Visit
of students
from Vytautas
Magnus
University
Nature
Sciences
Faculty





4 May. Expo Kaunas-2007



10 May. The seminar of "Intelligent Energy – Europe" project BALANCE at the Institute



7 June. Conference of young scientists and Ph.D Candidates "Youth Energy 2007" at LEI



22 June. The 75th anniversary of Prof. J. Jablonskis



24 July The 80th anniversary of Prof. A. Nemura

26 September. The first structural support projects 2007-2013 in the field of education and science were initiated



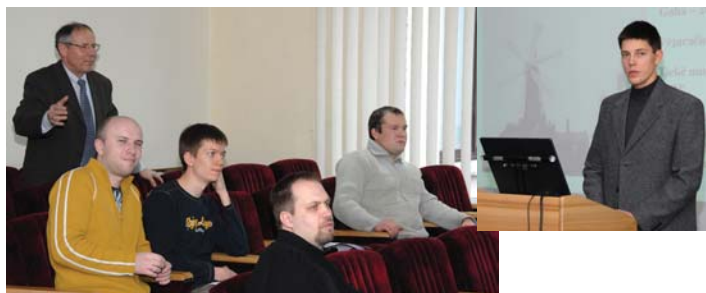
8 October. Prof. J. Vilemas became the laureate of V. Lykov (Belarus) award



11 October. Visit of employees of the State Chancellery of the Republic of Lithuania



23 November. Teachers from Šilutė town visit LEI



27 November. Seminar "Is wind energy needed in Lithuania" organized by LEI young scientists union



28 November. Participants of interactive European students' competition of pictures and photographs ManagEnergy and Kaunas district student works competition Wood fuel for energy



5 December. LEI – the prizewinner of competition "Lithuanian product of the year 2007" organized by Lithuanian Industrialists Confederation



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