LITHUANIAN ENERGY INSTITUTE

ANNUAL REPORT 2014

LITHUANIAN ENERGY INSTITUTE in 2014

MISSION OF THE INSTITUTE

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

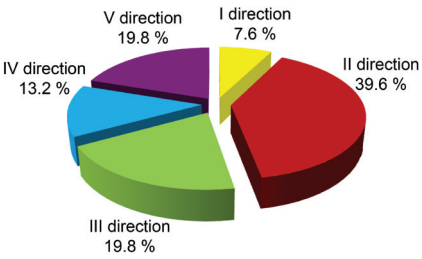
SCIENTIFIC COUNCIL OF THE INSTITUTE (in first line from left) – Dr. Arvydas GALINIS, Chief Research Associate of the Laboratory of Energy Systems Research; Dr. Rymantas JUOZAITIS, Chairman of Lithuanian Committee of World Energy Council, Prof. Dr. Habil. Eugenijus UŠPURAS, Chairman of the Scientific Council, Head of the Laboratory of Nuclear Installation Safety; Dr. Jūratė KRIAUČIŪNIENĖ, Deputy Chairman of the Scientific Council, Head of the Laboratory of Hydrology; Dr. Nerijus PEDIŠIUS, Head of the Laboratory of Heat-Equipment Research and Testing; Dr. Robertas POŠKAS, Senior Research Associate of the Laboratory of Nuclear Engineering. In the second line – Dr. Albertas GRYBĖNAS, Head of the Laboratory of Materials Research and Testing; Dr. Mantas MARČIUKAITIS, Head of the Laboratory for Renewable Energy and Energy Efficiency; Dr. Nerijus STRIŪGAS, Head of the Laboratory of Combustion Processes; Dr. Rimantas BAKAS, General Director of "Kauno energija" AB; Dr. Gediminas RAINYS, General Director of Lithuanian Confederation of Industrialists; Assoc. Prof. Dr. Habil. Algirdas KALIATKA, Chief Research Associate of the Laboratory of Nuclear Installation Safety. Not present in the picture: Skirmantas JUNEVIČIUS, Director of Engineering Department of "Amber Grid" AB; Mindaugas KEIZERIS, Member of the Board, Strategy and Development Director of "Lietuvos energija" UAB and Dr. Vitas VALINČIUS, Head of the Laboratory of Plasma Processing

THE OBJECTIVES OF THE INSTITUTE:

- perform permanent fundamental and applied scientific research at international level, experimental development activities, which is a must for sustainable development of Lithuania energy and other Lithuanian economy branches and for the integration to the European energy systems and European research area;
- while cooperating with business, governmental and public institutions, transfer scientific knowledge to technically and commercially beneficial processes and facilities, ensuring the development of innovative energy technologies, cost-effectiveness and safety of energy objects and systems, efficient use of energy resources, reduction of environmental pollution and deceleration of global warming;
- provide accessible state-of-the-art scientific information to the society,

SCIENTIFIC RESEARCH ACTIVITIES OF THE INSTITUTE

I. Thermal physics, gas and liquid dynamics and metrology research;
II. Research of materials, processes and technologies, devoted to use renewable energy sources, to develop hydrogen energy, to efficiently use energy sources and reduce environmental pollution;
III. Safety and reliability research of nuclear and thermal nuclear power engineering and other industrial objects;
IV. Methods of nuclear waste management, also terminating the operation of the Ignalina Nuclear Power Plant;
V. Simulation and management of energy systems, energy economy.



Distribution of researchers according to the research directions

promote the Lithuanian economy development based on innovations and knowledge;
– actively participate in the EU programmes and international projects, boost co-operation with alike world science research centres.

STRATEGIC OBJECTIVES

1. To perform fundamental and applied research in the fields of thermal physics, hydrodynamics, metrology, safety and reliability of energy objects, materials engineering, hydrology, and processes management.
2. To prepare energy sector planning conceptual and methodological basis in state's policy energy sector.
3. To prepare first-class specialists for energy and scientific research related to it.

MEMBERSHIP AND COOPERATION WITH NATIONAL AND INTERNATIONAL ORGANIZATIONS

LEI is a member of the following national associations:

Nuclear Energy Association **(BEA),** Lithuanian Electricity Association **(LEEA),** Lithuanian Energy Consultants Association **(LEKA),** Engineering Industries Association of Lithuania **(LINPRA),** Lithuanian Research Library Consortium **(LMBA),** Confederation of Lithuanian Industrialists (**LPK),** Lithuanian Thermotechnical Engineers Association **(LIŠTIA),** National Space Association of Lithuania, Lithuanian Gas Association **(DŪA),** Association for Energy Economics, Building Product Testing Laboratory Association **(SPBL).**

Institute is active in international organisations and networks: European Technical Support Organisations Network **(ETSON)**, European Network of Freshwater Research Organisations **(EurAqua)**, The European Association of National Metrology Institutes **(EURAMET)**, Euro-Asian Cooperation of National Metrological Institutions **(COOMET)**, European Nuclear Safety Training and Tutoring Institute **(ENSTTI)**, International Energy Agency Hydrogen Implementation Agreement **(IEA HIA)**, New European Research Grouping on Fuel Cells and Hydrogen **(N.ERGHY)**.

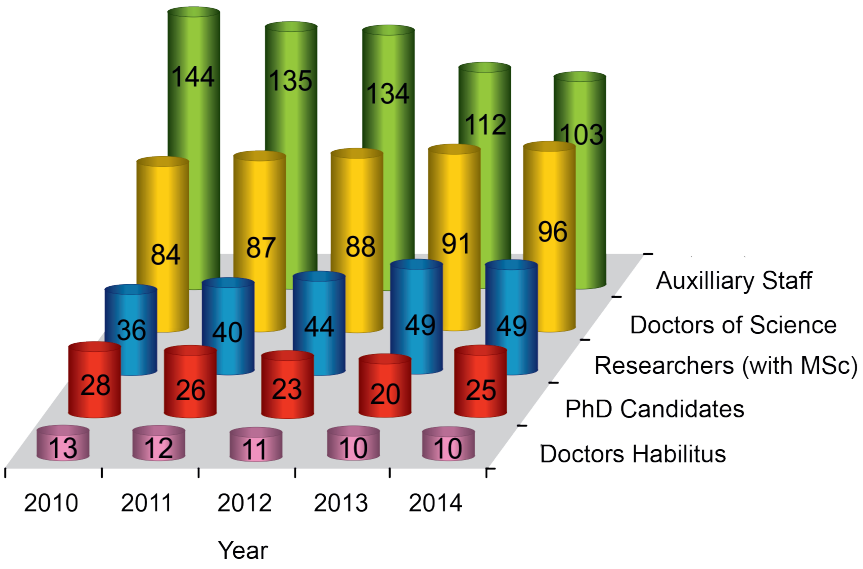
The Institute also participates in the activities of two international nuclear technological platforms: Sustainable Nuclear Energy Technology Platform **(SNETP)** and Implementing Geological Disposal of Radioactive Waste Technology Platform **(IGD-TP).**

REVIEW OF LEI ACTIVITIES IN 2014

January was marked by congratulations and awards on the occasion of accomplished works and achievements. Dr. Jurate Kriaučiūnienė and Dr. Nerijus Pedišius were awarded Badges of Honor of the Engineering Industries Association of Lithuania (LINPRA); on December 30, 2013, by Lithuanian Presidential Decree No. 1K-1686 *On awarding a Commemorative Badge*, Prof. Dr. Habil. Eugenijus Ušpuras was awarded a Commemorative Badge for his personal contribution to Lithuanian Presidency of the Council of the European Union in 2013; Prof. Dr. Habil. Eugenijus Ušpuras and Dr. Rolandas Urbonas received a letter of appreciation from the Ministry of Education and Science of the Republic of Lithuania for contribution to the success of Lithuanian Presidency of the EU Council in the field of education, science, and research. The Institute hosted a seminar on *Biofuel Development Perspective in Lithuania – Benefits and Risks*; students from Kazakhstan paid a visit.

In ***February***, *ENSTTI* trainer Gabrielle Tekerian, representatives of Lithuanian Electricity Association, pupils of Šiauliai district Pakapė Secondary School visited the Institute. The Institute organized a

discussion *Alternatives of development of heat and power sector*, board and supervisory committee meetings of Latvian-Lithuanian Cross Border Cooperation Program project HOTRISK. The appreciation was received from the Central Project Management Agency for successfully implemented structural assistance projects in the period 2007–2013. On February 19, Kaunas University of Technology (KTU), Lithuanian University of Health Sciences (LSMU) and Lithuanian Energy Institute (LEI) signed a joint activity agreement (partnership). This agreement established a promise to create favorable conditions for business and research cooperation in promoting development of innovative technological solutions and implementation of innovations on the national and international level.



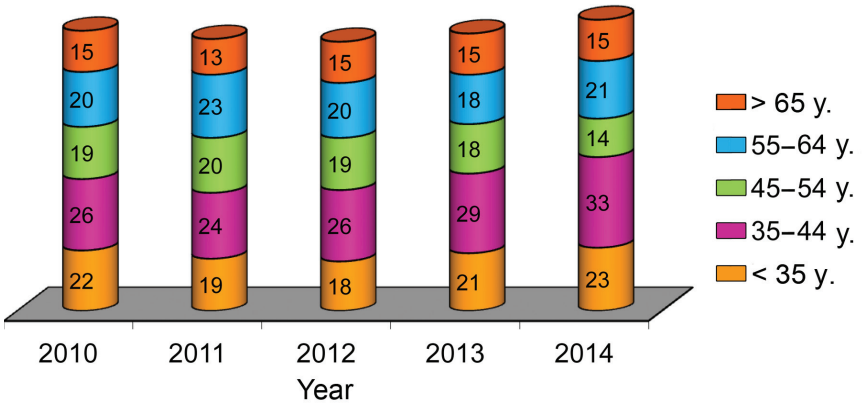
Variation of staff number

In ***March***, representatives of *Achema AB*, representatives of NATO Energy Security Centre of Excellence, and KTU students visited the Institute. The Institute hosted a specialized *Kauno Energija AB* public discussion *Features of national economic heat sector in assessment of practical experience and forecasts*, and a seminar *Visions and objectives of Santaka Valley in the international context*. Dr. Darius Jakimavičius won the contest of Lithuanian Academy of Sciences 2013 research papers by Young Scientists in biology, medicine and geosciences work group *Changes of balance elements of Curonian Lagoon water and their forecast based on natural and anthropogenic factors* and received an award. Young scientists of the Institute actively participated in Career Days organized by Kaunas University of Technology, where students were introduced to the activity of the Lithuanian Energy Institute, study and work opportunities there.

In ***April***, the Institute organized an Open Day, during which high school and university students were introduced to the activities of the Institute; they visited laboratories and attended lectures on scientific topics. Representatives of the Embassy of France, Ministry of Education and Science of the Republic of Lithuania, and Agency for Science, Innovation and Technology (MITA), KTU students, pupils of Šiauliai district Pakapė Secondary School, international partners from Estonia, Latvia, and Sweden visited the Institute. Board meeting of the Association *Santaka Valley*, general staff meeting of the Institute, Latvian-Lithuanian Cross Border Cooperation Program project HOTRISK seminar *Modeling tools and monitoring data necessary for the risk assessment*, a meeting of the monitoring committee, and NETZSCH-LEI seminar *Advanced Coupling Methods in Thermal Analysis* were held at the Institute. Employees of the Institute participated in KTU *Electric Power Days*. Moreover, employees of the Institute also received awards: Dr. Vidas Lekavičius received a letter of appreciation from the Lithuanian Committee of the World Energy Council, Dr. Raimundas Pabarčius received gratitude of the Chairman of the Seimas of the Republic of Lithuania, Dr. Egidijus Babilas received a congratulatory letter from the Minister of Energy of the Republic of Lithuania, Dr. Habil. Antanas Pedišius was conferred a *Lithuanian Energy Honor Award* of the Lithuanian Committee of the World Energy Council.

In ***May***, by Order No. 24.1-09-P1-30 of the Minister of Education of the Republic of Lithuania from May 9, 2014 *On the Director of Lithuanian Energy Institute* on May 13, 2014, a new director of Lithuanian Energy Institute Dr. Sigitas Rimkevičius has been appointed the for the five-year term. Another important event for the Institute: a new Scientific Council of the Institute has been elected. In addition to these exclusive events, a number of other events took place in May. For the 11th time, the Institute hosted an International *Conference of Young Scientists on ENergy Issues*. Also, ENSTTI (European Nuclear Safety Training & Tutoring Institute) courses *Criticality safety and thermal-hydraulics* were organized, which were attended by participants from Malaysia, Thailand, Ukraine, Armenia. Representatives of Minsk B. I. Stepanov Institute of Physics, Vytautas Magnus University students, Žiburys Secondary School students, and seventh graders of St. Casimir's Secondary School paid a visit to the Institute.

In ***June***, a scientific discussion *Directions of Lithuanian energy development and provisions of the National energy strategy* took place; a chairman of the Association and the Board was elected at the general meeting of the Young Scientists



Dynamics of age of scientists

Association of the Institute; Prof. Kazys Almenas gave a lecture for the Institute researchers.

In ***July***, Minister of Energy of the Republic of Lithuania, Jaroslavas Neverovičius, and representatives of LITBIOMA association visited the Institute.

In ***August***, the results of the contest in R&D commercialization were announced by the Ministry of Education and Science – Lithuanian Energy Institute (MB *Energy Solutions Group*) was among the 18 best startup projects, which were granted support checks of up to 70 thousand LTL for the initiation of business. Lithuanian Energy Institute was also one of the 400 companies and organizations that signed a Memorandum of good business practice upon the introduction of euro.

In ***September***, the Institute hosted training for application of ESCO model in the implementation of energy efficiency improvement projects, also an annual event taking place across Lithuania *Researchers Night 2014*. New full members and foreign members of the Lithuanian Academy of Sciences have been elected. Among them a longtime employee of the Institute Dr. Habil. Algirdas Kaliatka (a full member) and foreign members of the Lithuanian Academy of Sciences, Prof. Kazys Kęstutis Almenas and Prof. Bal Raj Sehgal, with whom Institute has long cooperation history, were solemnly inaugurated.

In ***October***, the Institute hosted training for Latvian-Lithuanian Cross Border Cooperation Program project HOTRISK, also a business and science forum *Implementation of the results of innovations and scientific research and experimental development – the guarantor of NEP breakthrough*. Lithuanian Energy Institute and NATO Energy Security Centre of Excellence signed a cooperation agreement. Prof. Dr. Habil. Eugenijus Uškpuras was appointed a chairman of the MITA Council of Experts in Physical and Technological Sciences.

The European Commission officially launched a fusion development project ***EUROfusion***, which will coordinate fusion research activity in Europe. Lithuanian Energy Institute that has been participating in fusion research activities since 2007 is also actively involved in this project with other 28 partners.

In ***November***, a winner of the expat Lithuanian Science award Dr. Algirdas Marchertas delivered a lecture; a seminar-training *Usage of solar energy in district heating systems* was held at the Institute; Mr. Mindaugas Keizeris, a Member of the Board of the *Lietuvos energija* JSC and Strategy and Development Director was elected a member of the Scientific Council of the Institute; professor E. N. Pysmennyj from Kiev University of Technology visited the Institute. As every year, reports on state-funded researches were defended at the Institute.

In ***December***, the Institute hosted ENSTTI training courses *Regulatory Framework for Decommissioning of Nuclear Facilities*; representatives of the Ministry of Foreign Affairs and MITA, and Varpo Gymnasium students paid a visit to the Institute; *VAE SPB UAB* and Lithuanian Energy Institute signed a cooperation agreement; a final seminar of Latvian-Lithuanian Cross Border Cooperation Program project HOTRISK *Mixed zones and water quality* took place.

The Institute has also been awarded a gold medal at the contest *Lithuanian Product of the year 2014*, organized by Lithuanian Confederation of Industrialists for the *Complex of works ensuring reduction of pollution at the thermal power plant No. 2 of the Vilniaus Energija UAB*.

CONTRIBUTION OF INFRASTRUCTURE OF NATIONAL OPEN ACCESS SCIENTIFIC RESEARCH CENTRE FOR FUTURE ENERGY TECHNOLOGIES

A successful use of EU Structural Funds enabled the Institute to form an equitable research and development base for research centers of the European Union countries. Presently, upon strengthening of the infrastructure of the research, services are provided more efficiently to Lithuanian businesses. Using the latest research equipment, Lithuanian energy companies have been offered innovative solutions, which in 2011–2013 were awarded at the contest *Lithuanian Product of the Year* of the Lithuanian Confederation of Industrialists. Also, in 2014, a gold medal at the Lithuanian Confederation of Industrialists contest *Lithuanian Product of the Year 2014* was conferred for the project *Implementation of flue gas recirculation system ensuring pollution reduction in Thermal Power Plant No. 2* implemented together with *Vilniaus Energija UAB*. Similar solutions are further implemented in other companies seeking to efficiently burn the

fuel and cause less pollution.

Effective use of R&D equipment (including the newly purchased equipment using EU Structural Funds) allowed the Institute to successfully participate in EU 7th Framework Program projects in 2010–2013. A total of 24 projects were implemented (the success rate is up to 36%). It is highly possible that the Institute will prove to be more successful in the new biggest Research and Innovation program Horizon 2020. In 2014 alone, the Institute together with partners submitted 23 project applications, seven projects out of which are funded; the Institute is the coordinator of one project.

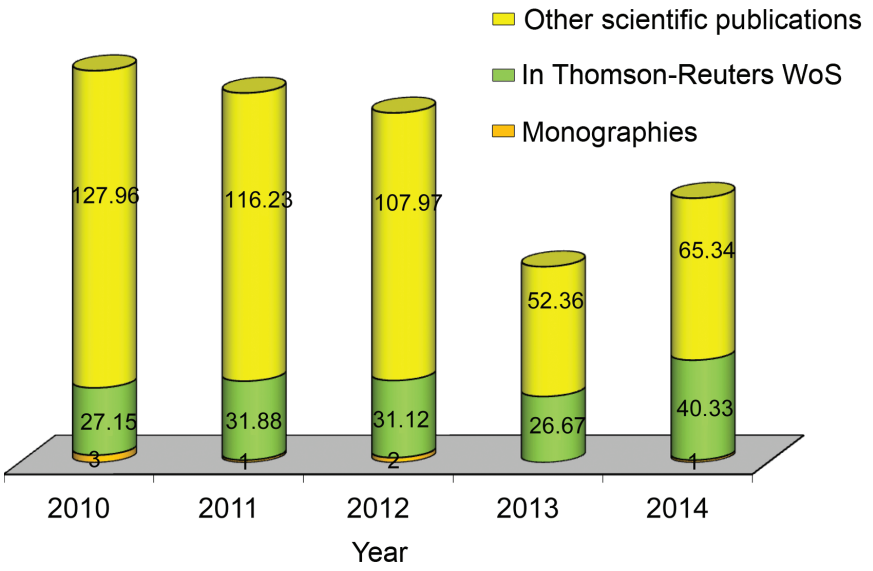
In recent years, new technologies and products have been developed, which await further implementation in practice by interested businesses: a) biomass and waste gasification device designed to produce low-calorific combustible gas to replace natural gas in heat and electricity production; b) hydrogenation technology for metals and their alloys; c) catalytic reactor for metal oxide fibers; d) software for nuclear power plant decommissioning and dismantling processes (DECRAD).

The Institute as an open access center will continue active cooperation with businesses, implementing provisions of National Open Access Scientific Research Centre for Future Energy motto "Innovative technologies, consulting, and solutions for energy!"

STATE FUNDED PROJECTS

In 2012 researchers of the Institute initiated ***Long-term scientific research and experimental development programmes***, approved on 23 02 2012 by the Order No. V-323 of the Minister of Education and Science of the Republic of Lithuania:

1. **Investigation of nuclear power plants' operation disruption and nuclear waste and spent fuel management processes and radiation impact analysis** (programme's duration 2012–2016). Programme's leader Prof. Dr. Habil. Povilas Poškas.
2. **Research on environmental impact and efficient use of renewable energy sources for energy production** (programme's duration 2012–2016). Programme's leader Prof. Dr. Habil. Vladislovas Katinas.
3. **Scientific research of safety important processes in nuclear and thermal-nuclear equipment** (programme's duration 2012–2016). Programme's leader Prof. Dr. Habil. Eugenijus Uspuras.
4. **Experimental and numerical research of combustion and plasma processes for improvement of energy generation technologies from renewable biofuel and reduction of environmental pollution** (programme's duration 2012–2016). Programme's leaders – Dr. Nerijus Striūgas, Dr. Vitas Valinčius.
5. **Economy and sustainability analysis of energy sector** (programme's duration 2012–2016). Programme's leader Prof. Dr. Habil. Vaclovas Miškinis.
6. **Investigation of single-phase and two-phase flow dynamics, heat and mass transfer processes** (programme's duration 2012–2016). Programme's leader Dr. Robertas Poškas.



Variation of publication number (authors' contribution evaluated)

In 2014, 13 state funded projects were implemented and 6 of them had been completed and defended, namely:

1. ***Investigation of condensing two-phase flow velocity field in horizontal rectangular channel*** (project leader Dr. M. Šeporaitis).
2. ***Research of application and intensification and development possibilities in Lithuania of small-scale wind power plants and solar energy systems*** (project leader Dr. M. Marčiukaitis).
3. ***Research of application of new generation heat pumps for heat production*** (project leader Dr. R. Škėma).
4. ***Synthesis and characterization of Mg-Ti metal hydrides designed for energy storage*** (project leader Dr. D. Milčius).
5. ***Synthesis of carbon coatings in argon-acetylene and in argon-hydrogen-acetylene plasma and investigation of their properties*** (project leader Dr. L. Marcinauskas).

Number of papers in scientific conferences

6. ***Development of Probabilistic Assessment Methods for Critical Energy Infrastructures*** (project leader Prof. Dr. Habil. J. Augutis).

In 2014 implemented National Research programme "Energy for the Future" projects:

1. ***ATE-02/2012 Research of local fuel thermal decomposition processes by developing efficient and ecological technologies*** (project's duration 2012–2014). Project leader Dr. V. Valinčius.
2. ***ATE-04/2012 Reliability and risk study of Lithuanian energy systems*** (project's duration 2012–2014). Project leader Dr. S. Rimkevičius.
3. ***ATE-06/2012 Investigation of Lithuanian energy security and assessment of energy security level*** (project's duration 2012–2014). Project leader Prof. Dr. Habil. J. Augutis.
4. ***ATE10/2012 Conversion of organic waste in water vapor plasma by reducing environmental pollution*** (project's duration 2012–2014). Project leader Dr. V. Grigaitienė.

As well implemented long-term institutional economy sciences research programme 2012–2014 ***Lithuanian challenges of long-term economic competitiveness***. Project Institute's representative Prof. Dr. Habil. Valentinas Klevas.

INTERNATIONAL PROJECTS

In 2014, **27** international programme projects were conducted, out of which:

EU research and innovation programme's *Horizon2020* project ***Implementation of activities described in the Roadmap to Fusion during Horizon 2020 through a Joint programme of the members of the EUROfusion consortium***. Institute's representative – Prof. Dr. Habil. E. Ušpuras.

Ten projects of 7th Framework Programme:

1. ***MATerials TEsting and Rules (MATTER).*** Institute's representative – Dr. G. Dundulis.
2. ***Nanotechnology Enhanced Extruded Fibre Reinforced Foam Cement Based Environmentally Friendly Sandwich Material for Building Applications, FIBCEM***. Institute's representative – Dr. J. Česnienė.
3. ***Advanced Multiphysics Simulation Technologies (AMST***). Institute's representative – Dr. A. Džiugys.
4. ***Code for European Severe Accident Management, CESAM***. Institute's representative – Dr. V. Vileiniškis.
5. ***CArbon-14 Source Term, CAST***. Institute's representative – Prof. Dr. Habil. P. Poškas.
6. ***Advanced Safety Assessment: Extended PAS, ASAMPSA_E.*** Institute's representative – Dr. R. Alzbutas.
7. ***Building a platform for enhanced societal research related to nuclear energy in Central and Eastern Europe, PLATENSO***. Institute's representative – Prof. Dr. Habil. P. Poškas.
8. ***Nuclear Cogeneration Industrial Initiative – Research and Development Coordination, NC2I-R***. Institute's representative – Dr. S. Rimkevičius.
9. ***Resource Efficient cities implementing ADvanced smart citY solutions (READY).*** Institute's representative – Dr. R. Gatautis.
10. ***Assessment of Regional Capabilities for new reactors Development through an Integrated Approach, ARCADIA***. Institute's representative – Dr. E. Urbonavičius.

European research area (ERA)

In 2007–2014 LEI researchers successfully implemented the following international programme projects:

- Horizon2020 Programme – 1;
- 6th Framework Programme – 12;
- 7th Framework Programme – 23;
- Intelligent Energy Europe – 28;
- International Atomic Energy Agency (IAEA) projects – 10;
- COST – 11;
- EUREKA – 3;
- Nordic Energy Research Programme (NERP) – 2;
- Baltic Sea Region 2007–2013 Programme – 3;
- South Baltic Cross-border Cooperation Programme 2007–2013 – 1;
- Lithuania-Latvia Cross-border Cooperation Programme – 1;
- Leonardo da Vinci Programme – 1.

DOCTORAL STUDIES

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

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

In the period 1992–2014 PhD studies were completed by 92 PhD students (out of 107), the dissertations were defended by 63. In 2014 9 PhD students were accepted to PhD students, total 25 PhD students studied.

In 2014 the following PhD theses were defended:

- on 16 June – ***Theoretical and Experimental Investigation of Aeration Phenomenon in the Air-Water Interface,*** Physical science, Physics (02P) **Adelė Vaidelienė** (Laboratory of Hydrology). Scientific supervisor Prof. Dr. Habil. A. Galdikas (Kaunas University of Technology);
- on 30 June – ***Investigation of Gas Migration in a Geological Repository,*** Technological Sciences, Energetics and Power Engineering (06T) **Darius Justinavičius** (Laboratory of Nuclear Engineering). Scientific supervisor Prof. Dr. Habil. P. Poškas;
- on 19 September – ***Investigation of Energy Systems Disturbances Impact on Energy Security*** (06T) **Linas Martišauskas** (Laboratory of Nuclear Installation Safety). Scientific supervisor Prof. Dr. Habil. J. Augutis;
- on 14 October – ***Investigation of Thermo-Hydro-Dynamic Processes in Water Steam Plasma and Its Application for Organic Waste Treatment*** (06T) **Andrius Tamošiūnas** (Laboratory of Plasma Technologies). Scientific supervisor Dr. V. Valinčius;
- on 7 November – ***A Investigation of Flow Regime and Physical Properties Influence on Liquid and Gas Mechanical Flow Meters' Charac-***

Dr. A. Vaidelienė

Dr. D. Justinavičius

Dr. L. Martišauskas

Dr. A. Tamošiūnas

Dr. E. Maslauskas

Dr. T. Kaliatka

teristics (06T) **Eugenijus Maslauskas** (Laboratory of Heat-Equipment Research and Testing). Scientific supervisor Dr. Habil. A. Pedišius;

– on 28 November – ***Study of the thermalhydraulic processes in nuclear fusion devices during loss of coolant event*** (06T) **Tadas Kaliatka** (Laboratory of Nuclear Installation Safety). Scientific supervisor Prof. Dr. Habil. E. Ušpuras.

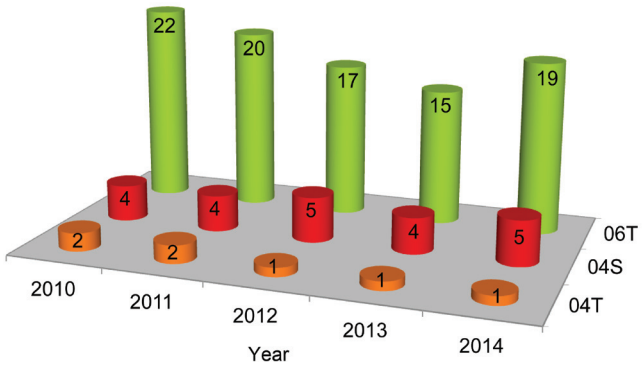
In 2014, at the initiative of LEI Young Scientists Association, the **Contest of the most active young scientists and PhD students** was organized.

The most PhD students were:

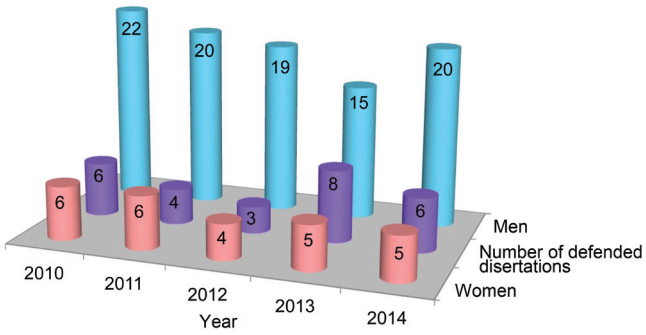
- first year – Andrius Gediminskas;
- second year – Giedrius Gecevičius;
- third year – Rolandas Paulauskas;
- fourth year – Lina Murauskaitė.

Acceptance to LEI PhD studies takes place in July, when there are spare places, the acceptance is continued in September.

Institute's director Dr. S. Rimkevičius congratulates fourth year most active PhD student Lina Murauskaitė at the New Year Carnival



Arrangement of PhD students according to science directions



Number of PhD students and defended theses

During PhD studies there is a possibility to participate in international projects, to take traineeships in foreign scientific centers, to participate in international conferences.

More information on PhD studies may be accessed at institute's webpage **http://www.lei.lt,** section – Information – PhD studies.

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

LABORATORY of HEAT-EQUIPMENT RESEARCH AND TESTING

MAIN DIRECTIONS AND RESULTS OF SCIENTIFIC RESEARCH AND APPLIED WORKS IN 2014

In 2014 the Laboratory performed research works significant for Lithuanian industry, business and science, actively cooperated with customers, taking into account general research and experimental development trends in European countries, developed national liquid and gas flow standards as well as measurement services and further expanded research, created experimental basis for perspective research of various types of biofuel and its practical application.

SCIENTIFIC RESEARCH AND EXPERIMENTAL DEVELOPMENT

The most important event should be considered the direction of R&D to solve the tasks formulated in new topic of 2013–2015 ***Research of gas flow mixture and its interaction with structurized surfaces aiming to efficiently and minimally polluting the environment use biofuel in heat equipment***:

- to investigate mixture of air, supplied to combustion zones in low capacity thermal equipment with the objective to determine optimum conditions, which would ensure efficient burning of solid fuel, including biofuel, and minimum emissions to the environment;
- to estimate and summarize the composition, calorific value and physical properties of solid biofuel, its mixtures and recovered fuel as well as composition of their combustion products;
- to improve combustibility properties of biofuel and recovered fuel or to retrieve new materials by applying thermal processing technologies;
- to investigate the processes of solid particles and separation of noncombustible components from combustion gas and gas obtained by gasifying biofuel by applying perspective technologies;
- to develop research of flow dynamics in micro-channels;
- to expand the application of the developed equipment and mastered methods designed to investigate permeability of various materials and visualize flow structure in order to deal with scientific and applied tasks in other fields.

This was preconditioned by up-to-date flow structure and transfer processes research equipment, purchased within the framework of *Santaka* valley program, and new experimental devices constructed. This topic was also developed during research based on the projects and programs, which have begun and were implemented in recent years:

- A project funded by the Research Council of Lithuania ***Research of local fuel thermal decomposition processes by developing efficient and ecological technologies (BIOKONVERS)***, implemented during 2012–2014 by three laboratories of the Institute;
- Projects funded by European Social Fund Agency: ***Development of innovative thermal decomposition technology and its application for utilization of sewage sludge (INODUMTECH)***, project code VP1-3.1-ŠMM-10-V-02-009; ***Research of properties of different kind of prepared biofuel, produced from agricultural waste and processed products, and application of this fuel for small and medium capacity heat equipment (AGROBIOATENA)***, project code No. P1-3.1-ŠMM-10-V-02-011;
- Long-term programs in 2012–2016: ***Research of dynamics, heat and mass transfer processes of single phase and two-phase flows***, completing three tasks; ***Research of renewable energy sources' usage for***

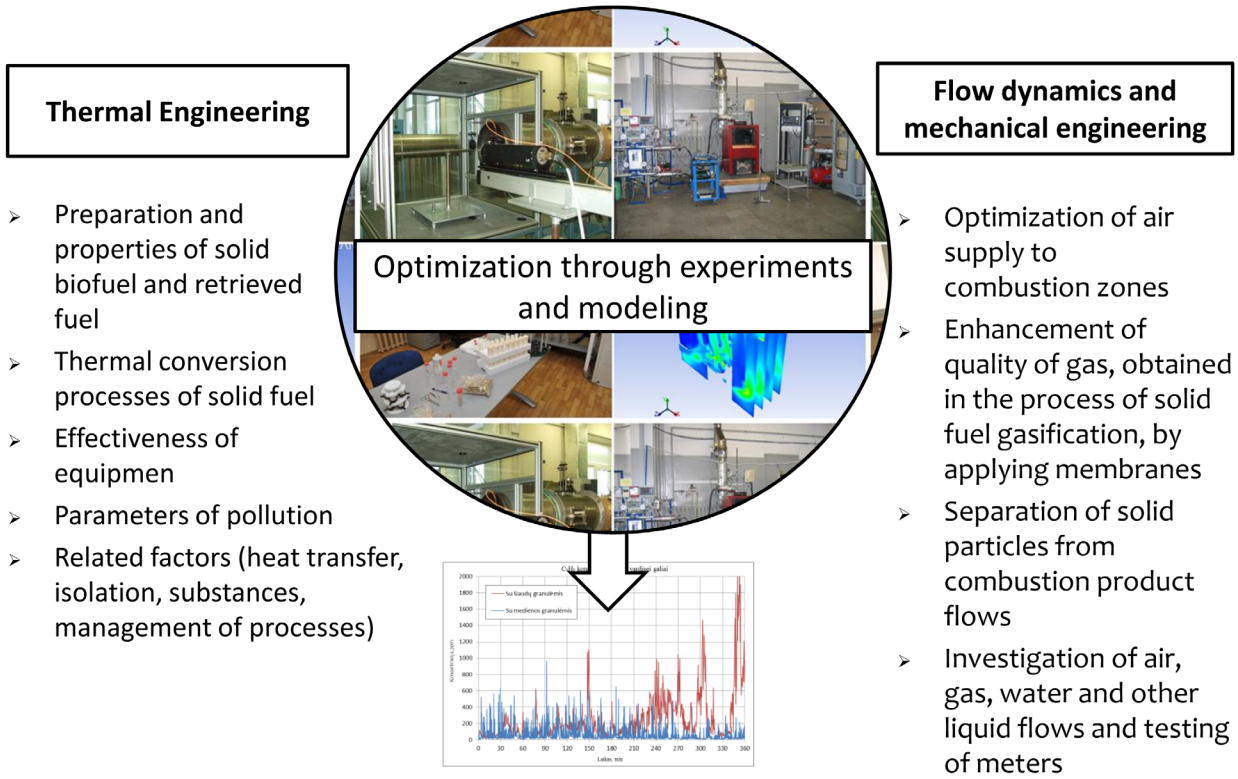


Figure 1. Directions and fields of the research and applied works of the Laboratory

eficient energy production and environmental impact, completing two tasks;

- ***Economy development and increase of competitive ability*** program, which covers annually panned and implemented R&D works in accordance with authorization of the Government of the Republic of Lithuania to maintain a base of four state standards for liquid and gas volume, volume flow rate and velocity units, and to ensure its appropriate operation and accounting of important energy resources and measurement accuracy of related sizes considering the demands of Lithuanian economy, business and science as well as requirements of international exchange.

In this way, the Laboratory performed scientific research and applied works in two directions (Figure 1) – energy and thermal engineering and measurement engineering, in the latter the greatest attention was given to the investigation of dynamics of liquid and gas flows and their measurements.

THE MOST IMPORTANT RESULTS WHILE IMPLEMENTING R&D IN 2014:

- For performing investigations on low power equipment heated by biofuel, a prototype of device for gasification of biofuel pellets has been developed (Figure 2), the structure of which allows using it for investigation of combustion efficiency of various types of biofuel and tasks aimed at reduction of pollution. A numerical modeling program that combines flow dynamics, energy transfer and chemical reaction equations was developed to calculate dynamic flow and thermal parameters. The initial results revealed that it could be effectively used during investigation, construction and enhancement of equipment, designed for burning biofuel with the lowest emissions to the environment;
- The construction of three experimental devices for investigation of flow mixing and expansion, gas permeability through membranes and flow in micro-channels

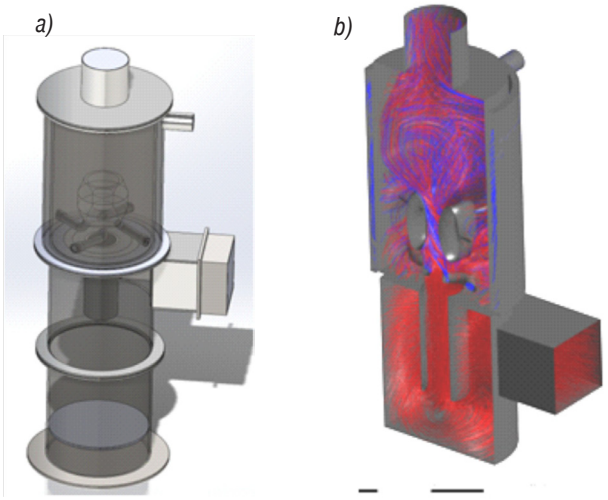


Figure 2. Images of experimental biofuel pellet gasification/ combustion device (a) and gas and secondary air flow (b)

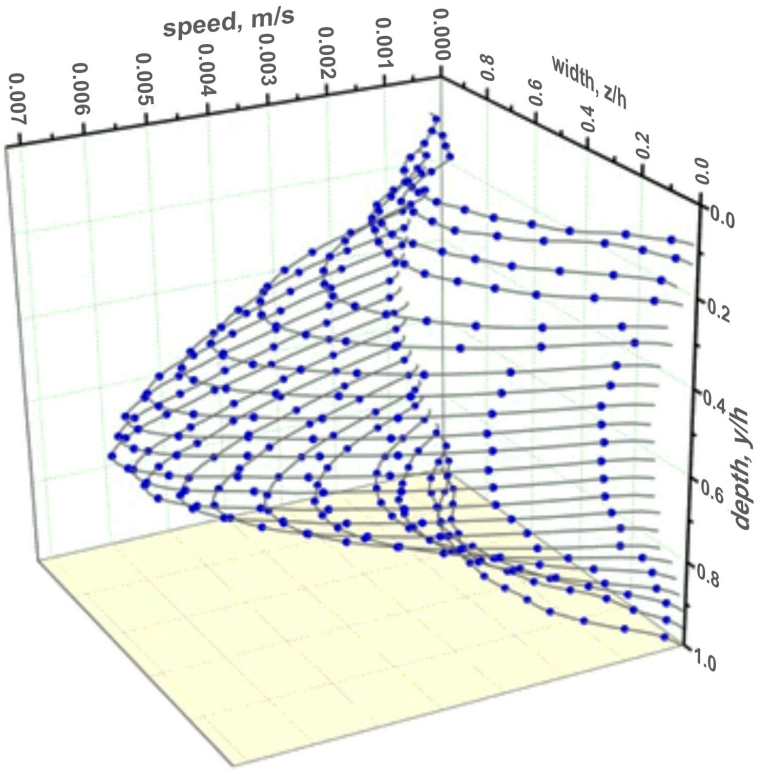


Figure 3. Velocity profiles in rectangular cross-section channel (0.5×0.5 mm²), measured by means of μPIV system

(Figure 3) has been completed by application of non-invasive laser anemometers and velocity measurement systems based on visualization of particle movement. The results of the research are confirmed by comparison with theoretical calculation results and existing experimental results of other researchers, and provide ample opportunities to carry out perspective studies of flow in channels and dynamics of flow expansion.

OTHER MOST IMPORTANT APPLIED WORKS AND SERVICES:

- Study on natural gas quality along with its revisions has been performed for designation of liquefied natural gas (LNG) terminal in Klaipėda to operate as ordered by SC *Klaipėdos Nafta* and Ministry of Energy of the Republic of Lithuania; reports with the assessment of meter types have been prepared for gas volume conversion devices FC1 (ELSTER) and Flow-X (SPIRIT IT B.V) and for inclusion of gas chromatographer GC EnCal 3000 into meter register of the Republic of Lithuania; up to 50 primary controls of these devices have been completed after their assembly at distribution stations of Lithuanian gas sector;
- Two new verification methodologies for JSC *Sanotech* measurement and remote data transmission systems SUPERCOM and IZAR were developed and validated by assessment of their conformity to the type. Following the order of SC *Kauno Energija*, primary screening of remote data transmission systems in objects of different designation was performed for 125 heat meters;
- Following JSC *Litesko* order, double-beam non-invasive calibration by ultrasonic flow meter SITRANS FUE1010 (Figure 4) of flow meters, mounted in the main thermal water supply and return pipes of 400 mm diameter, was performed in order to find out the causes of heat supply imbalance.

Figure 4. Junior researcher A. Bončkus performs measurements of Marijampolė heating network in the boiler house in order to determine the reasons of imbalance

- Works were accomplished and the Laboratory was accredited, and the Ministry of Economy of the Republic of Lithuania announced conformance of measurement systems for measuring the amount of continuous and dynamic liquids, other than water, with Technical regulation of meters (European Parliament and Council Directive 2004/22/EB) to assess the requirements based on module D. This will significantly speed up the conformity assessments for heat and water meters produced by Lithuanian manufacturers and will reduce their costs;
- Calibration of new Eiffel type air velocity device WK 832040-E, manufactured at WESTENBERG Engineering in Germany, before its operation was performed by Lithuanian Hydrometeorological Service under the Ministry of Environment;
- In 2014 the activity of the Laboratory as of an integral part of an open access *Centre for Renewable and Alternative Energy* expanded towards the tasks associated with scientific and applied research of biofuel exploitation processes. The volume of services provided to customers has significantly expanded.

Funds allocated for applied research carried out under the projects, applied works and services to customers in 2014 amounted close to 2.0 million LTL.

ACTIVITY ON THE INTERNATIONAL LEVEL:

- Implementing national standard laboratory functions, in 2014 the Laboratory participated in an annual meeting of the international organization EURAMET TK *Flows* and prepared and submitted information on indicators of functioning of the quality management system EURAMET TK *Quality*;
- International flow measurement comparisons were performed in gas volume range with the flow rate varying from 20 m^3/h to 1000 m^3/h under EURAMET Project No. 1296, which was organized by CMI (Czech Republic), and in which national measurement institutes from 12 European countries participated, and air velocity in range from 0.05 m/s to 1 m/s under EURAMET Project No. 1225, which was organized by BEV (Austria), and in which national measurement institutes from 7 European countries participated;
- Contacts have been maintained with the laboratories performing international comparisons; the laboratories of Italian INRIM Institute and Poland Gdańsk University of Technology have been visited; cooperation was carried on during organization of BEV (Austria) initiated EURAMET Project No. P1 312 ***Development of a guide on air speed calibration of solid anemometers***, in which national measurement institutes from 7 European countries will participate.

PUBLICATION AND ACKNOWLEDGEMENT OF SCIENTIFIC RESULTS:

- In 2014 after reorganization of the State Meteorological Service, Lithuanian Energy Institute has acquired the status of a designated institute as a part of decentralized Lithuanian National Institute of Metrology. On December 10, 2014 following the Resolution of Government of the Republic of Lithuania No. 1400, four new options of measurement and calibration of national standards were approved;
- Seminars organized: On January 16, 2014 seminar for the project Bioenergy promotion *Perspective of development of biofuel in Lithuanian – benefit and risks*, in which a researcher from the Environmental Policy Research Center of the Department of Political and Social Sciences at Berlin Freie University Michael Krug took part; on October 30, 2014 during BUSINESS and SCIENCE FORUM *Implementation of innovations and results of scientific research and experimental development – the guarantor of NEP breakthrough*, a stand paper was presented on a major range of services to commercial entities carried out in the Laboratory, and a project on calibration device of water flow meters DN100-DN500 was proposed;
- Minister of Energy of the Republic of Lithuania J. Neverovičius, representatives of Lithuanian Ministry of Foreign Affairs and MITA, French Embassy, Ministry of Education and Science of the Republic of Lithuania, NATO Energy Security Centre of Excellence, Association *LITBIOMA* (Figure 5), and the Association *Santaka Valley* Board paid visit to the Laboratory;

Figure 5. Representatives of the Association LITBIOMA in the Laboratory

- Defense and preparation of dissertations: on November 7, 2014 Eugenijus Maslauskas successfully defended his doctoral dissertation ***Investigation of Flow Regime and Physical Properties Influence on Liquid and Gas Mechanical Flow Meters' Characteristics*** (Figure 6); A. Tonkonogovas' dissertation work has been submitted to joint KTU/LEI doctoral committee, and the defense is planned for the early 2015; a new doctoral student M. Praspaliauskas has begun his doctoral studies, and doctorate students M. Valantinavičius and T. Vonžodas continued theirs;

Figure 6. Defense of the dissertation by E. Maslauskas

- Participation in international conferences: 21st European Biomass Conference and Exhibition in Copenhagen, Denmark; 7th St. Gallen International Energy Forum IEF on November 27–28, 2014 in Switzerland; 22nd European Biomass Conference and Exhibition on June 23–26, 2014 in Hamburg, Germany (Figure 7); WASET International Conference on Fluid Mechanics, on December 22–23, 2014 in London, UK;

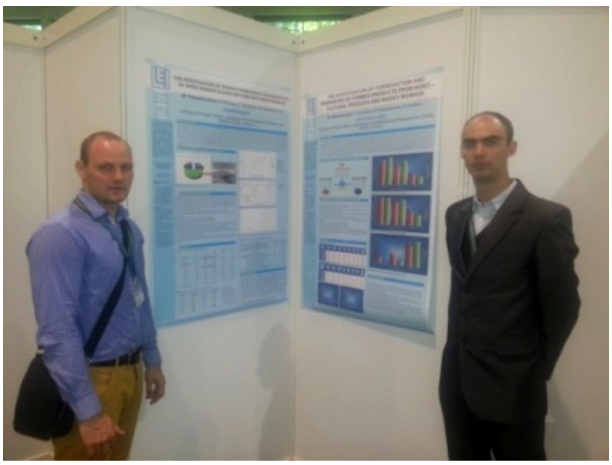


Figure 7. Doctorate students M. Praspaliauskas and M. Valantinavičius at the conference in Hamburg

- Most important published or submitted for publication works:
  Praspaliauskas M., Pedišius N., Gradeckas A. Heavy metals (Cd, Cr, Cu, Ni, Pb and Zn) concentration in stemwood of energetic trees fertilized with sewage sludge. *Submitted to the journal Ecological Engineering*;
  Praspaliauskas M., Pedišius N. Investigation of characteristics and use possibilities of sewage sludge in Lithuania's wastewater treatment plants. *Submitted to the journal Waste Management*;
  Maslauskas E., Pedišius N., Zygmantas G. Investigation of liquid viscosity influence on flow rate measurement by rotary vane meters. *Mechanika*. ISSN 1392-1207. 2014. Vol. 20, No. 2, p. 158–164;
- Awards:

on January 10, 2014 senior researcher of the Laboratory Dr. Nerijus Pedišius was awarded a Badge of Honor **of the Engineering Industries Association of Lithuania** (LINPRA);

on April 14, 2014 senior researcher, Dr. Habil. Antanas Pedišius was awarded a Badge of Honor of a Lithuanian Energy Specialist by Lithuanian Committee for World Energy Council.

Dr. Nerijus PEDIŠIUS
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LABORATORY of COMBUSTION PROCESSES

THE MAIN AREAS OF ACTIVITIES OF THE LABORATORY:

- improvement of efficiency of combustion processes;
- reduction of atmospheric emissions;
- development and improvement of burners and fuel atomizers;
- research of thermal destruction and gasification of solid calorific waste;
- numerical simulation of granular media and multi-particle systems;
- environmental impact assessment.

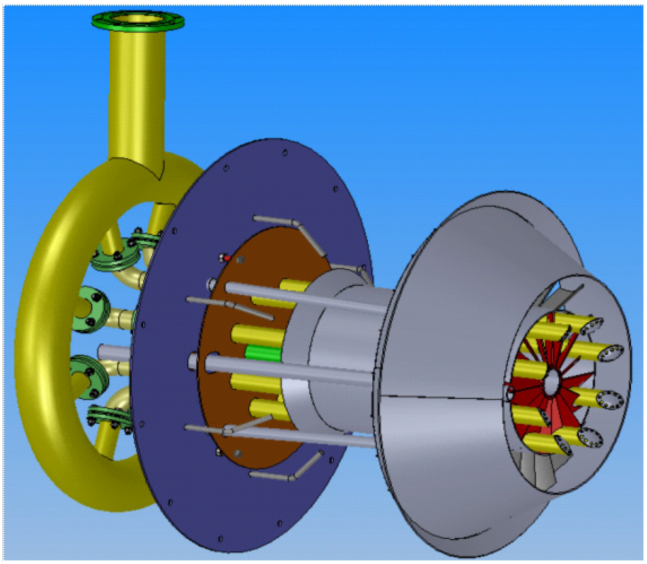
Research of the Laboratory of Combustion Processes is carried out in the fields of fuel saving, reduction of environmental pollution, and thermal decontamination of materials.

REDUCTION OF NITROGEN OXIDES FROM NATURAL GAS COMBUSTION WITH FLUE GAS RECIRCULATION

Directive 2010/75/ES ***On integrated prevention and control of industrial emissions (pollution)*** foresees more stringent requirements for environment protection and pollution than those currently in force, especially in relation to reduction of the amount of emissions into the environment; these requirements will come in force on January 1, 2016. For natural gas fuel, starting from 2016, the limits for nitrogen oxides (NO_x) are 3.5 times stricter – from 350 to 100 mg/nm^3. Burning furnace oil from 2016, norms for nitrogen oxides (NO_x) are 2.7 times stricter (from 400 to 150 mg/nm^3); for sulphur oxides (SO_2) – 8.5 times (from 1700 to 200 mg/nm^3); for solid particles – 2.5 times (from 50 to 20 mg/nm^3).

This is a complicated task for the existing burning devices: whether to replace the existing burners with the new ones with little amount of nitrogen oxides, or to install secondary measures for reduction of nitrogen oxides. In order to reduce NO_x concentration in combustion zones, it is necessary to avoid maximal temperatures of burning plume (1500–1600 ^oC). Now, quality enhancement of combustion process using burners of new type with specific peripheral air function and tertiary air injection over the flame dominates. One of less sophisticated measures employed is recirculation of flue gas. Recirculation of flue gas does make a major change in the combustion process; however, by employing it, the concentration of nitrogen oxides in emitted flue gas can be reduced by 20–25%. In order to reduce NO_x to a greater extent and achieve 100 mg/nm^3, more radical improvements are needed. Although, already several decades ago, reliable catalytic and non-catalytic NO_x amount reduction measures have been developed, they hardly find their place in industry due to high investment price and complex control process. Presently, another method has been suggested as well, namely, gradual reduction of NO_x generation in the course of the combustion process: that is additional fuel supply into the hottest zone of the flame plume. The research methods chosen by the Laboratory of Combustion Processes employ three NO_x reduction means: recirculation of flue gas, local additional fuel supply into the lower burner and gradation of the excess air into the upper burner in respect of the lower burner. By means of burners with LEI design, 200 mg/nm^3 of NO_x was easily achieved, and based on the regulation, this was an acceptable result. However, after

introducing the provision that in the future, NO_x concentration will have to be reduced to 100 mg/nm^3, experiments on improving combustion process in water and industrial boilers have begun. The Laboratory of Combustion Processes set up these goals and began implementing experiments with an elongated rectangular furnace boiler, the power of which ranges from 50 to 70 MW. In parallel, research with specially designed burners D30 for water boiler KVGM 100 was carried out. It was determined that the latter furnace boiler is highly acceptable for gas combustion: aerodynamics was formed in such a way that gas recirculation could take place in furnace space, for this reason, a longer way of combustion reaction is ensured. Burners designed for water boiler KVGM-100 were given standard D30. These burners have two main features: isolation of central and peripheral air flows and natural gas supply system dispersed through 8 injectors around central air with 7 vents in each injector. The design allowed rotating each injector separately in order to get the best combustion process with minimum excess air ratio and minimal emissions. From the very beginning, these burners were marked by high quality work; therefore, meticulous gas flow supply adjustments were conducted while forming a mode card, after several years since the first operation stage of the burners, when fuel oil or gas were burned. The design of the developed burners ideally corresponds to the geometrical shape of the furnace, i.e., flame plume did not burn the rear screen; the flame performed the turns in the furnace, and the combustion time was maximally long, while concentrations of CO and NO_x in the exhaust flue gas were minimal. In comparison to burners of other boilers, NO_x emission was more than by a quarter smaller. In one of the largest energy companies in Lithuania JSC Vilniaus energija, which exploits the mentioned water boiler by means of KVGM-100 with D-30 burners, experimental research for reduction of additional NO_x by recirculation of flue gas was carried out. Since NO_x concentration in flue gas emitted by this boiler is no more than 150 mg/nm^3 at the maximal load, while in other high-capacity boilers, NO_x emission in flue gas reaches up to 200–250 mg/nm^3, by additionally injecting flue gas into the airflow, it would be possible to achieve



General view of burner D30

the requirements specified in the new EU directive. After completing experimental testing and obtaining a positive result, it would be possible to avoid additional investment into reduction of NO_x by urea. In preparation for these experiments, in the Laboratory of Combustion Processes, combustion is modelled by software Fluent in order to evaluate potential NO_x reduction effect by means of flue gas recirculation. By comparing these results with the data presented in the literature and with the results obtained at SC Lietuvos elektrinė, it was determined that at actual recirculation of 20% for the case of natural gas combustion, NO_x concentration can be reduced by as many as 30%. It is notable that recirculation flue gas has to be supplied evenly, in flows across the entire air channel cross-section into the airflow supplied for combustion and mixed before achieving burners. During experimental testing, the flue gas was injected above air supply vents. In the vent, flue gas would mix with the air, supplied for combustion. The first measurements have already revealed better results than expected, and better results than it was anticipated following the theoretical calculations. Experimental research determined that at boiler load 75 and 95 % and using D-30 burners, JSC *Vilniaus*

Arrangement of boiler KVGM-100 burners central and peripheral airflows and natural gas

Fan and flues of flue gas recirculation system VK-5. Design boundaries and project boundaries are marked in red

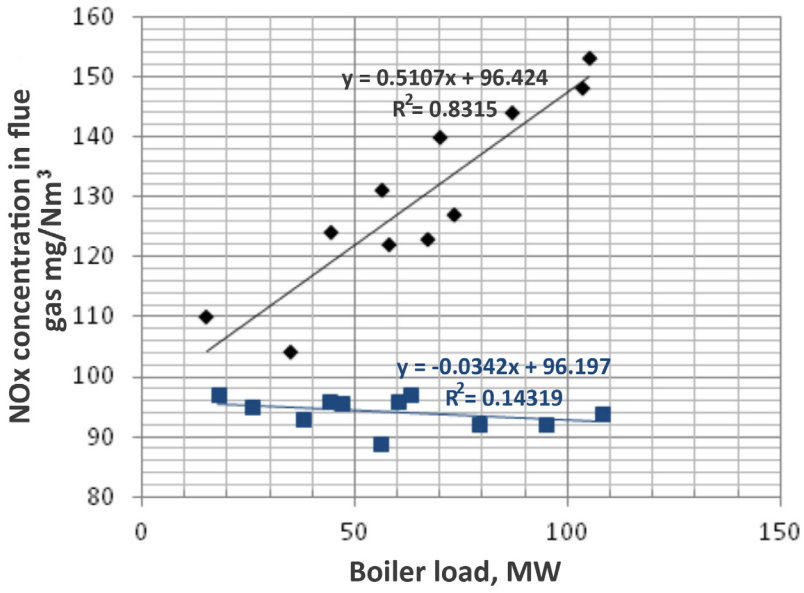
energija till 2016 would be able to implement European Parliament and Council directive adopted on November 24, 2010.

Flue gas recirculation system for water boiler No. 5 KVGM-100, object JSC *Vilniaus energija*, at CHP No. 2 (E-2), Elektrinės str. 2, Vilnius, was evaluated with a gold medal at the contest *Lithuanian product of the year 2014*.

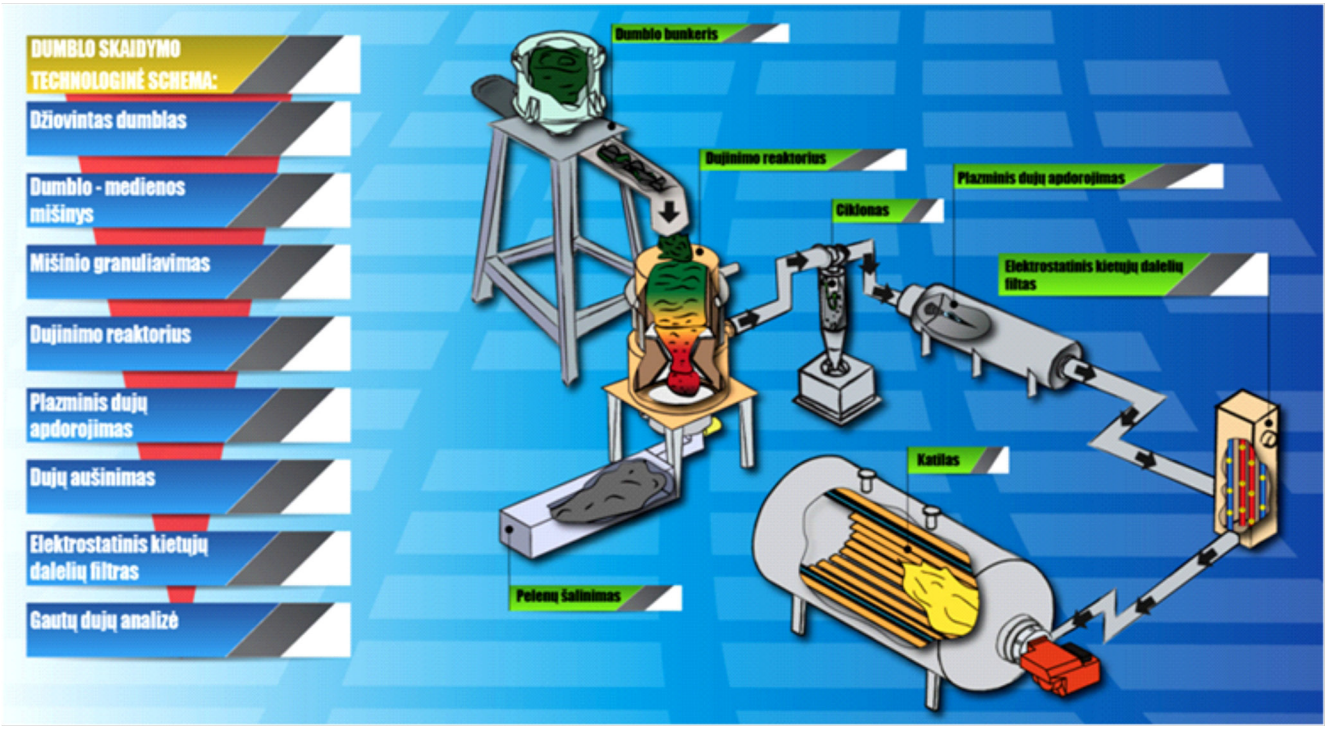
DEVELOPMENT OF INNOVATIVE THERMAL DECOMPOSITION TECHNOLOGY AND ITS APPLICATION FOR UTILIZATION OF SEWAGE SLUDGE (INODUMTECH)

In 2014, project under Lithuanian Human resource development action program of the third priority for the period 2007–2013 ***Improving researchers skills*** VP1-3.1-ŠMM-10-V ***Promotion of high international level scientific research*** funded by EU structural funds continued. Project title ***Development of innovative thermal decomposition technology and its application for utilization of sewage sludge (INODUMTECH)***. Project is administered by ESFA. Project was launched in January 2013, duration 30 months, i.e., until July 2015. LEI was allocated 2.259 million LTL.

With the expansion of infrastructure of wastewater collection and treatment, the amount of wastewater treatment sludge proportionally increases. At storage sites, large quantities of sludge are accumulated, and the management techniques used to date are becoming a threat to the environment and contradict the principles of sustainable development. Therefore, effective ways to treat sewage sludge are sought for. One of the innovative residual sludge disposal technologies is gasification. By applying this technology, during thermal decomposition, the valuable product is produced from sludge, i.e., flammable gas that can be used for generation of heat and power. Gasification process is applied not only for reduction of the volume of sludge



Dependence of changes of nitrogen oxide concentration on boiler load with (blue) and without (black) recirculation



LEI manufactured an experimental laboratory device. Its main component is gasification reactor, where thermal decomposition of sludge and its mixtures at the temperature 800–1000 °C takes place

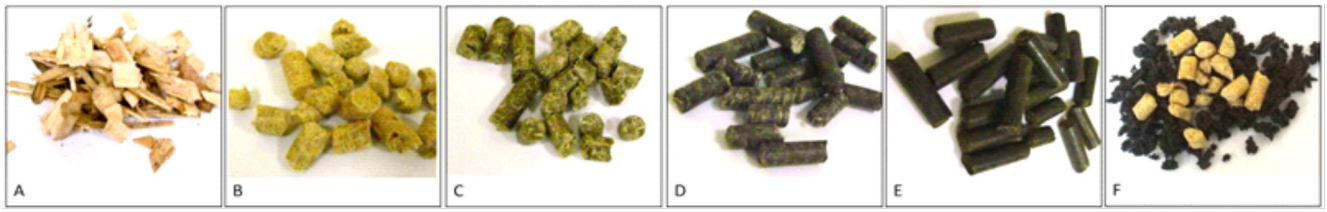
and extra energy production, but also to reduce environmental pollution.

The project is directly related to waste recycling, development of application of renewable energy sources and the major EU energy and environmental policy objectives: to reduce waste accumulation, increase energy supply security, reduce air pollution and greenhouse gas emissions, enhance competitiveness of manufactured production.

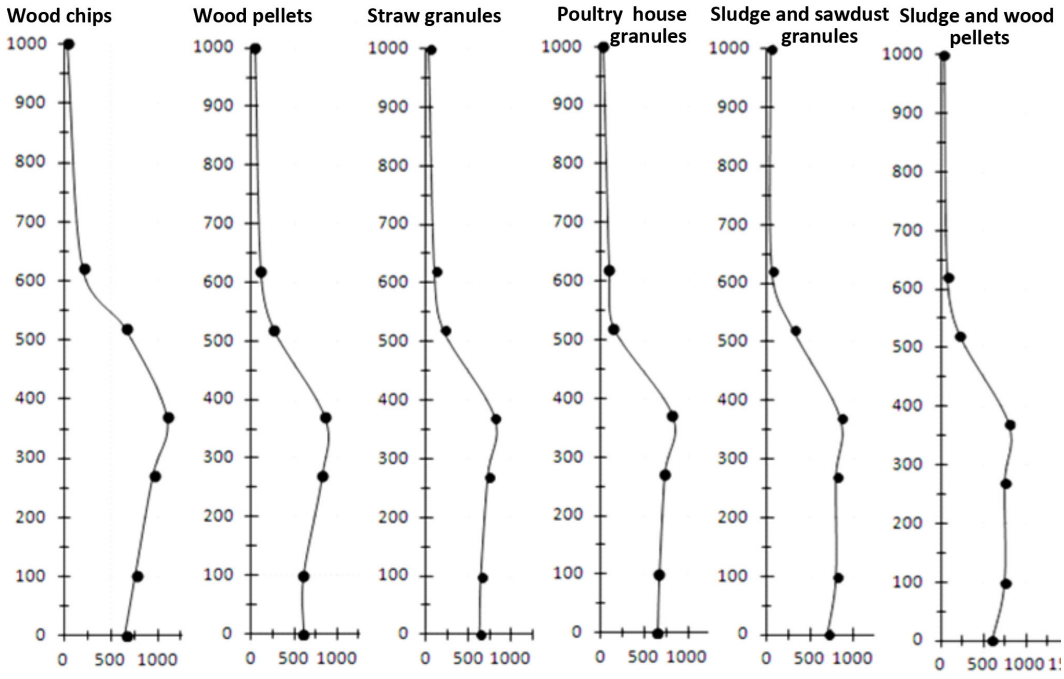
Researchers of LEI developed a 100 kW power experimental laboratory device, the main component of which is gasification reactor (sludge and its mixtures are decomposed at the temperature 800–1000 °C) and plasma gas decontamination equipment with auxiliary systems. Linear plasma generator of 40 kW power with atmosphere pressure and hot cathode was selected as a plasma source. Experimental research on thermal decomposition of sludge and its mixture with wood was performed. In order to determine patterns of fuel humidity, ash content, ash melting and release of volatile substances and influence of the fuel composition on the ash content in fuel, research on thermal decomposition of sludge and wood mixtures was carried out. All the necessary equipment for these investigations and experiments, starting from preparation of granular mixtures and testing their quality to combustion in a separate experimental device, equipped with all the necessary equipment for process efficiency and analysis of emissions into the environment and measurement equipment, was set in the Laboratory.

Prototype of sludge utilization was developed, and it is widely disseminated in order to attract possible Lithuanian and/or foreign investors, interested in creating commercial size operable prototype, suitable to utilize the amounts of sludge accumulated in small Lithuanian towns.

Gasification reactor



Investigated fuel types: A – wood chips (WC); B – wood pellets (WP); C – straw granules (SG); D – poultry house granules (PG); E – sludge and sawdust granules (SSP); F – sludge and wood pellets (SWP)

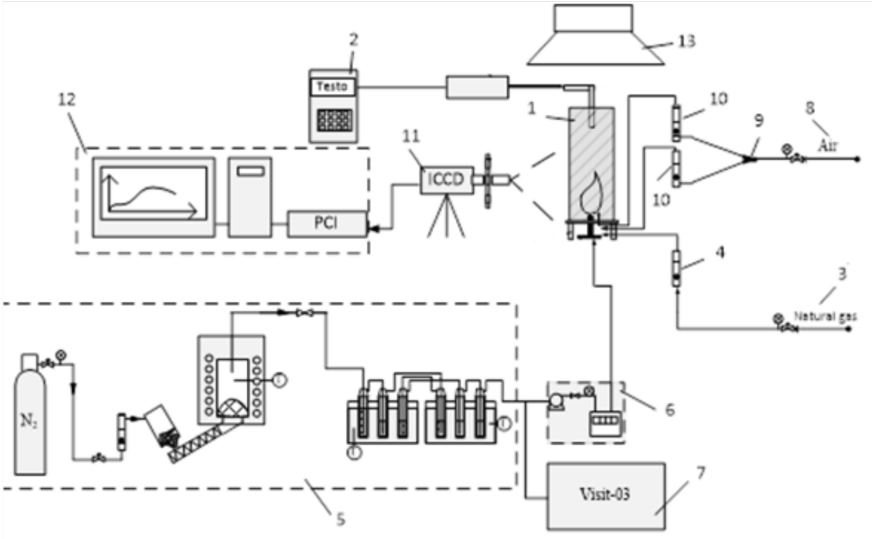


Temperature distribution in the reactor using various fuel types

Comparison of gasification of various types of fuel

Parameters	Various wood chips	Conifer pellets	Straw granules	Poultry house granules	Sludge and sawdust granules	Sludge and wood pellets
Fuel flow, kg/h	63	57	47	30	28	50
Air flow, Nm^3/h:	61	55	49	55	49	57
Primary	30	30	30	30	30	30
Seondary	5	5	5	5	5	5
Tertiary	26	20	14	20	14	22
Excess air coefficient (α)	0.21	0.20	0.29	0.41	0.39	0.24
Gas, Nm^3/h	130	122	109	90	87	113
Gas output, Nm^3/kg	2.06	2.14	2.32	3.00	3.11	2.26
Average gas composition, volume %:						
H_2	16.40	14.01	14,43	14.55	14.00	10.37
CO	22.60	24.27	14.59	17.42	16.40	19.01
CH_4	4.80	4.12	4.06	1.29	1.05	7.14
C_2H_2	0.11	0.13	0.09	0.07	0.06	0.10
C_2H_6	0.08	0.11	0.06	0.04	0.05	0.08
C_3H_8	0.06	0.03	0.03	0.03	0.02	0.06
CO_2	11.05	10.26	11.8	13.51	9.20	10.10
N_2	44.90	47.07	54.96	53.09	59.22	53.14
Lower gas calorific value, MJ/Nm^3	6.50	6.21	4.97	4.32	4.04	6.23
Exhaust of ash, kg/h	3	6	6	2.5	4	5
Amount of carbon in ash, %	82.10	84.32	55.43	32.41	34.92	42.76
Tar, g/Nm^3	0.43	3.31	0.41	1.11	1.24	2.15
Gas velocity, m/s:						
In outfall	2.72	2.55	2.28	1.88	1.82	2.37
In reduction zone	0.51	0.48	0.43	0.35	0.34	0.44
Cold gas effectiveness, %	82.7	75.1	75.3	80.7	75.4	82.7
Hot gas effectiveness, %	90.4	81.7	83.7	90.8	86.2	89.8
Volumetric load, MW/m^2	19.78	17.68	13.00	9.57	8.85	16.42

APPLICATION OF OPTICAL MICRO-MECHANIC SENSORS FOR CONTROL OF TECHNOLOGICAL PROCESSES

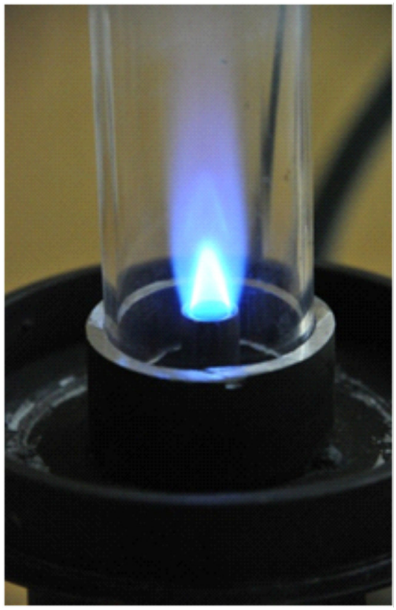


Experimental stand

In August 2014, project under Lithuanian Human resource development action program of the third priority for the period 2007–2013 ***Improving researchers skills*** VP1-3.1-ŠMM-08-K ***Implementation of research and development activities under the topics of national complex programs*** – ***Microsensors, microactuators and controllers for mechatronic systems*** (GoSmart) VP1-3.1-ŠMM-08-K01-015, administered by Agency for Science, Innovation and Technology, has ended. A two-year long project was initiated in 2012. *Go-Smart* project value is 1.83 million LTL. 94 thousand of those are allocated to LEI.

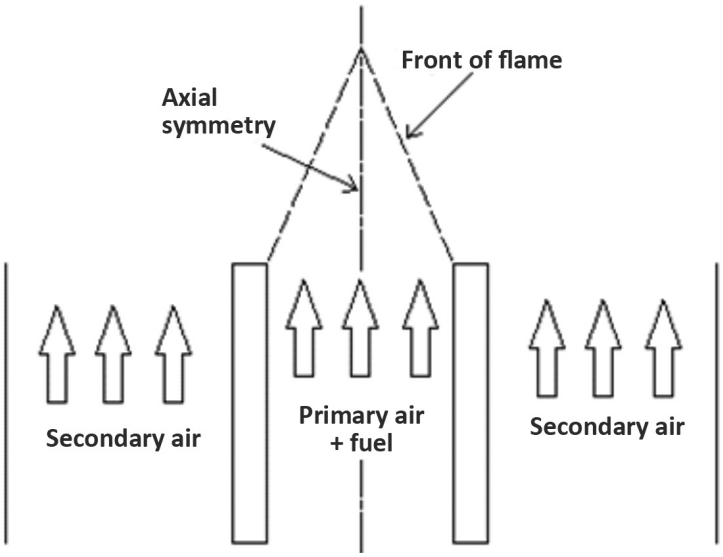
While improving designs of combustion devices, it is necessary to take into account the fact that they have to operate environmentally, economically and reliably under various modes of operation and using fuel with different composition and calorific value. For this purpose, combustion devices automatically adjustable to the mode of operation (smart burners) are the most suitable. They consist of an active control system, consisting of flame diagnostics device, diagnostic signal processing and system for selection of proper parameters and control system, which sets the operation mode of the burner based on the combustion parameters (e.g., fuel and air debit, etc.). Advantages of optical observation and control:

- Possibility of distant contact-free observation, therefore, a more favorable operation environment for the equipment;
- Non-invasive analysis – no impact on the flame structure;
- Fast operation – the processes that are observed in the flame, are reflected in the optical structure.



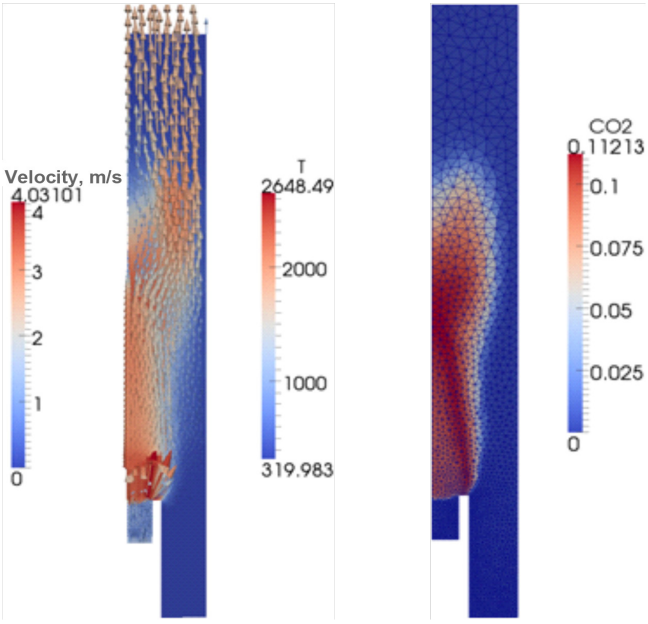
Laboratory burner and camera for spectroscopic analysis of flame

Measurement of flame emission spectra profile – spectroscope is connected with optical fibers



Principal scheme of the modified Bunsen flame

An experimental stand was manufactured for spectroscopic analysis; it consists of specially manufactured modified burner on the basis of Bunsen burner, spectroscope Andor Shamrock SR303, connected to hypersensitive (iCCD) camera Andor DH734, equipped with a set of special interference filters corresponding to wavelengths, and the laboratory reactor for production of generator gas, designed for production of gaseous fuel mixtures of different composition. During implementation of this project, theoretical and mathematical modelling and experimental methods were used.



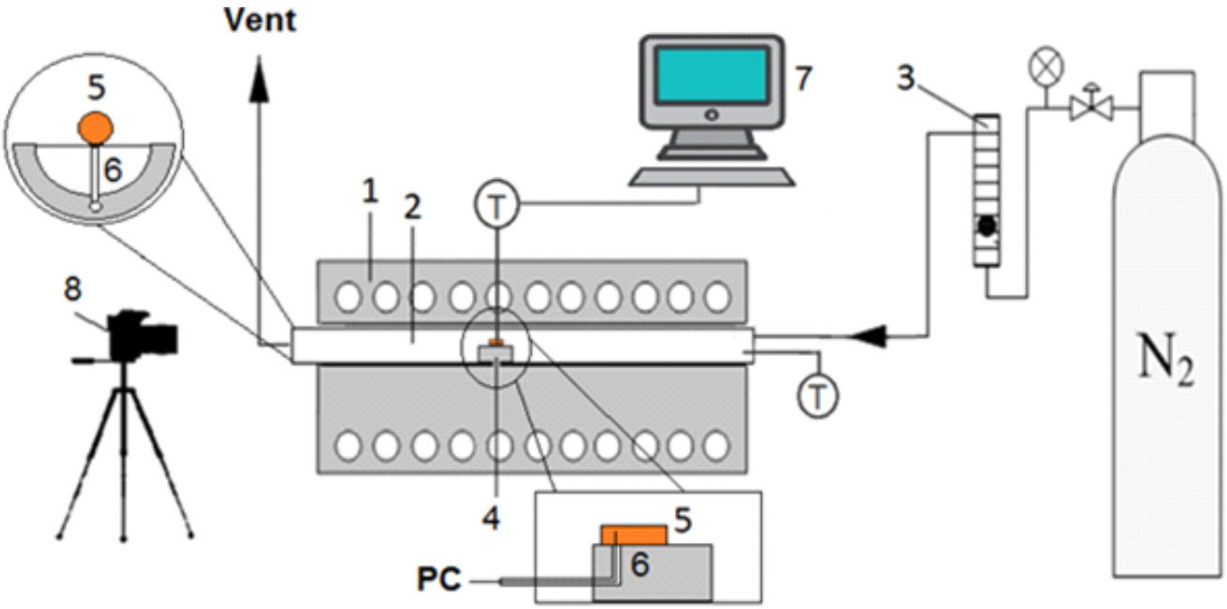
Gas velocities, temperatures and distribution of CO_2 mass fraction in flame, modelled by numerical fluid dynamics and chemical kinetics

EXPERIMENTAL ANALYSIS OF WOOD PELLET SIZE DYNAMICS DURING PYROLYSIS PROCESS FOR NUMERIC MODEL DEVELOPMENT

Renewable fuel sources are increasingly more often used for production of power and heat. With the increase of demand for these sources and their price, the ways are sought to use low quality biofuel. One of the means is gasification. During this process, solid fraction fuel is converted into higher-quality fuel – gas, which is used to generate power or heat. However, using biofuel for the gasification process, fuel adhesion occurs, and it stops the gasification process.

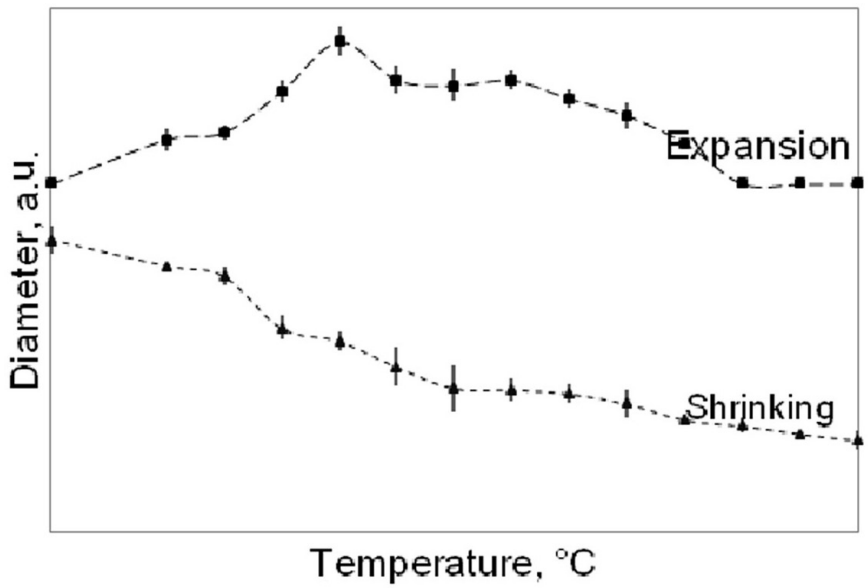
Granular wood fuel in gasification reactor moving from the pyrolysis zone into the oxidation zone, due to initial expansion of granules, stick together into a lump, and in this way, stop the further gasification process. This phenomenon is most often manifested in gasification of granules manufactured from recycled waste and has been scarcely researched.

Adhesion of wood pellets in pyrolysis zone of gasification reactor



Experimental setup schematics: 1 – electric furnace RS 80/500/13; 2 – ceramic pipe with sample tray inside; 3 – rotameter; 4 – sample tray with in-built thermocouple; 5 –wood pellet sample; 6 – K type thermocouple; 7 – computer for data collection and storage; 8 – Canon SX30 IS camera

In order to determine the nature of fuel adhesion due to expansion of granules and to uncover possible solutions for avoiding it, it is necessary to determine patterns of changes of wood pellets in size due to high temperature. Taking into consideration this fact, an experiment in horizontal electric furnace was conducted at the temperature of 300–1000 °C by creating an inert ambient; based on the obtained results, a theoretical research of changes of a wood pellet was carried out. This research is conducted using models of finite difference methods (FDM). Finite difference method is based upon approximation, i.e., substitution of partial derivative equations by partial difference equations. Such approximation of finite differences is of algebraic form, and the value of the sought for variable in the field of solution is determined from the values of adjacent nodes. The model follows the movement of every separate component particle, interaction with other particles and with other system elements, processes taking place in the particle. Therefore, while modelling, parameters of every separate particle are obtained, which allows analyzing biofuel as one particle or as a system of particles and applying the resulting model in industrial devices for combustion of granular biofuel in numerical modelling by means of Discrete Element Method.



Maximum expansion and shrinking of wood pellets at different heating temperatures

During the experiment, it was determined that wood pellet expands from the temperature 400 °C respectively by 3.8%, and afterwards starts shrinking. The expansion intensifies until 550 °C expanding the diameter of wood pellet by 12% of the initial diameter. Upon exceeding the temperature of 550 °C, the expansion of wood pellet fades, and upon achieving 900 °C, disappears due to intensive decomposition of wood, during which volatiles are fully released and the carbon is formed.

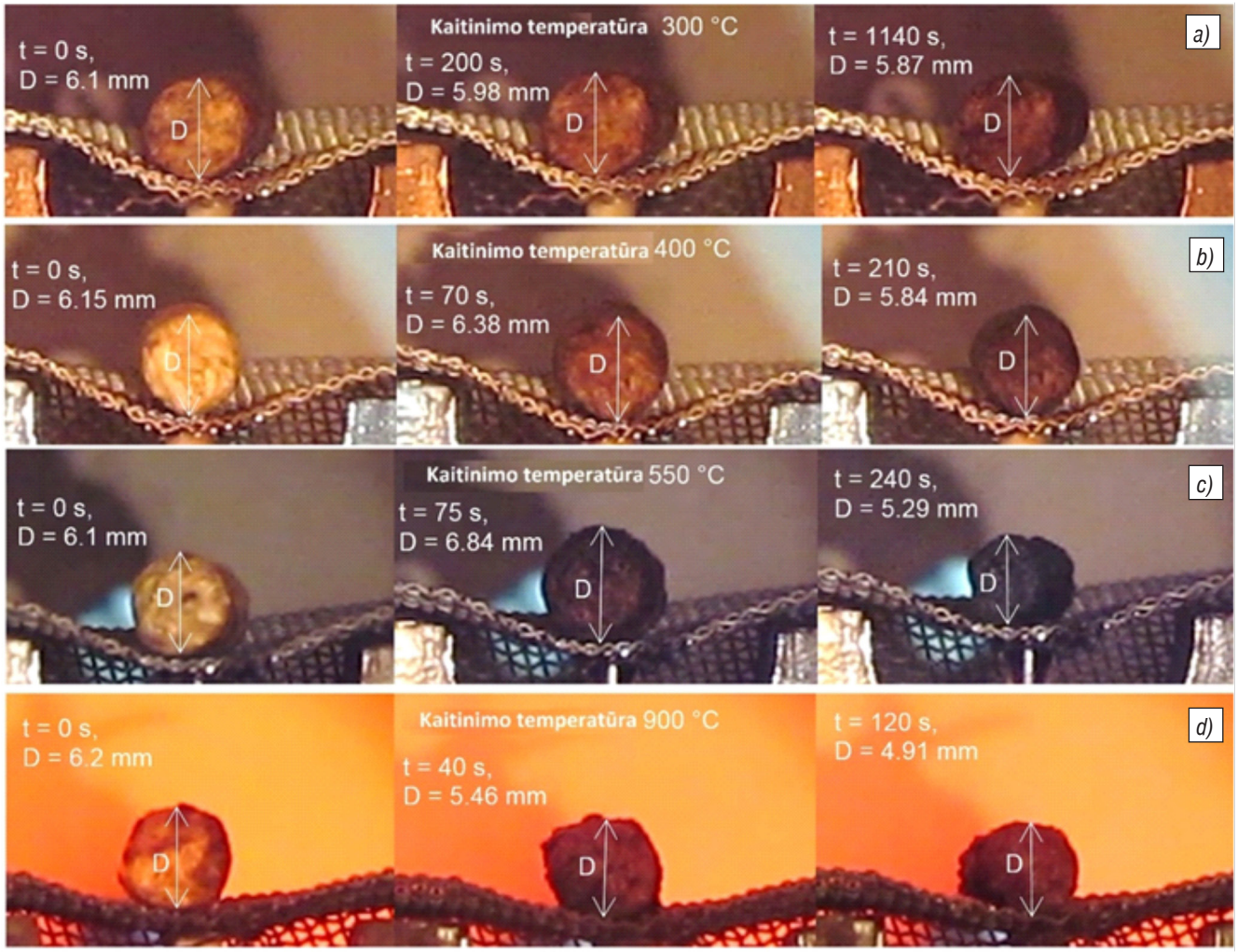


Image of wood pellet changes at different heating temperatures: a) – 300; b) – 400; c) – 550; d) – 900 °C

THEORETICAL RESEARCH OF DYNAMICS OF GRANULAR BIOFUEL AND COMBUSTION PROCESSES FOR BROADER APPLICATION OF RENEWABLE ENERGY SOURCES AND REDUCTION OF POLLUTION

In 2014, the research was conducted (Research supervisor Dr. A. Džiugys), during which two tasks, related to the usage of solid fuel for energy generation, were analyzed: size variation of solid fuel particle under the influence of temperature was analyzed experimentally and numerically, as well as the formation of larger capacity structures in granular media, when parameters of individual particles were known from discrete element modelling.

Using biofuel for the gasification process, fuel adhesion is faced, which stops the gasification process. Performing the analysis of gasification of wood pellets, it was noticed that granular wood fuel by moving in gasifier from the pyrolysis zone into the oxidation zone due to the initial expansion of granules stick together into a lump, which stops the further gasification process. This phenomenon is most often manifested in gasification of granules manufactured from recycled waste and has been scarcely researched.

In order to determine the nature of fuel adhesion due to expansion of granules and to find possible solutions to avoid it, it is necessary to determine the patterns of wood pellet changes in size due to the high temperature. Taking into consideration this fact, an experiment in horizontal electric furnace was conducted at the temperature of 300–1000 °C by creating an inert ambient; based on the obtained results, a theoretical research of changes of a wood pellet was carried out. This research is conducted using models of finite difference methods (FDM). After performing experimental and theoretical research of the change of the particle size, patterns of size change at various temperatures and in conditions of their change were determined. It was concluded that the changes taking place in diameter do not determine the speed of centre heating, but only the ambient temperature. The calculated peaks of centre velocity indicate chemical processes taking place in the granule and their intensities. The result of a numerical

model well correlates with the result of the experiment till the temperature 400 °C and at a higher than 900 °C temperature. After evaluation of the expansion phenomenon in the numerical model, the expansion trend stands out, but the shrinking of granule and residual diameter of granule are identical to the experimental results. The collected data of the experiment will be used for adjustment of the created numerical model.

Another task addressed in this work is related to mobility and looseness properties of granular materials. Applying a known group detection algorithm in graph theory, the creation of groups of particles, among which greater interaction forces are manifested, in the modelling task of looseness from the bunker was analyzed. Mechanical properties of granular material depend on the interaction of separate particles comprising it, due to which their noticeable properties are manifested on the macroscopic level, e.g., mechanical resistance to pressure. Modelling granular media by means of discrete element (DEM) or molecular dynamics methods, parameters of separate particles are obtained. A great impact on mechanical properties of granular media on the macroscopic level is caused by formation of force bridges. This research analyzes force groups, i.e., creation of such groups of particles, among which interaction forces are stronger than among the particles from different groups. For distinguishing these groups, a mentioned group isolation method is applied. Scattering of particles from the bunker is analyzed as a model task. Such phenomenon is encountered in many fields, related to granular media and research of bulk material and technology. As an example, granular bunkers in solid fuel boilers can be mentioned. The results analyzed here were obtained by applying group isolation method to the graphs, made at individual moments of time during the scattering process based on mechanical forces of interaction of particles.

EXPERIMENTAL AND NUMERIC STUDIES OF COMBUSTION AND PLASMA PROCESSES FOR ENHANCEMENT OF TECHNOLOGIES FOR ENERGY GENERATION FROM RENEWABLE BIOFUEL AND REDUCTION OF ENVIRONMENT POLLUTION

While implementing long-term institutional scientific research and experimental development program, two work groups, research of combustion and plasma processes, with different goals and tasks were formed. Four tasks were foreseen for achieving the research goals. For the implementation of these tasks during the third work period *Third period. Detailed experimental research of combustion and gasification, analysis of results, and optimization of processes*, in 2014 the implementation of the following works was foreseen:

- Analysis of physical parameters (air, amount of water, temperature, flow distribution, etc.), influencing the course of combustion and gasification processes;
- Investigation of patterns of main processes and their optimization;
- Numeric modelling of combustion process together with particle dynamics.
- Analysis and summary of the results.

On November 24, 2010, European Parliament and Council adopted directive 2010/75/ES ***On integrated prevention and control of industrial emissions (pollution)***, which sets more stringent requirements for environment protection and pollution than those currently in force, especially in relation to reduction of the amount of emissions into the environment; these requirements will come in force on January 1, 2016. Burning gas from 2016, the norms for nitrogen oxides (NO_x) are 3.5 times stricter – from 350 to 100 mg/nm^3. Burning furnace oil from 2016, norms for nitrogen oxides (NO_x) are 2.7 times stricter (from 400 to 150 mg/nm^3); for sulphur oxides (SO_2) – 8.5 times (from 1700 to 200 mg/nm^3); for solid particles – 2.5 times (from 50 to 20 mg/nm^3).

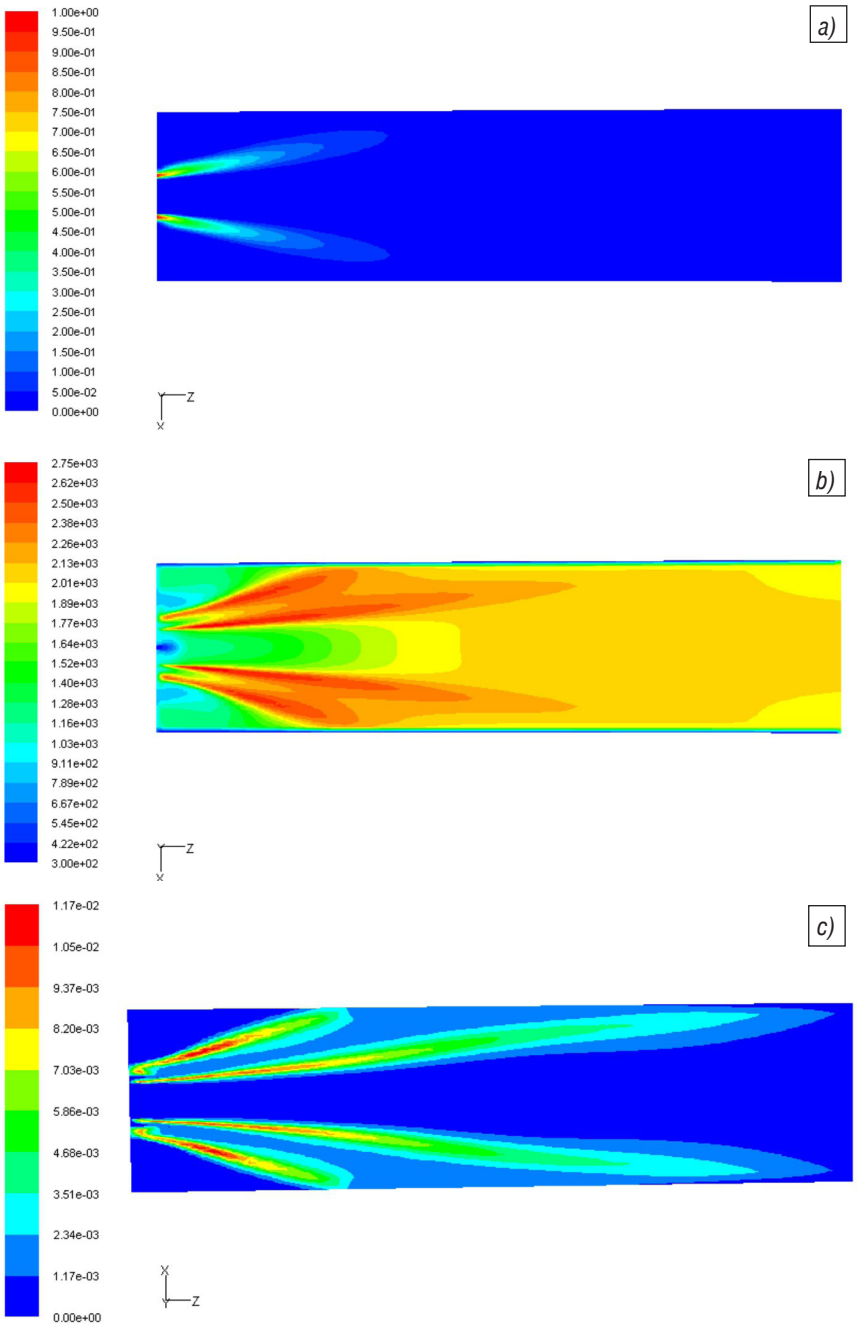
This is a complicated task for the existing burning devices requiring additional investments or R&D works: it is necessary to replace the existing burners with the new ones with little amount of nitrogen oxides and/or install secondary measures for reduction of nitrogen oxides.

In order to reduce NO_x concentration in combustion zones, it is necessary to avoid maximal temperatures of burning plume 1400–1500 °C. Now, quality enhancement of combustion process using burners of new type with specific peripheral air function and tertiary air injection over the flame dominates. One of less sophisticated measures employed is recirculation of flue gas. Recirculation of flue gas does not make a major change in the combustion process; however, by employing it, the concentration of nitrogen oxides in emitted flue gas can be reduced to 10–20%. In order to reduce NO_x to a greater extent and achieve 100 mg/nm^3, a sum of means for nitrogen oxide reduction can be used: low amount NO_x burners, flue gas recirculation, supply of over-flame air and secondary combustion of NO_x. However, after implementation of all the above-mentioned means for reduction of NO_x in emitted flue gas, NO_x concentration can be reduced by only 60%.

In the reporting period, the works in the field of reduction of atmosphere pollution continued, during which initial combustion process regulation technologies, secondary air injection and secondary fuel combustion in the second part of furnaces, were applied. Applied experimental tests were performed in water boiler KVGM-100 No. 5 (VK-5), exploited at water boiler house VŠK-II of

Combined Cycle Power Plant No. 2 of JSC *Vilniaus energija*, Elektrinės str. 2 Vilnius. Water boiler VK-5 is uniflow, of П-shaped water-tube type design, with forced water circulation. Volumetric thermal load of boiler furnace is ~ 350 kW/m^3, and the ratio of length and equivalent diameter L/De = 4.5. LEI designed burners D30 are installed in water boiler KVGM-100, and after performing the initial tests, it was determined that the furnace of the latter boiler is highly acceptable for gas combustion: aerodynamics is formed in such a way that gas recirculation could take place in the furnace space, thus providing a longer combustion reaction pathway. The burners have two main features: division of central and peripheral air flows and dispersed natural gas supply system. In the burner, gas is injected through 8 injectors with 7 vents installed in each injector. Injectors are mounted around central air. This design allows regulating every injector separately in order to obtain the best combustion process with minimum excess air ratio and minimal emissions.

In order to clearly understand how the use of strong and long secondary gas flows produces more CO gas, the case of combustion of highlighted gas flows was modelled by calculations. The results are obvious and warn that the option of large fuel flows should be used moderately. The example is given for a hypothetical case; the actual flows pass through the burning flame with a high turbulence, lower oxygen and gas gradients.



Gas injected in the air background forms flame, while edges of the flame are generated by bright CO stripes. a) – CH_4 concentration (by mass fraction); b) – Temperature (K) distribution in furnace; c) – CO concentration (by mass fraction)

Presently, production of combined heat and power (CHP) at low-power installations from biomass is encouraged. In the neighbouring Republic of Latvia, woodworking business acquired several small devices from the German company Spanner for production 30 kWe and 80 kWh. It is noteworthy that fuel has to be 10% dry, and the size of particles more than 4 mm. The gasification reactors of the layer moving downward generate proper gas by internal combustion engines. After evaporation of volatile substances in the reactor, a permeable layer of carbon is generated aerodynamically, which is ideal for internal tar decomposition. This type of reactors cannot use granular fuels. In that case, a layer of small carbon particles with high aerodynamic resistance is formed from the fuel.

Recently, two degrees gasification reactors have spread, in which partial fuel pyrolysis starts at the fuel supply stage. In this case, the fuel can be of various kinds and humid. Cases of pilot installations in Denmark, Austria are noteworthy, and they are promoted in other European Union countries. In this type of reactors, additional space is installed in the upper part. Pyrolyzed fuel is poured into this space and is mixed with preheated air, where at around the temperature of 1200 °C, it

partially oxidizes. Part of carbon oxidizes to CO gas, but the principal novelty is the fact that intensive tar destruction occurs.

The type of fuel becomes a secondary factor. Based on its properties, it is possible to adjust airflow system and the necessary temperature in the hot reactor ambient. For instance, water vapour of fuel humidity stimulates reaction of water vapour conversion, which increases the emission of hydrogen. It should be noted that dry wood pellets are a valuable source of gas generation.

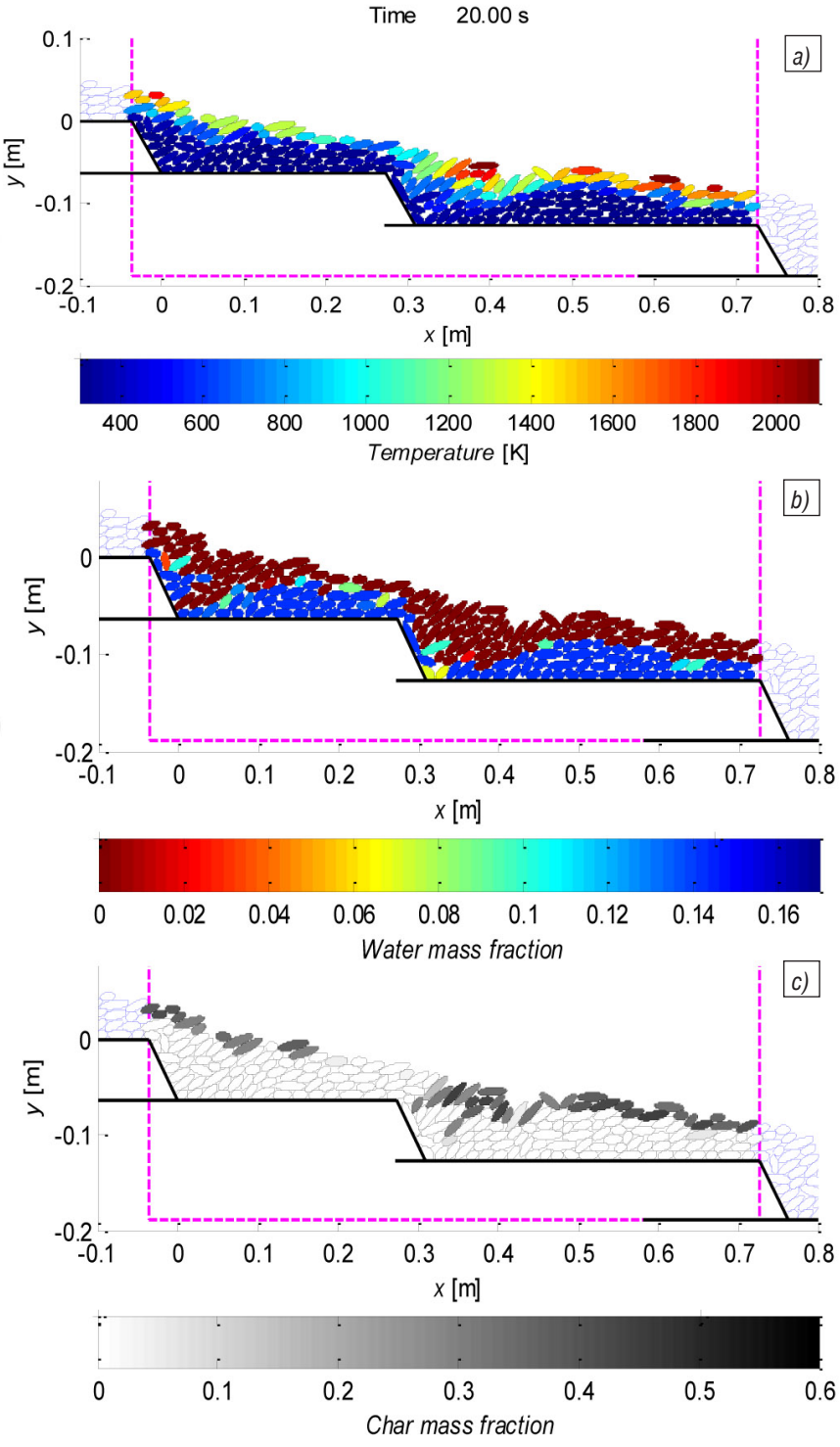
During this reporting period, the objective of the work was to experimentally determine patterns of non-stationary pyrolysis process of wood fuel, from initial heating until full heating.

Wood pyrolysis takes place in a cylindrical capsule. The capsule is put into a hot furnace and heated from 20 to 500 or 680 °C. The capsule is made of stainless heat-resistant steel (AISI 316), the average diameter of which is 55 mm, and length is 170 mm. K-type thermocouple is permanently fitted in the centre of the capsule. Another K-type thermocouple is installed in the wall of the capsule. Thermocouple readings are recorded by the computer. The initial experiments were performed with an empty capsule. The data obtained are considered the basic measurements for the analysis of other ongoing processes. Other tests have determined the temperature variation in porous and pyrolyzed fuel environment.

The course of pyrolysis of porous substance under conditions of variable heating was monitored by measuring concentration of the generated gas. Upon heating of fuel in the capsule, generated gas flows out through a tube mounted at the end of capsule into a combustion cell, where it is combusted. By means of a tube branching off from the capsule, gas sample is taken for analysis. A condensation system was mounted for collection of liquid products of the reaction. For indication of the course of the research, gas concentration was determined by portable gas gasification analyzer VISIT 03H. For detailed gas analysis, gas chromatograph Agilent 7890A with a thermal conductivity detector was used.

For the analysis of biofuel, 6 mm in diameter and 12 mm in length hardwood pellets and conifer wood cylinders of the same dimensions were used.

Combustion of biomass was numerically modelled by means of DEM. Movement and combustion of particles of elongated straw on a moving grate was calculated. The results of the numerical experiment revealed that the model of combustion of biomass particles quite well describes the processes of drying, pyrolysis and combustion of particles,



Position of particles, temperature (a), humidity (b) and amount of carbon (c) after 20 seconds. Fire grate movement period TA = 20 s

and it can be applied for calculation of industrial devices for combustion of biomass. In order to improve the accuracy of calculations, it is necessary to use a revised model of interaction of particles and gaseous environment.

The program is carried out consistently without disruptions; significant results have already been obtained by means of numerical and experimental methods by analyzing complex combustion and plasma processes, which in the nearest future will be applied in Lithuanian future energy, material science and latest fuel combustion technologies. The importance of the research is indubitable. After performing further scientific research, important information about possibilities and patterns of solid fuel conversion in products of combustion and water vapor plasma will be obtained. After analysis of dynamic and thermal processes by applying experimental methods, having evaluated and confirmed the hypotheses, a huge progress in the field of control and application of combustion and plasma technologies will be achieved. The work is in progress. It is estimated to publish planned scientific publications in the later years after the implementation of the program, after full completion of experimental research and after obtaining the results on the international level.

In 2014, 3 articles were published in *Thomson Reuters* database *Web of Science Core Collection* and 5 articles were submitted for publication. The dissemination of the results in publications and at the Lithuanian and international conferences – 10. During the entire period of programme implementation (2012–2014), 6 articles were published in *Thomson Reuters* database *Web of Science Core Collection*, 1 article in monograph and 27 in other publications, also including the conference material.

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LABORATORY of MATERIALS RESEARCH AND TESTING

MAIN RESEARCH AREAS OF THE LABORATORY:

- reliability of power plant facilities: research of metal ageing processes and degradation of properties due to the impact of operational factors;
- development and research of multifunctional materials and composites;
- testing of materials, assessment and analysis of their qualitative indicators.

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

The Laboratory carries out research aimed at the investigation of processes of ageing of steel and special alloys that are used as the constructional elements for power plants and to study patterns of aging processes, solve issues regarding control of these processes and service life. Applying mechanical tests, X-ray Diffraction (XRD) and elemental composition analysis, as well as optic and scanning electron microscopy, structural and property changes of steel and non-ferrous metal alloys are studied. Experimental and numerical methods are used to predict operational reliability taking into account material ageing processes and other operational factors. The implementation of this work focuses on the investigation of the fundamental physical and chemical phenomena affecting structure and properties of metals. In this research direction, researchers of the Laboratory participate in long-term institutional scientific research and experimental development programs: ***Scientific research of safety important processes taking place in nuclear and thermal nuclear facilities (Task 9)*** and ***Research of processes of nuclear power plant operation decommissioning, nuclear waste and spent nuclear fuel management and radiation impact analysis (Task 5)***.

In 2014, researchers of the Laboratory together with researchers of the Laboratory of Nuclear Installation Safety participated in the project ***Reliability and Risk Research of Lithuanian Energy Systems*** of the program *Energy for the Future* funded by the Research Council of Lithuania. In this project, the analysis of causes of gas-main pipeline failures and ageing processes was carried out along with the research on pipe metal properties after long-term operation.

GEOTERMA

Works, initiated in 2010 with JSC GEOTERMA, for performance of analysis of processes taking place in systems of Absorption Heat Pumps (AHP) and consultations, regarding maintenance of stable parameters of lithium bromide solution in heat pumps and other technological issues, have continued.

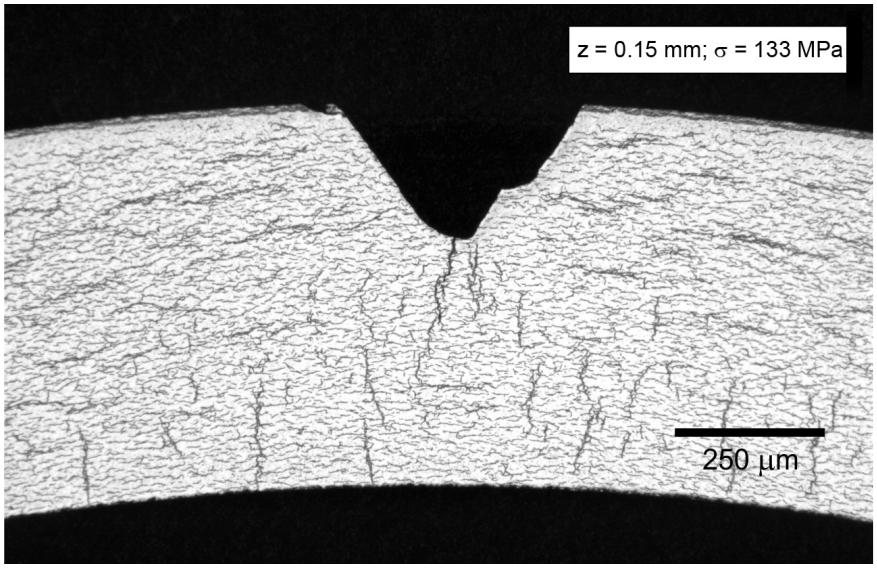
Research Council of Lithuania

In 2014, the project ***Service life assessment model for new generation steel*** funded by the Research Council of

Lithuania was launched. The objective of the work is to investigate structural changes in steel under high temperatures and their influence on the mechanical characteristics and fracture parameters. The structural changes will be determined after the investigation of phase transformations of steel structure, related to diffusion processes occurring under the influence of temperature, by assessing the evolution of steel carbides and changes of their crystal lattice parameters.

The Laboratory continues the research initiated in 1998 regarding degradation impact of hydrogen and hydrides on zirconium alloys. Since 2011, the Laboratory has been participating in the new research project ***Evaluation of Conditions for Hydrogen-Induced Degradation of Zirconium Alloys during Fuel Operation and Long-Term Storage*** coordinated by the International Atomic Energy Agency (IAEA). The objective of this work is to develop experimental procedures in order to assess conditions of hydride cracking in zirconium alloy fuel cladding and threshold stress intensity factor values and temperature limits, under which failure of fuel cladding may occur. By applying controlled hydriding, special construction samples were made of zirconium alloy fuel cladding, in which by changing stress levels, hydride cracking process under given temperatures was studied. The research is important for solving the issues of ensuring safe operation of nuclear power plants and assessing the resistance of fuel cladding to the hydride cracking during long-term storage of spent nuclear fuel.

Works of the project ***MATerials TEsting and Rules (MATTER)*** of European Union 7th Framework Program have continued. The project was launched in 2011 together with the researchers of the Laboratory of Nuclear Installation Safety. Fifteen work packages were formed according to the project tasks. The Laboratories participate in two working groups: *Manufacturing and welding* and *Testing activities in support of design*. Within the scope of the project, a new research on material behavior in the operational conditions of IV generation reactors was initiated. These investigations seek to determine criteria for safe application of materials in nuclear components, operating under high temperatures, taking into consideration the specifics of material ageing mechanisms. One of the main objectives of this experimental research is to identify the allowable fatigue limits and weld joint coefficient values of heat resistant steel welding seams, operating under high temperature and manufactured by applying up-to-date welding technologies. Taking into account the requirements for modern experimental procedures, a research methodology was developed for carrying out the experiments. The fatigue tests were performed at 550 °C under strain controlled conditions using dynamic testing machine Instron (Model 8801, 100kN) with a special testing equipment and software for experiment control. The resulted data of this work, describing the behavior of welding seams at high temperatures, are important for predicting their lifetime in the reactor components and in assessing the suitability of welding technologies in continuation of further research on the welding materials and processes caused by operational factors in the nuclear components. At the final stage of works of this project, the reports related to methodology for evaluation of fatigue resistance of welding seams, their durability and determination of weld joint coefficients, taking into account the given strain values, were prepared. A part of these experimental data is submitted and included in MatDB database.

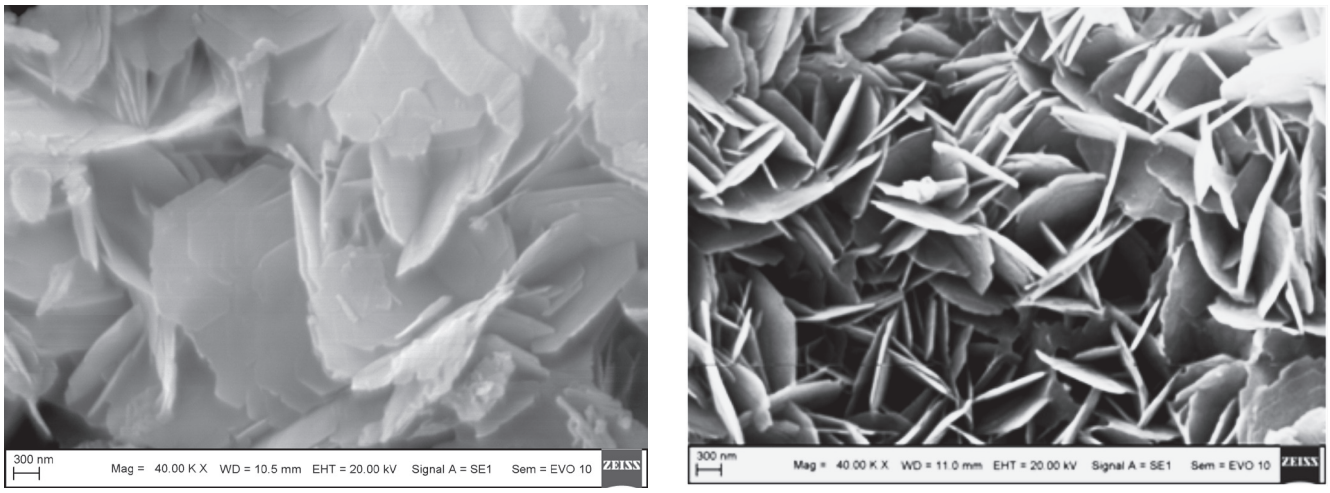


Hydride reorientation under tension at the top of notch in fuel cladding pipe, simulating defect

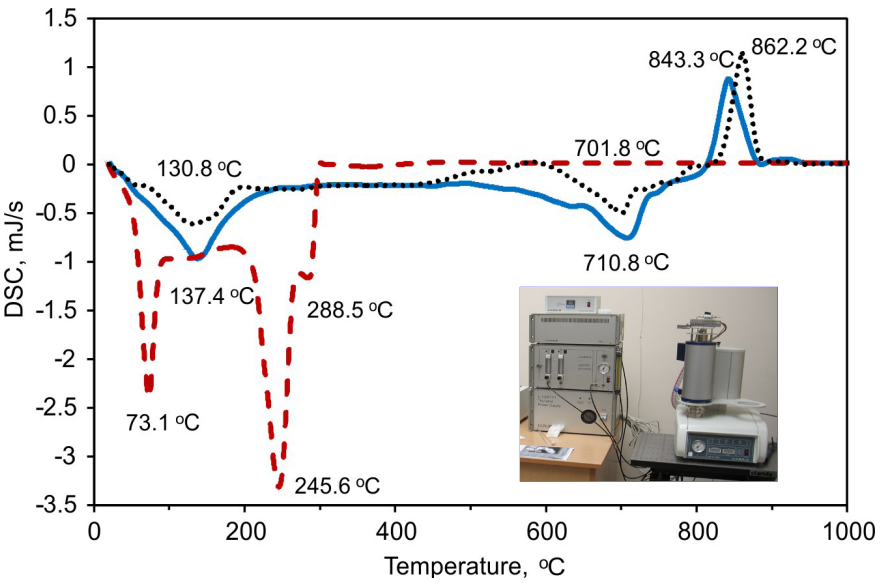
DEVELOPMENT AND RESEARCH OF MULTIFUNCTIONAL MATERIALS AND COMPOSITES

In 2014, a subsidy-funded scientific ***Research of impact of nano-sized modified admixtures on the structure of composite materials*** was launched. The work aims to investigate the structure of natural and synthetic layered nano silicates and to optimize the modification methodology; it also seeks to research the impact of modified silicates and complex nano-sized admixtures on the morphology of cement composite materials. The objective of this work is to investigate the impact of change of parameters of layered silicate crystal lattice on the structure of cement composite materials. It is also important to investigate the dependence of morphological change of cement binding materials on the complex nano admixture introduced to the composition, which consists of hydrophilic and hydrophobic nano-silicate. Simultaneous complex effect of these additive, taking into account their mutual relationship, will enable expanding the limits of use of nano admixtures, while optimizing the composition of composite cement binding materials.

Applying methods of x-ray diffraction analysis, simultaneous thermal analysis, scanning electron and transmission electron microscopy, and nitrogen sorption, modification methodology of layered phyllosilicates and structure of modified natural montmorillonite and synthetic gyrolite with intercalated Na^+ ions were specified and optimized. The obtained results are the first step in development of composite material, the components of which would be replaced by alternative and environmentally friendly materials, yet the structural properties of the material would remain unchanged.



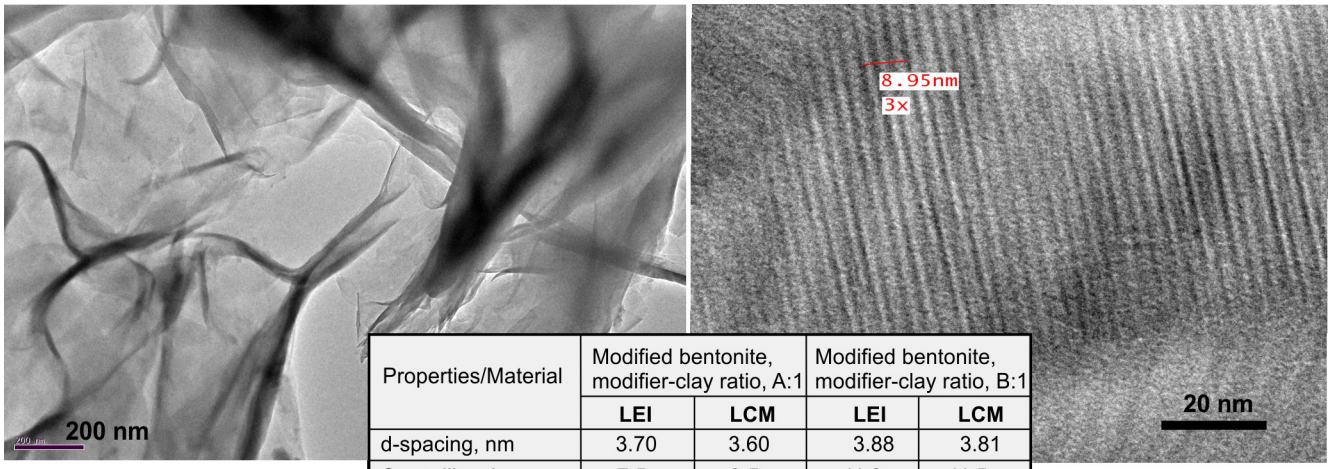
SEM images of synthetic original and modified gyrolite



Curves of thermal analysis of silicates and testing equipment

The final work stages of the European Union 7th Framework Program project ***Nanotechnology Enhanced Extruded Fibre Reinforced Foam Cement Based Environmentally Friendly Sandwich Material for Building Applications (FIB-CEM)***, launched in 2012, have continued. Ten partners from five European countries: Italy, Spain, United Kingdom, Denmark and

Lithuania participate in FIBCEM project, which upon successful cooperation have implemented the objective of FIBCEM project and developed a perspective, low-energy consuming technology for production of foam cement based roofing tiles and sidings enabling to reduce emissions of carbon dioxide into the environment. During implementation of this project, the researchers of the Laboratory did not only supervise the fourth work group (WP4) with the work objective to create a methodology for modification of phyllosilicates, but also worked together with other work groups, researchers from the United Kingdom BATH University and Technical University of Denmark implementing scientific research set in the program, related to specific features of nano-sized materials. In 2014, during the final reporting meeting of the project participants in Aalborg, Denmark (Cembrit), the researchers of the Laboratory presented nano-bentonite modification technology ready for the production process, which was successfully applied by the project partner Italian company *Laviosa Chimica Mineraria.*



Properties/Material	Modified bentonite, modifier-clay ratio, A:1		Modified bentonite, modifier-clay ratio, B:1	
	LEI	**LCM**	**LEI**	**LCM**
d-spacing, nm	3.70	3.60	3.88	3.81
Crystallite size, nm	7.5	9.5	11.8	11.5
S_{BET}, m^2/g	6.7	5.0	6.4	5.1

Modified nano-bentonite

TESTING OF MATERIALS, ASSESSMENT AND ANALYSIS OF THEIR QUALITATIVE INDICATORS

Researchers of the Laboratory provide accredited Laboratory services; perform material testing and assessment of their quality (the Laboratory complies with the requirements of LST EN ISO/IEC 17025). As a result of successful collaboration with economic entities, the Laboratory carries out research and provides consults on the quality issues of product manufacturing.

Laboratory is accredited to carry out tests on:

- plastic pipes,
- pre-insulated pipes,
- building mortars,
- refractory materials and products.

Services to customers. Testing of plastic pipe (determination of resistance to internal pressure)

In 2014, as the result of the work of the researchers of the Laboratory, four articles were published in journals listed in *Thomson Reuters Web of Science Core Collection* database. Two papers were presented at international conferences.

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LABORATORY of PLASMA PROCESSING

MAIN RESEARCH AREAS OF THE LABORATORY:

- development and research of DC plasma sources for wide range of applications;
- research of processes and phenomena taking place in discharge channels, exhaust plasma jets and flows;
- diagnostics of plasma and high-temperature flow and development of diagnostic measures;
- research on interaction of plasma jets and substances in various plasma-technological processes;
- research and implementation of plasma neutralization process of hazardous substances;
- synthesis of catalytic and tribological coatings in plasma ambient and analysis of their properties;
- research of thermal and heterogeneous processes for reacting product flowing around catalytic surface;
- formation and modification of constructional material surfaces in plasma;
- synthesis of micro- and nano- dispersed granules and mineral fiber from hardly meltable materials and analysis of their properties;
- generation of water vapor plasma and its application for fuel conversion and neutralization of hazardous waste.

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

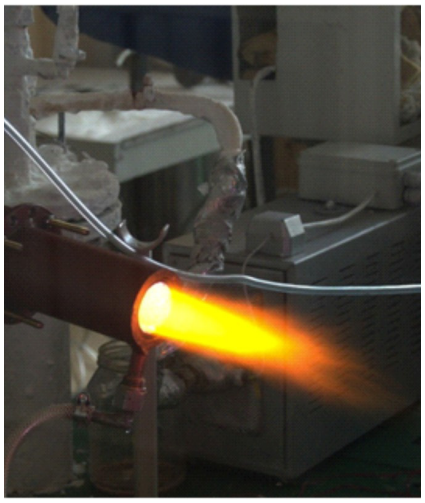
On the basis of acquired knowledge, the Laboratory of Plasma Processing is carrying out the following researches:

DEVELOPMENT OF PLASMA SOURCES AND RESEARCH OF PLASMA JET

The Laboratory of Plasma Processing develops new plasma generators up to 200 kW of capacity and improves the existing ones. Recently, a new design water vapor plasma generator has been developed. Based on the knowledge of processes, occurring in the reactive discharge chambers, and by means of the theory of similarity of plasma processes, its volt-ampere and thermal characteristics were generalized and stable operation modes were determined.

By means of water vapor plasma generator, conversion of gaseous, solid and liquid organic materials into hydrogen enriched synthetic gas was carried out.

The Laboratory continues the investigations on heat transfer in plasmatron reactive arc zone, as well as variation of electric arc strength in laminar and turbulent flow regime, the impact of various factors on the characteristics of plasma flows and jets, specific features of arc radiation with different gas flows. Operating

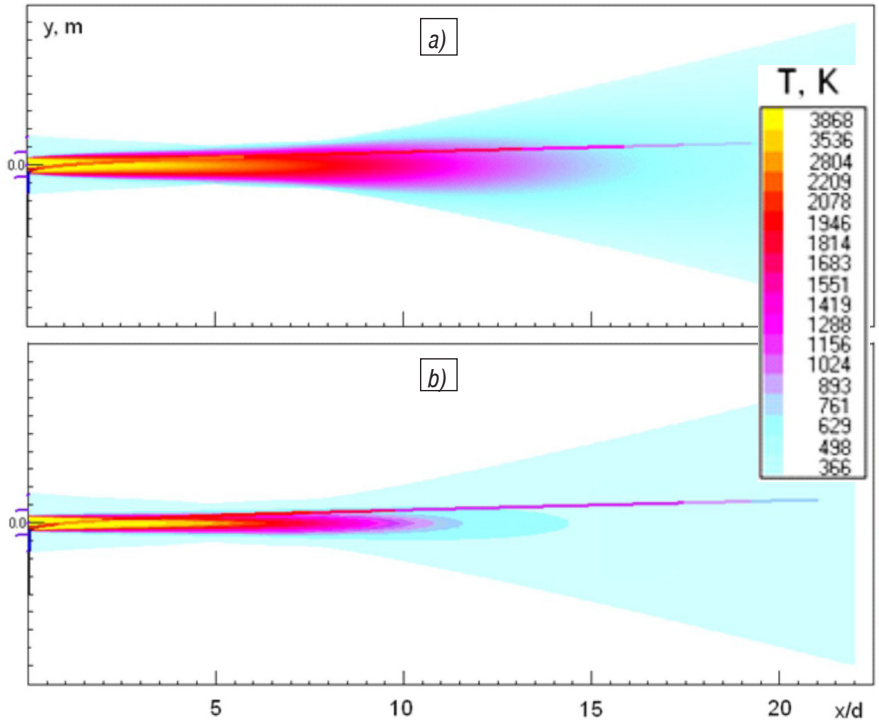


Air plasma jet discharged from direct current linear plasma generator

modes of linear electric gas arc heaters and reactors and their operating characteristics have been examined, conditions of increase of duration of operation have been determined, arc turbulence and new methods of energy application in plasma equipment have been analyzed.

DIAGNOSTICS OF PLASMA AND HIGH TEMPERATURE JETS

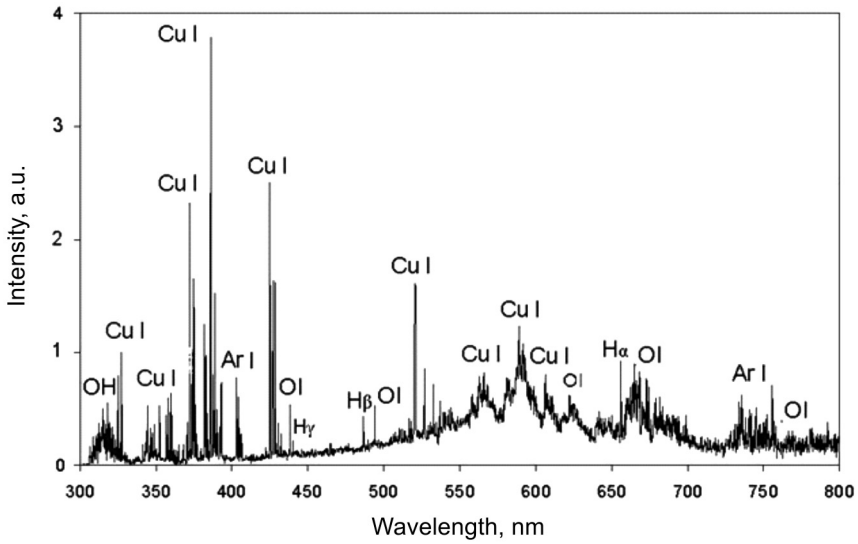
Formation of high-temperature and plasma jet, its dynamics, heat exchange in the channels of different configuration, their cells, and in elements of heat exchangers are investigated in the Laboratory. Plasma diagnostics is performed in the Laboratory by applying numerical and experimental methods. A numerical research of heated gas jet in the channel was performed applying hydrodynamics software ANSYS Fluent. The calculation was performed to solve full Navier-Stokes and energy equations based on the dynamic k-ε model. However, the numerical research becomes especially difficult when multiphase jets are flowing, and the solid particles are injected into the jet. This occurs due to specific plasma properties; therefore, numerical research of two-phase plasma jets is performed applying software package Jets & Poudres, adjusted to modeling plasma jets.



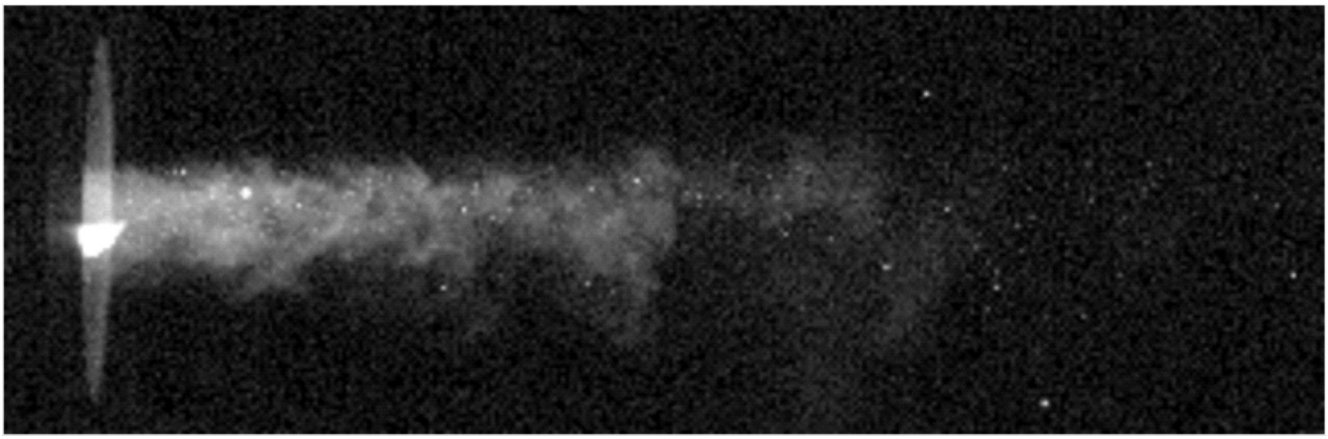
Distribution of temperatures (a) and velocities (b) in the air plasma jet with a speeding 50 μm Al_2O_3 particle

Recently, non-contact methods have been widely applied for plasma diagnostics in the Laboratory. One of them is optical spectroscopy method; its main device is an optical spectrometer AOS-4. It is a very fast optical measurement system that may be used for the investigation of peaks of gas emission spectra in a wavelength range of 250–800 nm. The system is also used to examine composition of plasma elements and emission spectra.

A high-speed optical camera with CMOS sensor, 1280×800 pixel matrix, which enables high-speed recording and capturing of moving objects at a very high speed, is used for multiphase plasma flow visualization and determination of some dynamic characteristics. The Laboratory uses *Phantom Miro M310* high-speed camera.



Elemental composition of argon and water vapor plasma jets discharged from 47.6 kW power plasma generator, identified using optical spectroscopy method

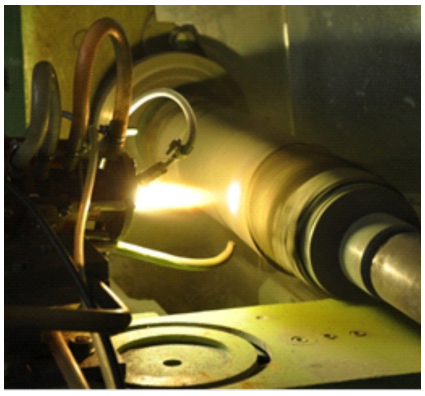


Movement of alloy and granules and the process of mineral fibre formation in supersonic plasma jet, observed by high-speed video camera

LAYERS OF CONSTRUCTION MATERIALS BY PLASMA TECHNOLOGIES

Synthesis of coatings in plasma flows

Plasma spray technology for surface formation, developed in the Laboratory, was applied for catalytic, tribological and protective coatings formation as well as for hard ceramic coatings, which are employed for improving the operational characteristics of constructional material surface layers in mechanics, chemistry, energy and medicine. These coatings improve the corrosion resistance up to 10^2–10^3 times, significantly decrease the friction coefficient and reduce the mechanical wear. The use of plasma technology decreases the demand for expensive constructional materials, since cheap materials covered with different thickness coatings replace large amounts of used expensive materials.



Formation of various metal alloys in air plasma at atmospheric pressure

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

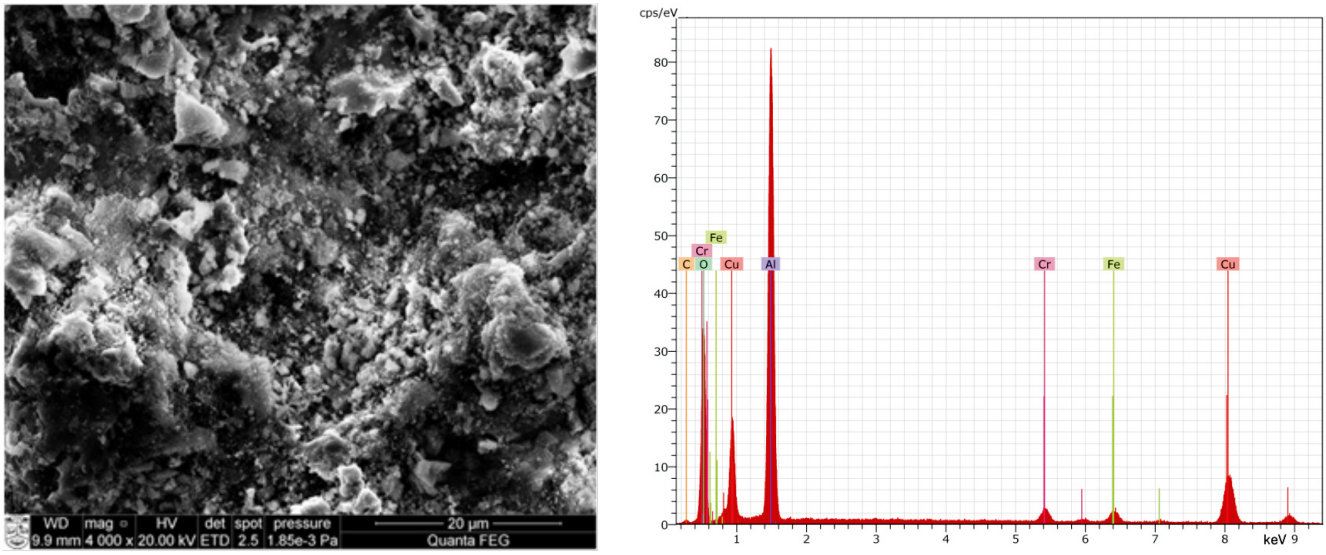
Catalytic coatings

In the fields of science and production, a worldwide attention has recently been given to the renewable energy technologies, hydrogen energy, programs of fuel synthesis and saving, issues related to the reduction of environmental pollution and their solution. All these areas require special purpose and composition catalysts that are used in approximately 70% of chemical reactions carried out worldwide. The production of the up-to-date catalytic reactors is a time and finance consuming chemical process performed by precipitating platinum group metals. For this reason, the catalytic reactors are expensive; their ceramic substrates are non-durable, and the meshes often melt and block the reactors due to poor thermal conductivity. In the new generation of catalytic neutralizers, a metal substrate is substituted for ceramic one, and noble metals are replaced by cheaper metal oxides, zeolites and other materials that are successfully used as effective catalysts.

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

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

On the basis of metal oxide cata-



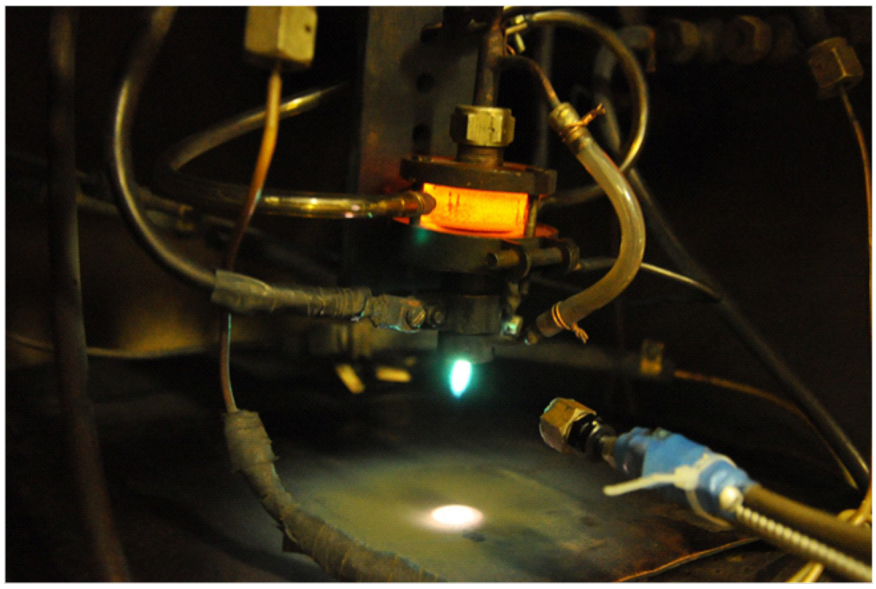
Catalytic Al_2O_3 coating (on the left) and its elemental composition (on the right)

lytic coatings, formed employing plasma method, catalytic reactors efficiently reducing the emission of CO, SO_2, NO_x, HC and other pollutants have been developed. By the catalytic combustion behavior, these reactors are very similar to the ones composed of noble metals. The work related to this issue continues in accordance with the project of the Baltic Sea Region Program 2007–2013. Presently, an innovative efficient catalyst for sulphur compounds oxidation is being developed on the basis of TiO_2.

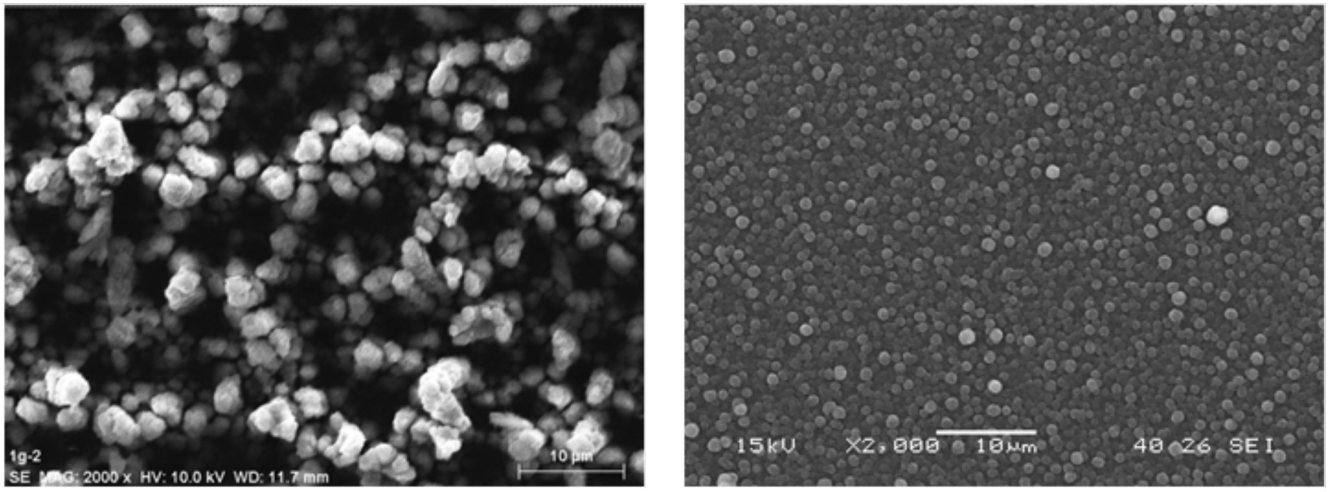
Carbon derivative coatings

Technological modification of surface layers of constructional materials by forming multifunctional coatings is widely applied in surface engineering. One of the possibilities of using plasma technology is the synthesis of plasma polymers. Plasma polymers are thin membranes precipitated by plasma method that may be applied in a wide range of fields: microelectronics, medicine, biotechnologies, manufacturing of semiconductors, etc. Plasma polymers are usually synthesized in a vacuum, but their structures have not been thoroughly studied yet. Due to the low price and good mechanical properties (resistance to corrosion, strength, small autonomous mass, small irrigation angle), hydro, halocarbon polymers and hydrogenated carbon films or their groups compete with the best up-to-date materials and alloys. After evaluation of the situation in the field of plasma polymer synthesis and research, it should be noted that plasma polymerization process requires more detailed knowledge, especially about the influence of coating parameters on the obtained plasma polymer properties and the stability of their time and temperature. One of the plasma polymer groups is innovative materials composed of plasma polymers mixed with metals or ceramics. Such composite materials form a new class of coatings, made of composites and non-composites, and are characterized by a variety of electric, optical and mechanical properties. The developed plasma polymers are mostly used as solid and protective coatings. The application of carbon derivatives for polymer synthesis is currently expanding.

Although the plasma coating formation process in the atmospheric pressure has been widely used in practice for a long time, yet, it has not been fully investigated in terms of physics. It is claimed that



Operating carbon coating synthesis facility generating argon/acetylene plasma



Morphology of amorphous graphite-type coating surfaces after nanosecond long radiation exposure

the chemical, physical and mechanical properties of the coating as well as its composition and structure are affected by about 50 factors. The prevailing ones are the following: composition of initial materials, dislocation of materials introduced in plasma jet, construction of plasmatron, working characteristics, distance from plasmatron to substrate, temperature, pressure and the type of working gas. Currently, a great deal of attention is directed towards developing solid carbon coatings of various composition and properties on different surfaces (steel, Al_2O_3, quartz glass, etc.) and investigating their properties by available methods.

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

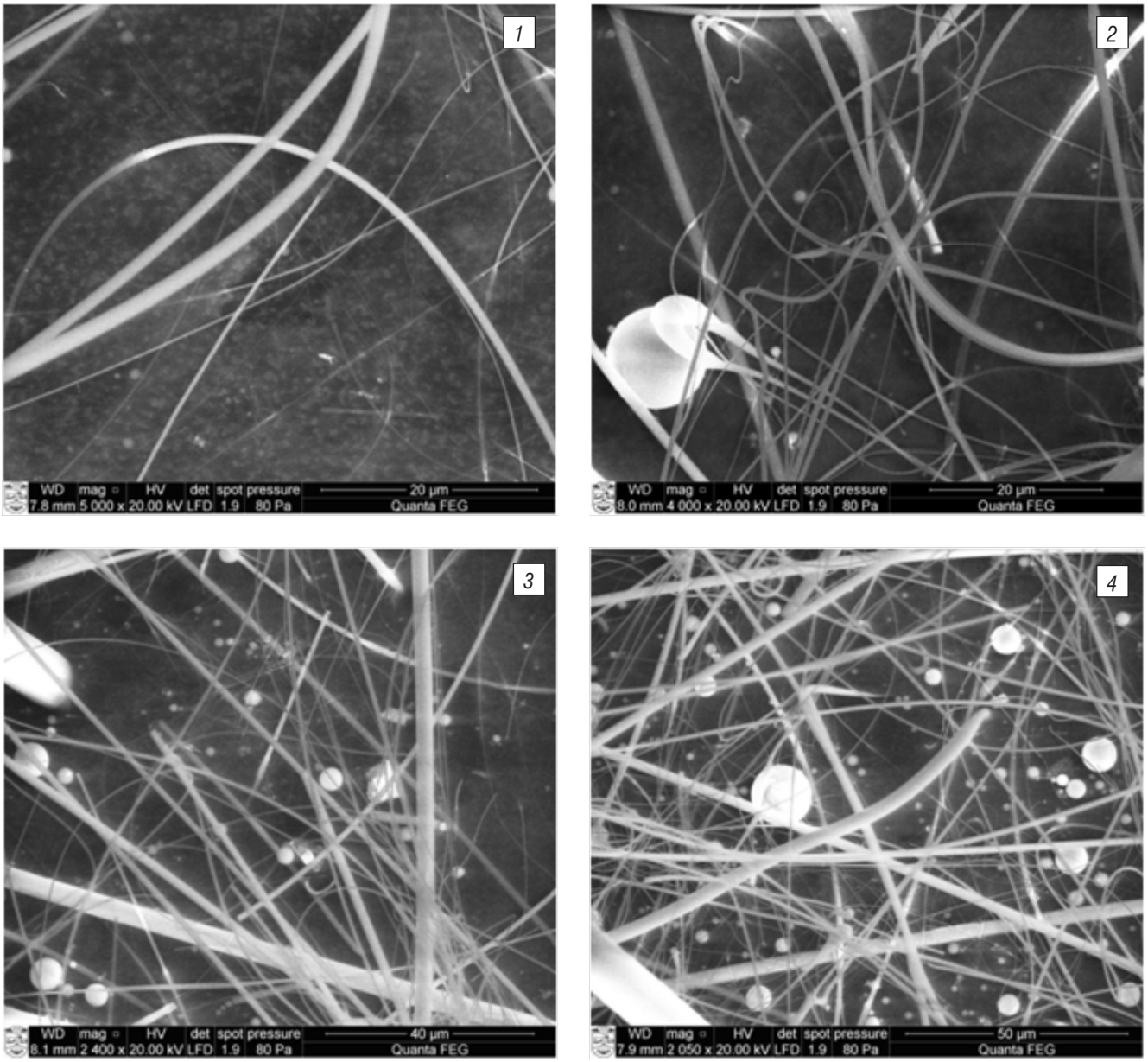
Following the performed research, the synthesis of supercondenser electrode coatings was realized, and carbon derivative coatings were obtained by developing them in the atmospheric-pressure plasma in argon/acetylene ambient. The electrical characteristics of the coatings enable increasing the capacity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

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

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

Plasma technology is the only alternative to obtain a high quality high-temperature fiber. Plasma deposited fiber has unique properties such as resistance to high temperature, low thermal conductivity, and high chemical stability. By melting and stringing ceramic materials and forming mineral fiber, an experimental plasma device with 70–90 kW capacity plasma generator has been developed at the Laboratory of Plasma Processing. It enables to form a splint from dispersed particles, using air as plasma forming gas and auxiliary gas mixtures. Cheap and widely spread in nature ceramic materials (quartz sand, dolomite, clay, aluminum oxide, industrial ceramic waste, etc.) are used as raw materials for producing heat resistant ceramic fiber.

After conducting experimental and numerical research, it was determined that dynamic and energetic characteristics of plasma jet have major impact on the plasma process of pulping ceramic materials. Since melting temperature of ceramic materials reaches up to 2500 K, the temperature of plasma jet inflowing into the reactor should be 2500–3000 K, whereas velocity – 700–1000 m/s in order to completely melt and pulp dispersed ceramic particles. The average mass plasma jet temperature and velocity along the length of the reactor channel evenly reduces and changes at the end, respectively, by 14



SEM images of zeolite fiber gained at different plasma flow velocities: 1 – 1600 m/s, 2 – 1500 m/s, 3 – 1200 m/s, 4 – 1000 m/s

and 10%, not taking into account plasma generator operating regimes. This enables to easily regulate plasma jet parameters in the reactor chamber. After getting physical explanation of the mechanism of ceramic fiber formation in plasma-chemical reactor, it was determined that melting of particles occurs in the reactor channel, whereas formation of fiber elements, which lasts 4–10 ms, occurs behind the reactor limits. After injection raw material and dispersed particles into the reactor, heat exchange occurs not only between plasma jet and reactor walls, but also among dispersed particles, which has impact on the reduction of plasma jet temperature. It was investigated that heat exchange of plasma jet and dispersed particles is more intensive the greater is the concentration of particles in the jet and the smaller their measurements are. With increase of concentration of mass cold dispersed particles in plasma jet from 6 to 24%, the heat flow into the reactor wall reduces from 6 to 31% due to intensive flow heat transfer to particles.

Plasma jet velocity is one the main factors conditioning the quality of ceramic fiber since with the increase of velocity of plasma jet discharge from the reactor by 60%, the developed fiber yield increases by 5%, whereas the fiber diameter comprising the splint and granular amount in it reduces.

The derived fiber is irreplaceable in the production of muffle furnaces, MHD generators and blast-furnaces, and due to splendid sound isolating properties – for sound isolation as well. The ceramic fiber can also be suitable in manufacturing of different filtrating materials, also as constructional, concrete solidifying material, whereas certain composition ceramic splint may serve as a catalyst.

WATER VAPOR PLASMA TECHNOLOGY

Rational exploitation of natural resources and environment protection from pollution by industries, household, medical waste are important tasks of the contemporary industry; it is likewise important to search for alternative energy resources. Decontamination of gaseous, liquid and solid waste is carried out by employing various methods. The hazardows waste can be disposed reducing the emission of pollutants into the environment, however the most rational way is to recycle them and get new useful products. Decomposition of different types waste with plasma method, due to unique plasma properties, it is characterized as an extremely environmentally friendly process. Plasma process uses water vapor, which is a coolant, and raw material, while in this plasma, practically all endothermic reactions can be carried out, the most persistent chemical compounds can be broken down to atoms; and by such water vapor plasma technology, synthetic gas (CO + H_2) can be derived by decomposing organic waste.

The process and efficiency are determined by the device structure, technical characteristics and plasma jet parameters. Scientific literature lacks data about heat transfer in plasma-chemical reactors, mechanism of electric and thermal processes and interaction of plasma flow with treated materials. Therefore, the tasks of performing research are to model and construct a plasma-chemical reactor, designed for gaseous, liquid and solid waste decomposition and reveal mechanism for jet interaction with decomposable materials, investigate elemental composition of the resulting products, assess efficiency of the process. When the temperature is high (starting at 4000 K), water vapor mass enthalpy is about 6 times greater than air enthalpy. At high temperature, water vapor decomposes into oxygen, hydrogen and their compounds, which

Operating water vapor plasma facility designed for decomposition of organic materials

react in plasma-chemical reactions. Extremely rapid chemical processes occur in water vapor plasma, when reactive elements H and O are formed. Due to this flow property, hydrocarbons introduced into water vapor plasma are decomposed very efficiently. This technology may be applied for decomposition of waste and environmentally hazardous materials or turn them into synthetic gas during the conversion.

Various experiments of organic material decomposition were carried out. Chosen gaseous substances – hydrocarbons, liquid materials – toluene, glycerol, and solid materials – wood granules were introduced into the plasma-chemical reactor to perform the conversion.

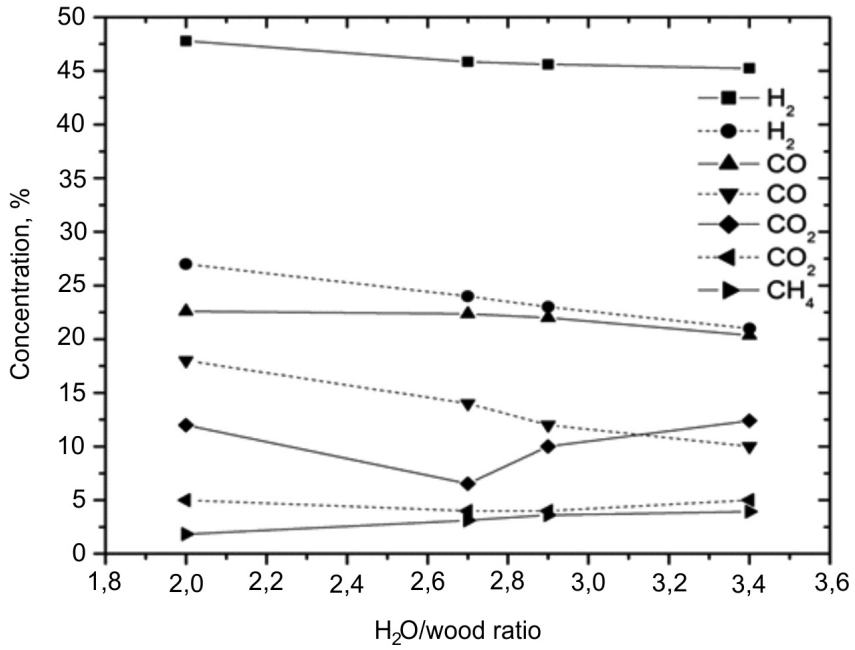
The obtained results and conclusions

Linear direct current water vapor plasma generator with step formed electrode was designed and manufactured. Plasmatron was tested at a variety of modes by supplying air and overheated water vapor.

Thermal and electric properties of water vapor plasma generator were determined. It was established that the flow of discharged from plasmatron jet is turbulent. Heat transfer in water vapor plasmatron between electric arc, heated gas and electrode walls generally occurs by means of convection.

Parameters of plasma jet of gas heated in plasmatron were determined: flow of heated water vapor 2.63–4.48×10^{-3} kg/s, average temperature of plasma jet 2400–3300 K, average flow velocity 210–600 m/s, efficiency factor 0.7–0.78, Reynolds number 2750–6000.

After diagnostics of water vapor plasma jet performed by optical emission



Dependence of change of reaction products on H_2O/wood ratio. Continuous line – experimental results, dotted line – results calculated by digital software for temperature 2800

spectrometer, the results confirmed that water vapor in plasmatron discharge is dissociated and is comprised of OH, H_2, O (I), Ar (I) elements. Detected atomic hydrogen peaks H_α (656.2 nm), H_β (486.1 nm) and H_γ (434.1 nm) demonstrate that hydrogen atoms in water gas plasma are in excited state and are chemically very active. Spectral peaks of metal particles Cu and Fe are very intensive and demonstrate significant erosion of plasmatron electrodes, and care should be taken to reduce it.

After analyzing formation of active radicals in water vapor plasma by numeric methods, it was determined that with the increase of temperature up to 4100 K, dissociation of water vapor occurs. Concentration of water vapor decreases to 1%, while concentration of atomic elements H and O comprising it constantly increases.

The tests of gaseous, liquid and solid material conversion showed that in the ambient of water vapor plasma, synthetic gas H_2+CO could be obtained. Its concentration in the general mass balance of the reaction products comprised over 55%.

After performing the tests on conversion of various organic waste, it was determined that the maximum efficiency (67% H_2) is achieved by decomposing gaseous waste. Decomposing liquid and solid waste, 34–27% of H_2 was obtained, since extra energy had to be provided for the gasification.

PROJECTS IMPLEMENTED IN THE LABORATORY

In 2014, researchers of the Laboratory participated in international projects and programs:

- 2012–2014 scientific group technological development project ***Ceramic fiber catalyst formed by plasma technologies for reducing pollution emission*** financed from State budget of Lithuania**.** Main project objective is to develop a catalytic ceramic fiber of desired properties by applying plasma technology, from which to produce metal oxide fiber catalyst of required properties designed for neutralizing environment pollution, to design and produce experimental research equipment of catalytic properties and realize research in real exhaust combustion product flows.
- National research program ***Energy for the Future*** project ***ATE02/2012 Research of local fuel thermal decomposition processes by developing efficient and ecological technologies***.
- National research program ***Energy for the Future*** project ***ATE10/2012 Conversion of organic waste in water vapor plasma by reducing environmental pollution***.
- EU support measure *Promotion of high international level scientific research* project ***Development of innovative thermal decomposition technology and its application for utilization of wastewater sewage (INODUMTECH)***. During the project, it is planned to develop a sample prototype of 100 kW power gasification process-technology designed to utilize the amount of sludge comprised in wastewater treatment enterprises of small Lithuanian towns. The project idea is implemented together with the Laboratory of Combustion Processes, Laboratory of Nuclear Engineering and Laboratory of Heat-Equipment Research and Testing.
- 2012–2014 state-funded work ***Synthesis of carbon coatings in argon-acetylene and in argon-hydrogen-acetylene plasma and investigation of their properties***. In this work, measurements of hydrocarbon gas by plasma optical emission spectrometer were performed. Temperature of argon-acetylene and argon-hydrogen-acetylene plasma jet was evaluated. The influence of technological processes (power, amount of gas) on the temperature of discharged plasma jet was determined. Composition of argon-acetylene and argon-hydrogen-acetylene plasma, predominating radicals and types of particles and patterns of their change were analyzed.

  Carbon structure coatings from argon-acetylene and argon-hydrogen-acetylene gas plasma were formed. Influence of acetylene gas flow and distance (temperature) on the type of formed carbon structure coatings, optical features and specific surface area was determined. Capacity of condensers with carbon electrodes was measured. Influence of hydrogen gas on the morphology and structure of the obtained coatings was assessed. Exposure of graphite-type carbon coatings to nanosecond and picosecond long impulses was performed. Influence of parameters of laser exposure process (number of impulses, energy of impulses, wave length) on elemental composition of graphite-type carbon coatings, types of connections was determined; optical features of coatings were evaluated.
- 2012–2016 long-term institutional scientific research and experimental (social, cultural) development program. The title of the work is: ***Experimental and numerical investigations of combustion and plasma processes for enhancement of energy generation technologies and renewable biofuel and for reduction of environment pollution;*** for implementation of the program, two work groups with separate goals, investigation of combustion and investigation of plasma processes, have been designated. In 2014, the following works were carried out in the Laboratory:
  - Methodology for investigation of water vapor plasma jet was cre-

ated, and analytical technology was selected;
  - Dynamic and energetic characteristics of plasma jet were measured and analyzed;
  - The spectral qualitative-quantitative analysis of water vapor plasma was performed;
  - The assessment of the uncertainty of results was performed.
- 2013–2015 international activity *COST TD1208 Plasma in Liquids*. The researchers of the Laboratory implement an individual project in this activity ***Application of water vapor plasma for liquid waste processing***, through implementation of which, new plasma-chemical reactor will be developed for decomposition of organic materials of various composition and converting them into synthetic gas with increased amount of hydrogen. Researchers from 26 European countries participate in the activity.

The personnel of the Laboratory of Plasma Processing consists of 9 scientists with a doctoral degree, 1 junior researcher and highly experienced ancillary personnel: 3 engineers and 3 highly qualified foremen.

In 2014, the scientific and technological production of the Laboratory was presented at international (8 papers) and national (2 papers) conferences, 6 scientific articles were published in the journals listed in Thomson-Reuters database Web of Science Core Collection; PhD student Andrius Tamošiūnas defended his dissertation ***Investigation of Thermo-Hydro-Dynamic Processes in Water Steam Plasma and Its Application for Organic Waste Treatment*** and obtained a doctoral degree.

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CENTER for HYDROGEN ENERGY TECHNOLOGIES

MAIN RESEARCH AREAS OF THE CENTER:

- research in the field of hydrogen energy technologies:
  - synthesis of hydrogen separation membranes and analysis of their properties;
  - synthesis hydrogen production using water reactions with metals and nanoparticles of their alloys;
  - synthesis and analysis of properties of metals and their alloy hydrides designed for hydrogen storage;
  - synthesis of hydrogen fuel cell elements anodes/electrolytes/cathodes applying physical vapour deposition methods;
  - analysis of materials properties used for NiMH battery electrodes.

In 2014 state funded project ***Synthesis and characterization of Mg-Ti metal hydrides designed for energy storage*** was completed. Main issues limiting the application of metal alloys are related to hydrogenation/dehydrogenation process. Presently metal alloys intended for hydrogen storage are widely used. They are formed using chemical technologies. During hydrogenation process of the obtained alloys, hydrogen pressure reaches up to 10 MPa, and dehydrogenation occurs at the temperature up to 500 °C.

The main objective of this work is to discover metastable phases of magnesium hydride, destabilized using titanium additives, where a material efficiently adsorbs/desorbs hydrogen. The main originality of the work is to synthesize $MgTiH_{16}$ thin layer structures by using magnetron sputtering technologies and complex hydrogenation of materials in plasma and high pressure and temperature. It was observed that after hydrogenation by plasma ion implantation, the increase of all crystalline lattice parameters of magnesium – titanium samples is observed, which occurs due to internal stress between the formed coating and quartz substrate.

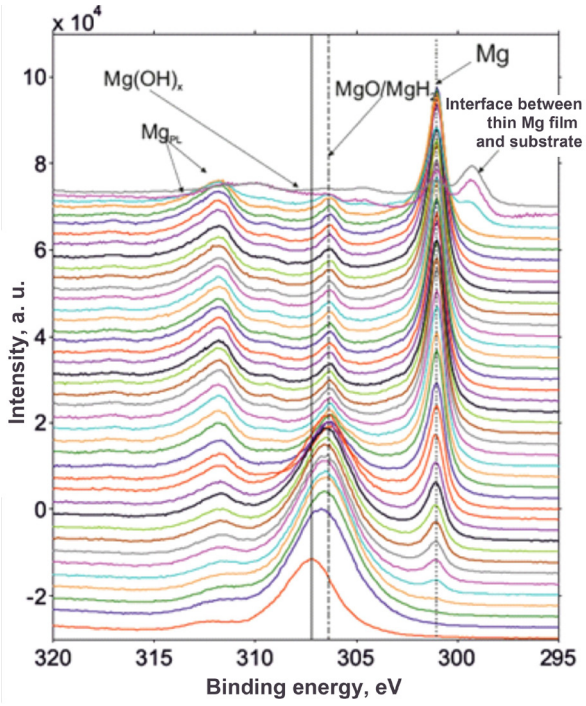


Figure 1. XPS spectra of in-situ hydrogenated magnesium surface coatings in hydrogen plasma

However, even in this way formed films during its hydrogenation maintains crystalline shape. During the process of hydrogenation in hydrogen plasma, metal Mg-Ti films is only saturated with hydrogen, but only a small part of the material is transformed from metal into crystalline hydride phase; therefore, we believe that this model of hydrogenation process is not efficient, forming compounds of magnesium – titanium hydride on quartz substrate. One of the main findings of the work is related to the experimental fact that in the process of plasma hydrogenation of pure Mg, if after the synthesis the sample is not taken out of the vacuum chamber, and the hydrogenation is performed in *in situ* mode, a significant increase of the amount of obtained crystalline hydride phase is observed (Figure 1). It is probable that the equivalent results would be obtained also in the case of thin Mg-Ti coating using *in situ* hydrogenation approach.

In co-operation with professors and students of the Department of Physics at Vytautas Magnus University (VDU) and the Department of Physics at Kaunas University of Technology (KTU), the established Center for Hydrogen Energy Technologies accumulates equipment necessary for the research, allows teachers at the Department of Physics at Vytautas Magnus University and at the Department of Physics at Kaunas University of Technology use modern educational aids, prepare highly qualified specialists (including all study levels) and develop competitive research. It is equally important that LEI has become a powerful center of attraction for young researchers (Figure 2).

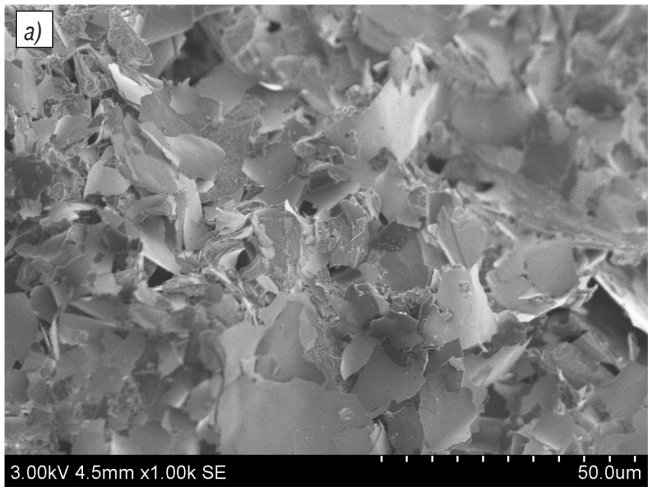
Figure 2. Students from Kaunas city universities are frequent guests of Center for Hydrogen Energy Technologies

In 2014 the researchers of the Center actively participated in the research of group 32 *Hydrogen based energy storage* of International Energy Agency Hydrogen Implementation Agreement (IEA HIA) and in the activities of EU COST program MP 1103: *Nanostructured materials for solid-state hydrogen storage*. In these works, chemical destabilization of metals and their alloy hydrides is carried out by introducing new elements into materials, which form intermediate derivatives during hydride decomposition, thus preventing the system from relaxing to the lowest energy state or form a destabilized hydride during hydrogenation.

In 2014 the researchers of the Center continued working on the Project ***Modification of properties of polystyrene foam surface by means of nanocrystalline oxide coatings*** (NANOPUTPLAST; Agreement No. VP1-3.1-ŠMM-10-V-02-019). During the research, two technologies were developed, and two patent applications were submitted to the Patent Bureau of Lithuania:

1. Synthesis of nanocrystalline clusters on water-soluble substances by means of magnetron sputtering method (Figure 3). Application number LT2014 509;

2. Protection of polymer material surfaces the use of nanocrystalline oxide coatings (Figure 4). Application number LT2014 510.



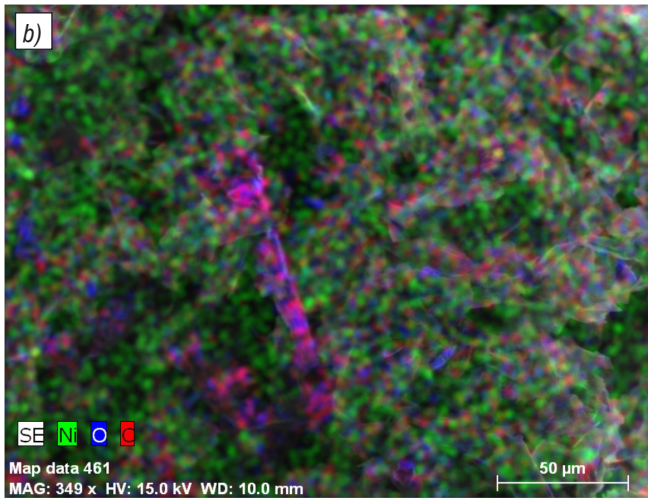


Figure 3. Ni clusters obtained on water-soluble substances (a); elemental map (b)

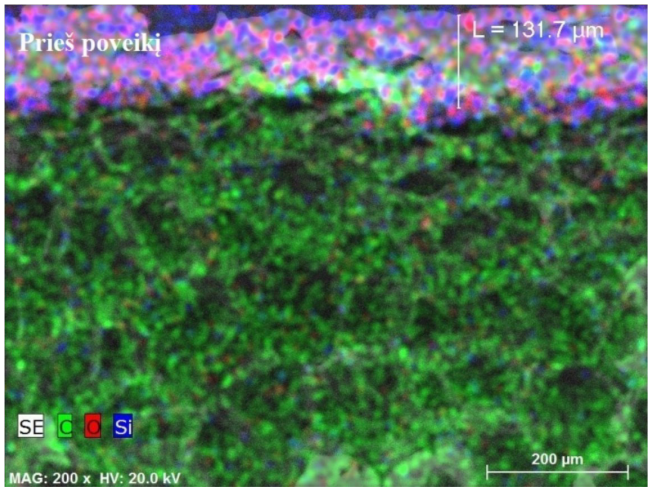


Figure 4. Nanocrystalline SiO_2 coating on the surface of polystyrene foam

In 2014 the researches of the Center published three research articles in journals listed in *Web of Science Core Collection* in *Thomson-Reuters* database and presented five papers at the international conferences.

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LABORATORY of NUCLEAR ENGINEERING

MAIN RESEARCH AREAS OF THE LABORATORY:

- investigation of thermal processes in energy equipment components:
  - research of heat and mass transport in the equipment of biofuel-fired objects; reduction of emission along with flue gases resulting from biofuel combustion using electrostatic precipitators;
  - forced and mixed convection, turbulent and transition flow regimes, one and two-phase flows, influence of channel geometry, variable physical properties, roughness, effect of transient conditions and centrifugal forces;
  - numerical modelling of heat transfer and transport processes in various channels and geological structures;
- safety of spent nuclear fuel (SNF) management: modelling of fuel characteristics, safety and environmental impact assessment of storage and disposal facilities, normative and legislative base;
- safety of radioactive waste management: strategy, safety and environmental impact assessments of treatment technologies and storage and disposal facilities, normative and legislative base;
- evaluation of different factors related to decommissioning of nuclear power plants: planning and cost of decommissioning and dismantling; radiological characterization of the area, buildings, systems and equipment; safety and environmental impact assessment of individual facilities; normative and legislative base;
- assessment of fire hazard at nuclear power plants and other important facilities;
- research related to construction of the new nuclear power plant in Lithuania.

Researchers of Nuclear Engineering Laboratory together with other laboratories of the Institute coordinate and implement two long-term scientific research and experimental development programmes, which were approved by the Ministry of Education and Science of the Republic of Lithuania in early 2012:

MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF LITHUANIA

- ***Investigation of single-phase and two-phase flow dynamics, heat and mass transfer processes (2012–2016).*** The objective of the programme is to develop research methods and perform investigations of single-phase and two-phase flow structure, heat and mass transfer regularities in dealing with the efficiency of new heat energy production from biofuel schemes, energy and mass flow measurement and heat and mass transfer intensification tasks under transient flow conditions, flow in transition region, impact of physical features and buoyancy forces and vapor condensation processes.
- ***Investigation of nuclear power plant decommissioning and nuclear waste and spent fuel management processes and radiation impact analysis***

(2012–2016). The objective of the programme is by applying numerical and experimental research methods and taking into account the peculiarities of Ignalina NPP decommissioning processes to analyze and estimate radiation impact on humans and environment during management, storage and disposal of SNF and radioactive waste.

RESEARCH OF THERMAL PROCESSES IN ENERGY EQUIPMENT COMPONENTS

Biofuel is rather widely used in many countries for heat and electric power production. It (wood, straw, grain, etc.) is considered a renewable energy source, causing the least environmental impact; this is why its consumption increases not only in the newly built, but also in the reconstructed boiler houses in Lithuania. However, one of the major drawbacks comparing biofuel combustion to gas or liquid fuel combustion is quite large release of solid particles into the environment. With the growing number of devices burning biofuel, the emission of solid particles increases. Due to the harmful impact to the human health, the amount of solid particles in the flue gas of the combustion devices is limited, i.e., various filters that capture these solid particles are installed. The efficiency of cyclone and other mechanical devices capturing solid particles usually used in Lithuania is too small for capturing small particles streaming with the flue gas; by means of electrostatic precipitators, very high efficiency of gas (flue gas) cleaning can be achieved. While burning fuel, different sizes of solid particles are emitted, and the composition of flue gas changes; due to this, the efficiency of electrostatic precipitators changes. An exhaustive analysis of these factors enables solving relevant issues related to upgrading technologies in the Lithuanian energy sector.

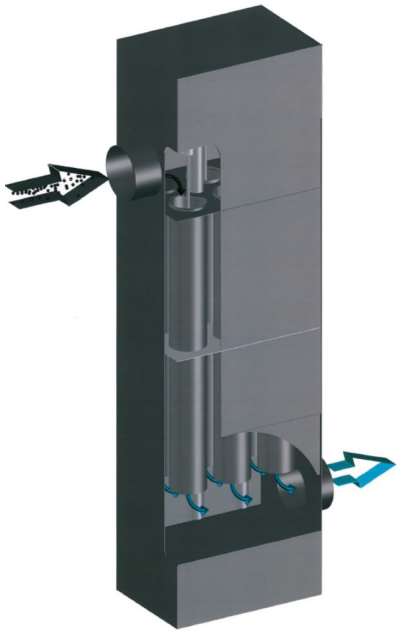
Research Council of Lithuania

Researchers of the Laboratory in the frame of the project ***Research of local fuel thermal decomposition processes by developing efficient and ecological technologies (2012–2014)***, financed by national research programme *Future Energy* of the Research Council of Lithuania together with other laboratories of the Institute conducted investigations on cleaning flue gas. During the project, an experimental device was manufactured, and preliminary research was performed. A prototype of the electrostatic precipitator manufactured at the Laboratory was used for the research. Relative concentration of the particles was determined taking into consideration the voltage supplied to the electrostatic precipitator when discharge electrode is positive or negative. The conducted research enabled to determine the efficiency of the electrostatic precipitator.

Mokslas · Ekonomika · Sanglauda
Europos Sąjunga
Europos socialinis fondas
Kuriame Lietuvos ateitį

Researchers of the Laboratory together with other laboratories of the Institute also implement another project ***Development of Innovative Thermal Decomposition Technology and its Application for Utilization of Sewage Sludge (2013–2015)*** based on the measure of the third priority ***Strengthening capacities of researchers Promotion of High International Level Scientific Research*** of the program for the Development of the action of human resources approved by the Ministry of Education and Science. Sewage sludge is retrieved as waste in Lithuanian wastewater treatment enterprises. While the infrastructure of wastewater collection and treatment expands, the amount of sludge generated during wastewater treatment increases proportionally. Huge amounts of sludge stored in sludge sites begin to evoke hazard for the environment and contradict to sustainable development principles. Therefore, the most effective methods are searched to treat wastewater sludge. One of the most innovative methods for utilization of waste sludge is its gasification. Applying this technology, a valuable product is released from sludge during thermal decomposition – flammable gas, which may be used in heat and electricity production. Gasification enables to reduce not only the volume of the generated sludge and obtain additional energy, but also to reduce the environmental pollution. During the project, it is planned to develop a pilot prototype of gasification process-technology of up to 100 kW, which will be highly promoted to attract possible Lithuanian and/or foreign investors interested in commercial size operating technology, applicable for utilization of sludge generated in small towns of Lithuania.

In 2014, during implementation of this project, an experimental research of flue gas purification was performed. The research results demonstrated that when burning biofuel (wood pellets), the most part of solid particles with diameters ranging from $\sim 0.4\,\mu$m to $\sim 15\,\mu$m dominate in untreated flue gases. The largest amount of particles is with the diameter up to $\sim 4\,\mu$m. Solid particles from flue gases are cleaned using electrostatic precipitator. When the voltage applied to the precipitator was 12 kV, the obtained results showed that the decrease of concentration of solid particles



Prototype of electrostatic precipitator manufactured at the Laboratory

was ~99%. During gasification of biofuel pellets, concentration of solid particles is greater; moreover, the combustion process and its control process are more complicated; this is why the decrease of particle concentration using the electrostatic precipitator was ~85%.

The Laboratory also carries out investigations on heat transfer and hydrodynamics in energy equipment for different purposes (in elements of nuclear reactors, various heat exchangers, etc.). In both laminar and turbulent flow cases, surface roughness, centrifugal and buoyancy forces (mixed convection) can impact heat transfer in many energy installations, which under certain conditions can become a reason for an accident in different installations. Therefore, in order to analyze such problems in depth, the laboratory performs experimental mixed convection investigations in various channels. In parallel, numerical investigation is also performed using ANSYS CFD code (ANSYS, USA), which is widely applied in the world for modeling fluid movement and heat transfer in complex two and three-dimensional systems. Taking into consideration the flow mode, various models of laminar, transitional and turbulent transfer are used. Additionally, such research was initiated in geological structures while analyzing the possibilities of Ignalina NPP spent nuclear fuel disposal.

In 2012, the Laboratory participated in activity of the project ***Santaka Valley*** by the open access scientific research and experimental development (R&D) centre obtained LDA and PIV equipment, designed to investigate flow structure in gas and liquids in wide range of velocity variation. This equipment can measure flow velocities, pulsations, and vortex rotational frequencies, and it can visualize them, etc. Furthermore, the Laboratory obtained liquid crystal thermography equipment enabling to measure temperature of various objects and variation of temperature of an individual visual part of the analyzed object in a remote non-invasive way.

In 2013, according to the European Union structural fund support measure ***Innovation Vouchers LT*** administered by the Agency for Science, Innovation and Technology, researchers of the Laboratory improved the efficiency of JSC Wilara beebread dryer. After experimental research and numeric modeling of air flow distribution, non-uniformity of drying airflow was resolved.

In 2014, fundamental experimental and numerical research of mixed convection heat transfer and flow structure in flat channel in turbulent and transitional flow areas applying ANSYS CFD (USA) software continued.

RESEARCH ON SAFETY OF SPENT NUCLEAR FUEL MANAGEMENT

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

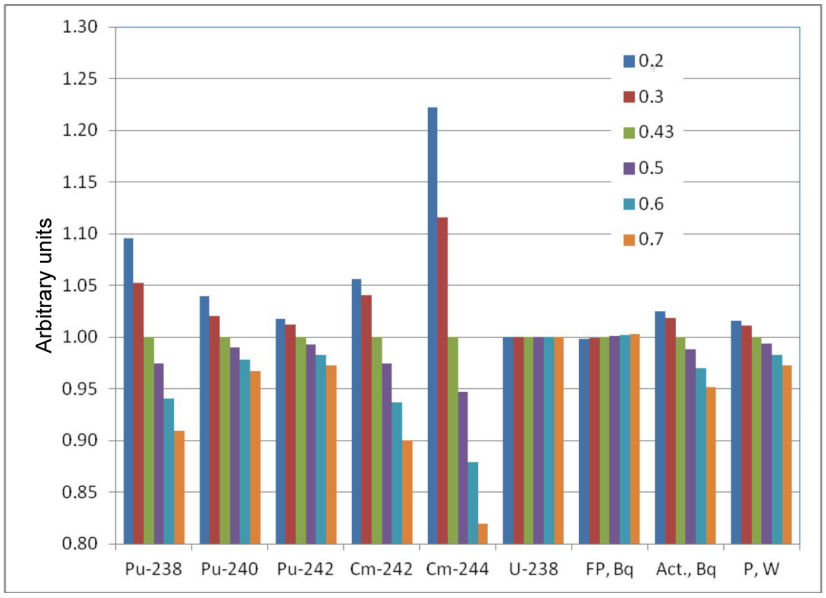
Implementing the research on SNF disposal in Lithuania, the Laboratory experts with the assistance of Swedish experts proposed the concepts of a deep geological repository in clay and in crystalline rocks for SNF and long-lived intermediate level waste in Lithuania. The concepts on disposal are constantly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

The Laboratory together with consortium GNS – NUKEM Technologies GmbH (Germany) implements an extensive project ***Design and Installation of the Interim Storage Facility for RBMK Spent Nuclear Fuel Assemblies from Ignalina NPP Units 1 and 2*** (2005–2015). This project comprises the analysis of all activities related to the design, construction, installation, commissioning, operation and decommissioning of the new SNF storage facility and the performance of all necessary works related to SNF removal, packaging, sealing and transfer as well as operation of the appropriate equipment for implementation of chosen design concept. It is planned to store approximately 200 new type CONSTOR casks with intact and damaged SNF in the new storage facility. Researchers of the Laboratory prepare Environmental Impact Assessment and Safety Analysis Reports of this SNF storage facility (opera-

tional time no less than 50 years) and offer support in licensing the storage facility. In 2007, *Environmental Impact Assessment Report* was approved by the Ministry of Environment; in 2009, *Preliminary Safety Analysis Report* (PSAR) was prepared and agreed upon, and the license for construction of the new SNF storage facility was issued by VATESI. In 2010–2011, PSAR Addendum, which presents the evaluation of safety aspects of damaged RBMK-1500 nuclear fuel assemblies management and storage, was prepared. In 2014, taking into consideration certain changes to the technical design made during construction works of SNF storage facility, the *Updated Safety Analysis Report* was prepared, and according to VATESI comments, PSAR Addendum, related to management of damaged SNF assemblies, was revised.

In 2014, scientific study financed by the budget subsidies ***Integrated research on generation of radioactive contamination, its impact and migration upon termination of RBMK-1500 reactor operation and storage and disposal of radioactive waste*** (2013–2015) continued. In this study, the researchers of the laboratory by means of numerical methods evaluated the way the nuclide content of the RBMK spent nuclear fuel, radiation characteristics, dissipation of residual heat in the long-term storage change, and the way these parameters depend on the load of the reactor, density of coolant and cross-section libraries used in modeling. This assessment is important for estimating the impact of ionizing radiation on the environment and ensuring safe operation of SNF storage facilities. Fuel with different U-235 enrichments was used during Ignalina NPP operation; however, as the assessments of gamma and neutron emission spectra reveal, the initial fuel enrichment has insignificant influence on the radiation characteristics.

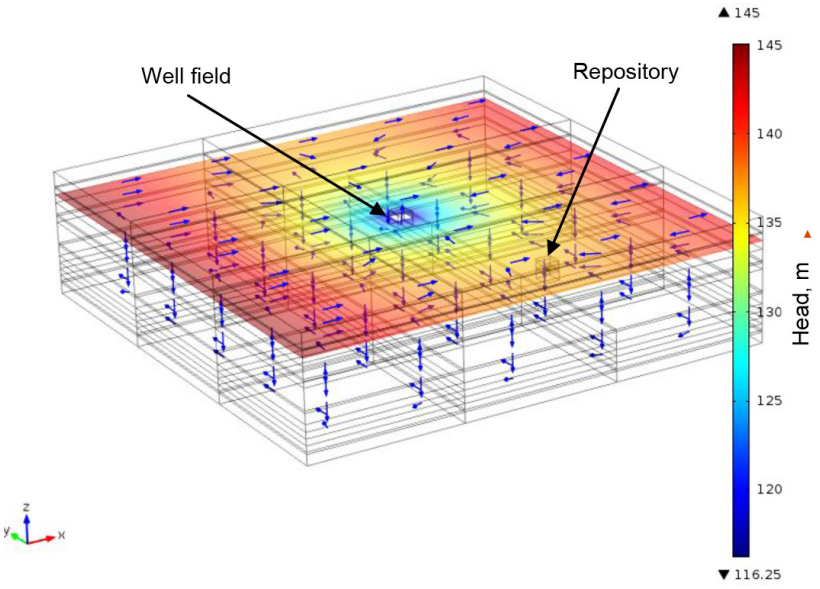
Moreover, this scientific research financed by the budget subsidies continued



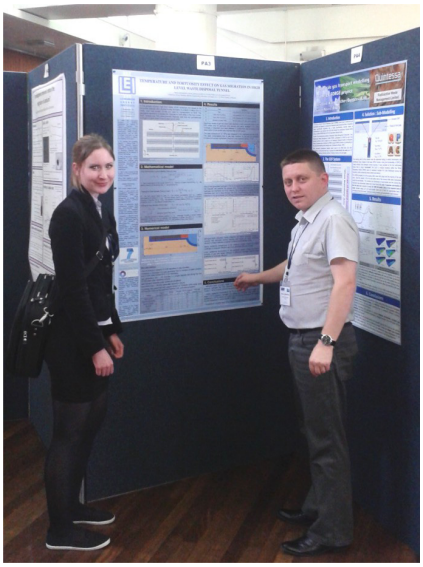
Dependence of characteristics of RBMK-1500 fuel assemblies on the density of coolant

the study of radionuclides, gas and heat migration in engineering and natural barriers of geological repositories. Taking into consideration the geological conditions of the Ignalina NPP region, conceptual and numerical models for groundwater flow and radionuclide transport in geological repository implemented in crystalline rocks were developed. After the assessment of the influence of natural barrier properties on the radionuclide I-129 migration, it was determined that the uncertainty of hydraulic conductivity had a more significant impact on radionuclide concentration than the uncertainty of diffusion coefficient and porosity.

After the assessment of gas migration in the module of a geological repository, situated in clay formation, it was determined that engineering interfaces, tunnel filling material and excavation disturbed zone (EDZ) are the main migration and accumulation materials of gaseous hydrogen generated due to corrosion of steel SNF



Groundwater flow directions in the Ignalina NPP region assessing radionuclide release from geological repository (using software COMSOL)



Dr. D. Grigaliūnienė and Dr. D. Justinavičius present the results of the research at the international conference GEODISPOSAL (24–26 June 2014, Manchester, the United Kingdom)

containers. The sensitivity analysis that evaluated the influence of characteristics of engineering interfaces on gas migration showed that the maximum gas pressure in the module (in cases of reference and local sensitivity analysis) did not exceed the lithostatic (geological environment) pressure at a depth of 500 meters, thus it is not sufficient to disturb mechanical stability and functionality of the system of engineering barriers.

In 2014, the researcher of the Laboratory participated in a workshop in Sweden, where scientists from countries (France, Finland, Sweden, and Switzerland) with more advanced programmes in the field of geological disposal presented the concepts of their repositories, shared practical experience and challenges, arising during construction of underground tunnels of geological repositories for disposal of SNF. The seminar participants also visited Swedish SNF interim storage facility, copper SNF container plant in Oskarshamn, and Äspö underground research laboratory, situated in crystalline basement at the depth of 450 m under the Baltic Sea.

In 2014, researchers of the Laboratory also participated in the IAEA Technical meeting on *Understanding and Establishing an Adequate Engagement Process with the Relevant Stakeholders in Pursuing a Geological Disposal Programme* in Vienna (Austria) called to establish cooperation ties with the interested parties.

Researchers of the Laboratory use software code SCALE (USA) for modeling fuel characteristics (assessment of criticality), for assessment of nuclide content of spent nuclear fuel and evolution. PETRASIM (USA) and GOLDSIM (USA) software tools are used for assessment of safety of radioactive waste repositories. Using this software, modeling of radionuclide/gas transfer (one-phase/two-phase flow) in porous and fractured medium is performed. Software codes COMSOL (USA) and COMPASS (GRC, the United Kingdom) are used for evaluation of influence of thermal-hydro-mechanical and chemical processes on groundwater migration in geotechnical environments.

SAFETY RESEARCH OF RADIOACTIVE WASTE MANAGEMENT

Since 1994, the Laboratory has been actively involved in the analysis

Dr. D. Justinavičius with the participants of the workshop on the construction of geological repositories (13–14 May 2014, Oskarshamn, Sweden)

of the radioactive waste management problems at the Ignalina NPP. Laboratory experts together with the experts from SKB International (Sweden) carried out several projects, which assessed the existing Ignalina NNP waste storage facilities and the possibilities to transform them into repositories.

In 2002, the Laboratory together with Framatome ANP GmbH (Germany) participated in performing the environmental impact and safety assessments for the Ignalina NPP cement solidification facility and the interim solidified radioactive waste storage facility.

In 2004–2005, together with French companies Thales Engineering and Consulting, ANDRA and the Institute of Physics, PHARE project ***Safety Assessment and Upgrading of Maišiagala Repository*** in Lithuania was implemented. The Laboratory specialists participated in preparing Safety Analysis Report, developed the database containing information on radioactive waste, which is stored in the Maišiagala storage facility, and performed a comprehensive nuclide composition analysis.

In 2002–2005, a great deal of attention was given to the siting of a new near-surface repository for radioactive waste in Lithuania, scientific research related to the radionuclide migration from radioactive waste repositories and its impact on safety. With the assistance of Swedish experts, researchers of the Laboratory determined the criteria for choosing a near-surface repository site, improved the reference design of a near-surface repository and prepared the implementation programme. The impact of *heterogeneous* (uneven) waste activity distribution on radionuclide migration from model near-surface repository was investigated.

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

In 2008–2013, the Laboratory, as a partner of Lithuanian consortium (JSC *Specialus montažas-NTP*, LEI, SC *Pramprojektas*, JSC *Vilstata*) implemented the project ***Installation of Very Low Level Radioactive Waste Repository (Landfill)***. *Landfill* repository is intended for disposal of very low-level radioactive waste generated during Ignalina NPP operation and decommissioning. The entire *Landfill* facility will be comprised of three repository modules and a buffer storage, where waste will be stored until its disposal. In 2009–2013, researchers of the Laboratory prepared *An Environmental Impact Assessment Report* for the planned economic activity, two preliminary safety analysis reports (for the buffer storage and the waste disposal units), two general data sets, the final safety analysis report and the waste package description of the radioactive waste packages intended for disposal.

In 2014, the Laboratory together with NUKEM Technologies GmbH (Germany) continued implementing the project ***New Ignalina NPP Solid Waste Management and Storage Facility*** (2006–2015). This facility is intended for solid radioactive waste retrieval, sorting, transportation, treatment (following envisaged technologies), packaging, characterization and storage. The entire facility will be comprised of several facilities located at two sites: the solid waste retrieval facility at the existing Ignalina NPP solid waste storage buildings, and the new facility located nearby INPP for solid waste treatment and storage. In 2008, *Environmental Impact Assessment Report* was agreed upon and approved at the Ministry of Environment. Also, two Preliminary Safety Analysis Reports (PSARs) were prepared: *New Solid Waste Treatment and Storage Facility at Ignalina NPP* and *New Solid Waste Retrieval Facility at Ignalina NPP*. The first PSAR was approved in 2009, and VATESI issued a license for the construction of the storage facility. In 2009, two more PSARs *New Solid Waste Retrieval Facility for Retrieval Unit 1 and Retrieval Units 2–3 at Ignalina NPP* were prepared. In 2010, both PSARs were submitted to the institutions for review. The first PSAR was updated following the recommendations by the institutions, and at the end of 2010 was approved by VATESI, while in the middle of 2011, the permission to build the facility was received. In 2011–2014, the second PSAR was updated considering the recommendations of the institutions. In the late 2014, VATESI approved documents justifying safety for *Waste Retrieval Units 2–3*. An updated PSAR is currently prepared for release. In 2017–2018, the *Final Safety Analysis Report* will be prepared.

In 2014, the Laboratory together with partners from French companies *AREVA TA* and *ANDRA* and Lithuanian partners JSC *Specialus montažas-NTP* and *Pramprojektas* continued the project ***Low and Intermediate-Level Short-Lived Radioactive Waste Near-Surface Repository (Design)*** (2009–2015). The repository is intended for disposal of low and intermediate-level short-lived radioactive waste generated during Ignalina NPP operation and decommissioning. In 2010–2011, the specialists of the Laboratory made a considerable contribution to the preparation of Design Options Report, Waste Inventory Report and Site Revalidation Report, which were submitted to the Contractor and approved. In 2012, Basic Engineering Design Report for ***Low and***

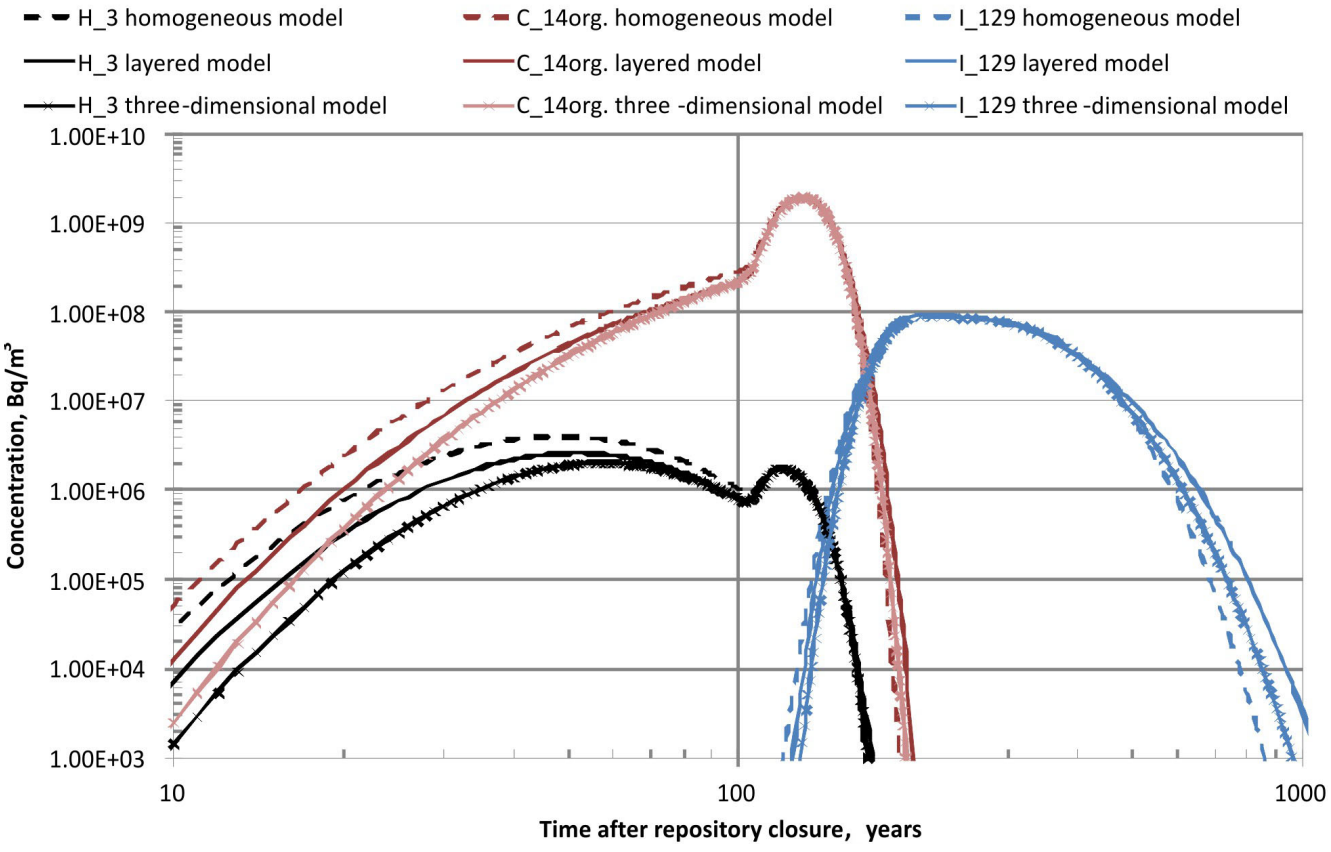
intermediate-level short-lived radioactive waste near-surface repository was prepared and submitted. For this report, the experts of the Laboratory prepared four chapters: waste inventory, long-term safety assessment, waste acceptance criteria and waste package specification as well as environment monitoring and surveillance overview. In 2014, researchers of the Laboratory finished the preparation of the preliminary safety analysis report and submitted it to the Customer. The conducted safety assessment covers the operational period and long-term safety (period after closure of the repository). In 2014, repository environment monitoring program was prepared and submitted to the Customer.

In 2014, researchers of the Laboratory began the Strategic Environmental Impact Assessment (SEIA) of the project of Development Programme for Radioactive Waste Management that is prepared by Radioactive Waste Management Agency (RATA). SEIA report establishes, characterizes and evaluates the possible significant consequences of the implementation of Development Programme for the environment, including spent nuclear fuel and radioactive waste management. In 2015, a public introduction to the Development Programme for Radioactive Waste Management and SEIA Report will take place, the society and responsible state institutions will be consulted.

In 2014, researchers of the Laboratory continued the scientific research financed by the budget subsides, in which they performed investigations of impact of waste zone inhomogeneity evaluating radionuclide migration from the near surface radioactive waste repository. For this purpose, three models of waste zones with various complexities were created: homogenous, layered and three-dimensional.

The results of the investigation revealed that assessing migration of short-lived radionuclides, the homogenous model is very conservative (an increased impact of radionuclides is obtained). Therefore, in order to optimize the repository design and still preserve the necessary safety level, more complex models of waste zone should be used.

Researchers of the Laboratory use software AMBER for modeling migration of radioactive and non-radioactive contaminants in the environment (Quintessa, the United Kingdom). For the analysis of contamination of environment due to constant or one-time release of radionuclides into the atmosphere, surface water and soil or their initial contamination and calculation of human received doses software code GENII (PNNL, USA) is used. Software codes GWSCREEN (INEEL, USA) and DUST (BNL, USA) are used to assess the leaching of radionuclides from a surface type radioactive waste storage. For modeling water balance,



Comparison of volumetric concentrations of leached radionuclides below the repository

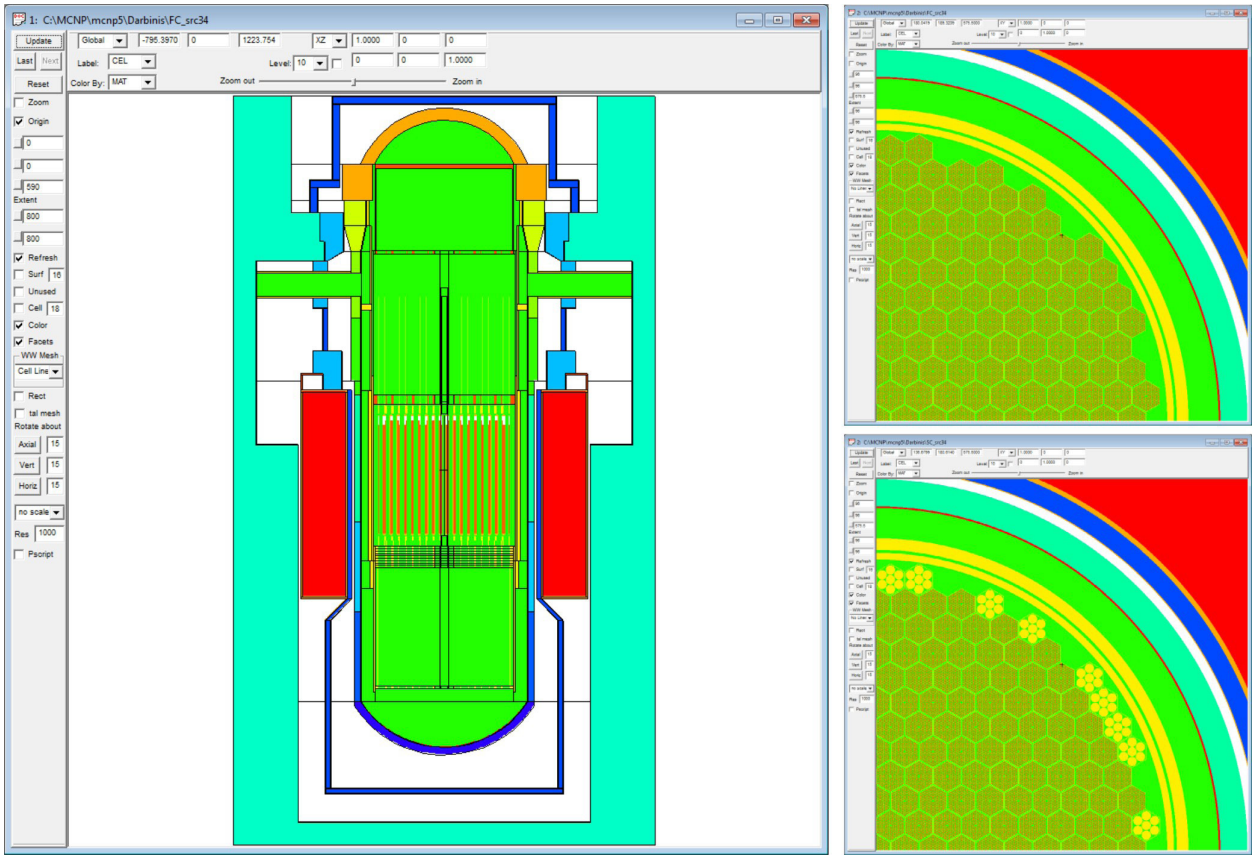
forecasting underground water level, evaluating scenarios of climatic change software GARDENIA (BRGM, France) is used. Geochemical research is being carried out using software EQ3/6 (Lawrence Livermore National Laboratory, USA) that enables to compile models for the assessment of chemical processes taking place in the analyzed water/solid phase systems, designed for modeling chemical changes of contaminants (radionuclides), solubility and sorption in water/solid phase systems.

EVALUATION OF DIFFERENT FACTORS RELATED TO DECOMMISSIONING OF NUCLEAR POWER PLANTS

Back in 1998, researchers of the Laboratory initiated research related to Ignalina NPP decommissioning. Our experts participated in PHARE project preparing ***The Preliminary Ignalina NPP Decommissioning Plan*** as well as ***The Final Ignalina NPP Decommissioning Plan***. In 2004, researchers of the Laboratory, in accordance with the order of the Ministry of Economy of the Republic of Lithuania prepared projects for Ignalina NPP decommissioning programme and its implementation measures plan for 2005–2009. In 2005–2008, in cooperation with the Institute of Physics the project ***Development of Radiological Characterization Programme for Equipment and Installations at Ignalina NPP*** was implemented.

Since 2007, Nuclear Engineering Laboratory has actively participated in Ignalina NPP dismantling projects. The Lithuanian Energy Institute, as a partner of consortium Babcock (former VT Nuclear Services Ltd) (the United Kingdom) – LEI – NUKEM Technologies GmbH (Germany), implemented the project ***Ignalina NPP Building 117/1 Equipment Decontamination and Dismantling*** (2007–2010). With the same partners, was implemented the project ***Ignalina NPP Building V1 Equipment Decontamination and Dismantling*** (2009–2012).

In 2009, specialists of the Laboratory prepared and coordinated with the institutions the *Environmental Impact Assessment Report*; in 2010, *General data collection on waste disposal* was prepared. Specialists of the Laboratory participated during preparation of the *Basic design*, which, in 2010, was coordinated and transferred to the Customer, and *Detail design* and *Safety justification*, which were coordinated with the institutions. Researchers of the Laboratory analyzed the equipment in Building 117/1, the amount of accumulated waste and their characteristics and carried out the assessment of the planned economic dismantling and decontamination activity. On 1 December 2010, employees of the Ignalina NPP, based on the prepared documentation, began dismantling and decontamination



VVER-440 reactor model developed by MCNP computer program

of the equipment in Building 117/1, which were completed in October 2011.

Researchers of LEI Nuclear Engineering Laboratory, as partners of consortium *Babcock* (the United Kingdom) – LEI – NUKEM Technologies GmbH (Germany), also implemented the project ***Ignalina NPP Building V1 Equipment Decontamination and Dismantling*** (2009–2012). In 2010, specialists of the Laboratory finished preparation of *General data collection on waste disposal*. In 2011, specialists of the Laboratory prepared and coordinated with the Ministry of Environment *The Environmental Impact Assessment Report*. In 2012, *Basic design* and *Safety justification* were coordinated, and *Detail design* was submitted to the Customer. In 2012, employees of the Ignalina NPP, based on the prepared documentation, began dismantling and decontamination works of the equipment in Building V1. At the end of 2013, dismantling stage D1 was completed, during which about 640 tons of equipment were dismantled. During 2023–2028, it is planned to implement dismantling stage D2 of Building V1.

In 2014, Laboratory of Nuclear Engineering, as a partner of international consortium (JSC *Specialus montažas*-NTP – FTMC – LEI – ATP (Bulgaria) – INRNE (Bulgaria) – VNIIAES (Russia) continued the project ***The Evaluation of the Material Backlog and Radiological Inventory of Kozloduy NPP Units 1 to 4 (2012–2015)***. The objective of the project is to carry out a detailed evaluation of the radiological status of the equipment, structures, compartments and the radioactive waste and assess the total radiological inventory and material backlog of the Kozloduy (Bulgaria) NPP Units 1–4 (WWER). In 2014, main tasks performed by the experts of the Laboratory included neutron activation and dose rates verification calculations for the structures of Unit 3 WWER-440 reactor.

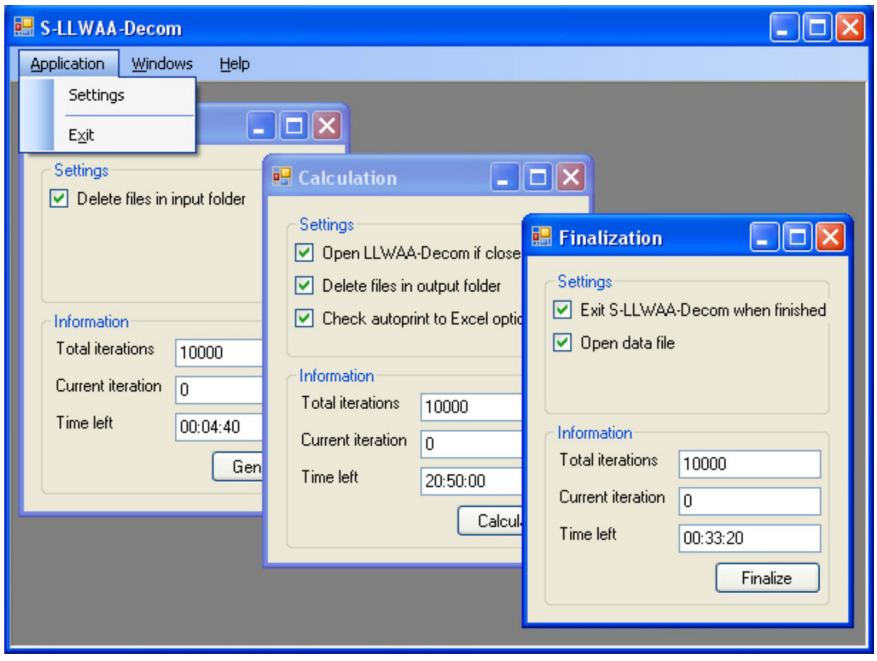
In 2014, researchers of the Laboratory further improved their developed software code DECRAD. The main objective of application of software code DECRAD is to assess the cost and expenses of dismantling and decontamination works, estimate labour requirements, calculate radiation doses received by personnel, plan the quantity and activity of the accumulated radioactive waste, assess the number of packages and other parameters related to decommissioning of nuclear facilities. This software code can be applied toplanning and analysis of decommissioning works for various nuclear facilities and individual buildings or units. Also, using DECRAD software a *Multi-criteria Decision Analysis* may be performed. The AHP *(Analytic Hierarchy Process)* method used in parallel with the DECRAD programme is one of the most relevant methods for selecting the alternatives for dismantling nuclear facilities.

In 2014, DECRAD-ACT program (developed in 2013) was further improved; it expands the functionality of DECRAD and is designed for collecting and processing data on activated nuclear reactor components. This program is used in the abovementioned Kozloduy NPP project.

For the analysis of uncertainty and sensitivity of radioactive contamination results, caused by uncertainty of the input parameters, researchers of the Laboratory developed an extension model of LLWA-Decom program on .NET platform and an interface with MATLAB software. This system is used for the analysis of radiological contamination of Ignalina NPP systems.

In 2014, researchers of the Laboratory continued the research work financed by the budget subsidies, the objective of which is by applying modern numerical research methods to assess and specify characteristics of radioactive waste, resulting from decommissioning and dismantling of RBMK reactors, determining the selection of waste treatment methods, engineering structures of handling and storage facilities and repositories, and to perform integrated analysis of radioactive exposure of personnel and population due to ionizing radiation caused by radioactive waste and spent nuclear fuel.

In 2014, researchers of the Laboratory carried on the IAEA coordinated project ***Data Analysis and Collection for Costing of Research Reactor Decommissioning (DACCORD)*** (2012–2015). The objective of this project is to present



Expansion model of program LLWA-Decom and interface with MATLAB software

Junior researcher G. Poškas with other participants of the project DACCORD (24–28 November 2014, Vienna, Austria)

means, recommendations and assistance in preparation of the preliminary assessment of expenses for countries that are implementing or plan to implement dismantling of small nuclear facilities or experimental nuclear reactors.

Researchers of the Laboratory improved their competence in this field by participating at the international applied research workshop organized by the Ignalina NPP on the issues of decommissioning of uranium-graphite nuclear reactors (15–16 July 2014, Visaginas), training course *Assessment of occupational exposure due to intakes of radionuclides* organized by the IAEA (June 2–6, 2014, Athens, Greece), and regional workshop *Experiences in radiological characterization and activation calculations for decommissioning* organized by IAEA (15–19 December 2014, Visaginas (Ignalina NPP)).

Since 2002, the Laboratory has been carrying out fire safety assessment at nuclear power plants and other important facilities. Researchers of the Laboratory consulted by Swedish experts, assessed fire safety of the reactors of Unit 1 and Unit 2. Moreover, they assessed fire safety

Dr. E. Narkūnas and Dr. A. Šimonis with other participants of the applied research workshop in the central hall of the reactor of Unit 1 at Ignalina NPP (15–16 July 2014)

Dr. A. Šimonis with participants of the IAEA training course at the Greek Atomic Energy Commission (EEAE) (2–6 June 2014, Athens, Greece)

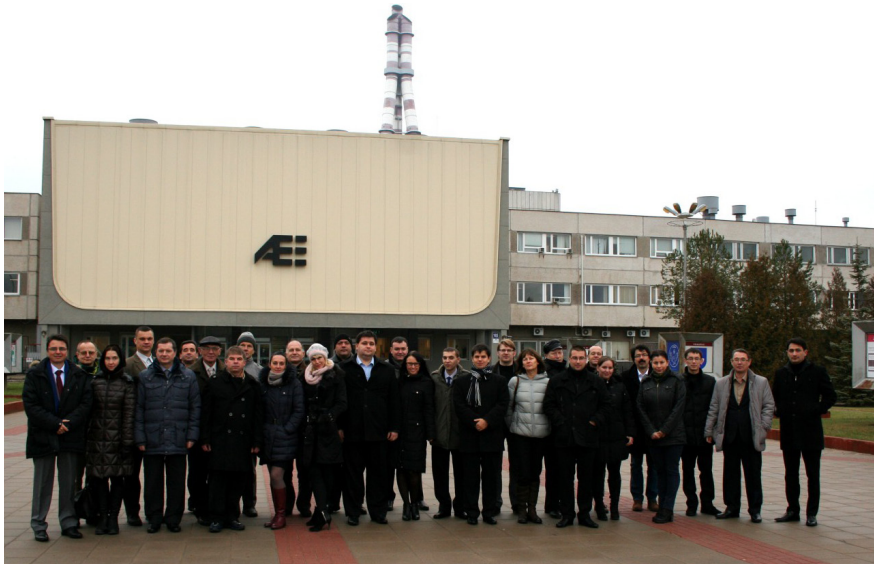
of some renewed Ignalina NPP rooms with changed designation and the newly designed Ignalina NPP SNF and radioactive waste storage facilities. An external fire impact on the new INPP Solid Waste Storage and Treatment Facility was assessed, and the analysis of fire hazard in the most dangerous areas in case of an internal fire in the facility was performed. In 2009, the impact of fire during the implementation of dismantling and decontamination of Ignalina NPP Building 117/1 was evaluated and fire safety of the newly designed buffer storage and disposal units of *Landfill* repository was assessed. In 2010, the impact of fire during the implementation of dismantling and decontamination of Ignalina Unit V1 was assessed. In 2012, based on Detail design documentation, the fire hazard impact in the very low level radioactive waste repository was estimated, and in 2014, during preparation of documents justifying safety of the low and intermediate level radioactive waste repository, fire hazard analysis of this facility was performed.

At the end of 2014, researchers of the Laboratory began implementing a research work ***Fire hazard analysis of bitumen radioactive waste storage facility*** (2014–2015), in which they will perform fire hazard analysis for the Ignalina NPP bitumen radioactive waste storage facility.

For modeling neutron, photon and electron (radiation) transport, researchers of the Laboratory use software code MCNP-MCNPX (Los Alamos National Laboratory, USA). The assessment of scattered gamma radiation emanating from various nuclear facilities (e.g., Radioactive Waste Storage and Disposal Facility, etc.) is carried out by software MicroSkyshine. Personnel effective doses are assessed by software VISIPLAN (SCK-CEN, Belgium) and MICROSHIELD (GroveSoftware, USA). Modelling of dispersion of contaminants emitted by various contamination sources is performed by AERMOD VIEW (Lakes Environmental Software, USA) software. Fire modelling is performed by software code PYROSIM (USA).

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

In 2007–2009, at the consortium, researchers of the Laboratory together with Pöyry Energy Oy (Finland) conducted research related to the construction of a new nuclear power plant in Lithuania. The *Environmental Impact Assessment Program for New Nuclear Power Plant* and *New Nuclear Power Plant Environmental Impact Assessment Report* were prepared. In the EIA Report, possible environmental impacts of the construction and operation of the new NPP were assessed in coop-



Dr. E. Narkūnas with participants of the IAEA regional workshop at the Ignalina NPP (15–19 December 2014)

Dr. A. Šmaižys at the IAEA Regional Workshop on Radiological Consequence Analysis (1–5 September 2014, Yerevan, Armenia)

eration with other Finish and Lithuanian institutions (Institute of Botany, Institute of Ecology and National Public Health Surveillance Laboratory). According to the EIA Report of 2009, positive conclusions of the competent authorities were made concerning the planed economic activity; therefore, following this EIA Report, the Ministry of Environment made a motivated decision on the construction possibilities of a new nuclear power plant in Lithuania.

In 2014, researcher of the Laboratory participated in the IAEA regional workshop *Radiological Consequences Analysis for Nuclear Power Plants and Power Units* that took place in Yerevan (Armenia), where issues related to the assessment of radiological consequences of beyond design basis and severe accidents were discussed. During the meeting, a presentation *Radiological Consequence Analysis in EIA Report of Planned New NPP in Lithuania* was given; the review of radiological impact of beyond design basis and severe accidents in Lithuania was presented.

Since 2008, researchers of the Laboratory have been actively participating in the European Union 7th Framework Programme funded scientific research and coordination and support activity projects. The following projects have already been implemented: ***Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste (CARBOWASTE)*** (2008–2013), ***Fate of Repository Gases (FORGE)*** (2009–2013), ***New MS Linking for an Advanced Cohesion in EURATOM Research (NEWLANCER)*** (2011–2013), ***Sustainable network of Independent Technical Expertise for radioactive waste disposal (SITEX)*** (2012–2013). In 2014, researchers of the Laboratory continued work in three EU 7th Framework Programme funded projects.

- ***CArbon-14 Source Term (CAST)*** (2013–2018). This project aims

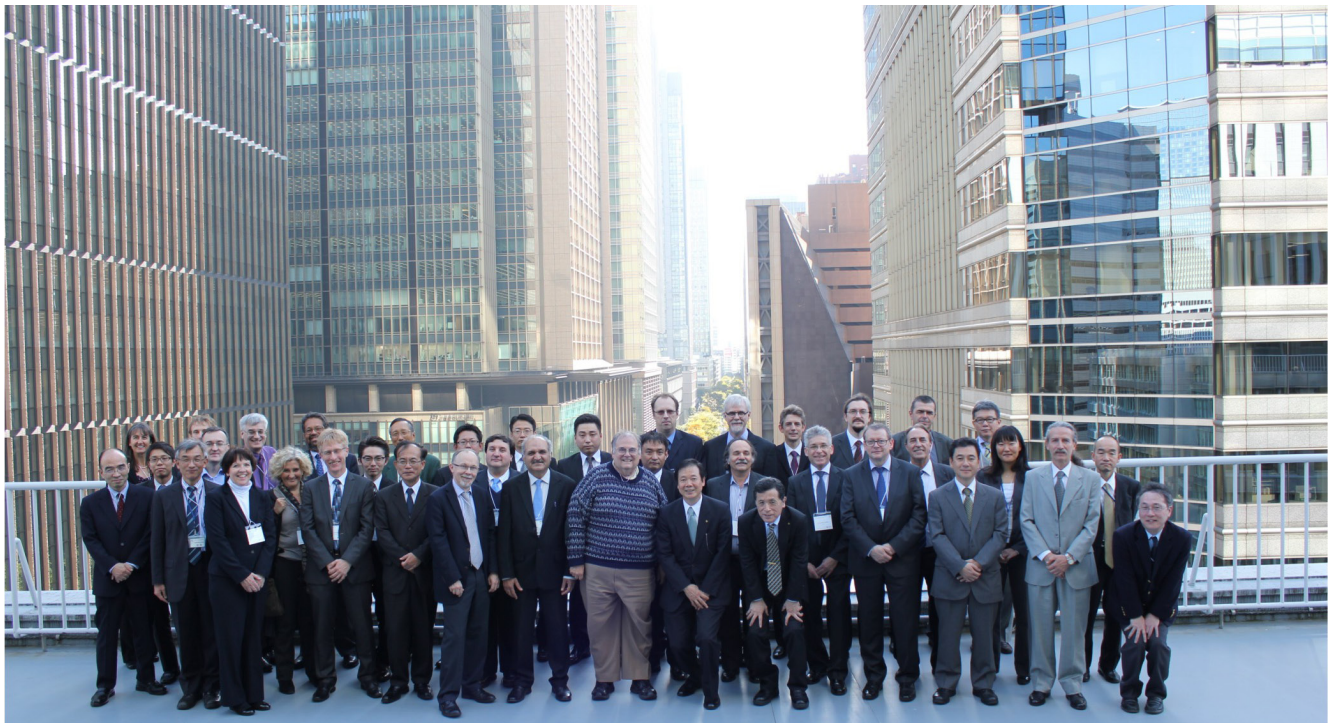
Dr. E. Narkūnas with participants of CAST project in the meeting in Brussels (21–22 October 2014, the Kingdom of Belgium)

to develop understanding of the generation and release of C-14 from radioactive waste materials under conditions relevant to waste packaging and disposal to underground geological disposal facilities. The project will focus on releases from irradiated metals, ion-exchange resins and graphite. The project is implemented by 33 partners from 12 EU countries and 3 non-EU countries. In 2014, information about radiocarbon inventory in and its releases from the reactor RBMK-1500 irradiated graphite and about evaluations of radiocarbon in safety analyzes in Lithuania was collected and systematised. In October 2014, researcher of the Laboratory also participated in the general assembly meeting of the CAST project in Brussels (the Kingdom of Belgium).

- ***Assessment of Regional Capabilities for New Reactors Development through an Integrated Approach (ARCADIA)*** (2013–2016). The objective of the project is to support and develop nuclear scientific research in new EU states related with the development of IV generation reactors, devoting the main attention to ALFRED (lead cooled reactor) demonstrator. The project is implemented by 26 partners from 14 EU states. Researchers of the Laboratory participate in this project together with the Laboratory of Nuclear Installation Safety.

- ***Building a platform for enhanced societal research related to nuclear energy in Central and Eastern Europe (PLATENSO)*** (2013–2016). The objective of the project is to enhance the capabilities of research institutions in Central and Eastern European countries to take part in the EU research with respect to governance, social and societal aspects linked to nuclear energy. The project is carried out by 19 partners from 12 EU states. In 2014, two PLATENSO partner meetings took place; one in Warsaw (Poland), and the other in Barcelona (Spain) where project achievements were presented and future works were discussed.

Researchers of the Laboratory constantly participate in research projects and programmes coordinated by the IAEA. The following projects have already been completed: ***Improving Long Term Safety***



Dr. A. Šmaižys at the research project meeting coordinated by the IAEA (10–14 November 2014, Tokyo, Japan)

Rector of the Kaunas University of Technology Prof. Dr. Habil. P. Baršauskas hands over a doctoral degree diploma to D. Justinavičius (24 September 2014)

Assessment Methodologies for Near Surface Radioactive Waste Disposal Facilities (ISAM) (1998–2001), ***Application of Safety Assessment Methodology for Near-Surface Waste Disposal Facilities (ASAM)*** (2002–2005), ***Disposal Aspects of Low and Intermediate Level waste derived from decommissioning activities*** (2002–2006), ***The Use of Numerical Models in Support of Site Characterization and Performance Assessment Studies of Geological Repositories*** (2005–2010). In 2014, two projects were implemented:

- ***Treatment of RBMK-1500 irradiated graphite in order to meet disposal requirements in Lithuania*** (2010–2014); this project is implemented within the framework of joint research project ***Treatment of irradiated graphite in order to meet waste acceptance criteria for disposal*** coordinated by the IAEA. In 2014, all the foreseen works related to investigations of radiological properties of RBMK-1500 irradiated graphite in Lithuania were completed, and in 2015, the IAEA plans to issue a general project report;

- ***Investigation of RBMK-1500 Spent Nuclear Fuel and Storage Casks Performance during Very Long Term Storage.*** (2012–2016); this project is implemented within the framework of the project ***Demonstrating Performance of Spent Fuel and Related System Components during very Long Term Storage*** coordinated by the IAEA. In November 2014, in Tokyo (Japan), a second meeting of project participants took place, where the results of research conducted in various countries were discussed, and the research of the features of RBMK-1500 spent nuclear fuel and storage containers in Lithuania was submitted. The participants visited Tokai nuclear research center *Nuclear Development Corporation* (NDC).

MAIN RESULTS

In 2014, the project ***Research of local fuel thermal decomposition processes by developing efficient and ecological technologies*** (2012–2014) financed by national research programme of the Research Council of Lithuania *Energy for the Future* implemented with other laboratories of the Institute was completed.

On 30 June 2014, a researcher of the Laboratory Darius Justinavičius defended a doctoral dissertation in the field of Technological Sciences, Energy and Thermal Engineering ***Investigation of gas migration in a geological repository*** and was conferred a doctoral degree.

Researchers of the Laboratory implemented 17 applied studies and earned almost a million litas. Moreover, they actively improved their qualification by participating in various training programs, coordinating meetings, delivered five papers at the international conferences (in Portugal, the United Kingdom, Czech Republic, and Lithuania) and three papers at the national conferences, published six articles in journals listed in *Thomson-Reuters* database *Web of Science Core Collection*.

Prof. Dr. Habil. Povilas POŠKAS
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LABORATORY of NUCLEAR INSTALLATION SAFETY

MAIN RESEARCH AREAS OF THE LABORATORY:

- safety assessment of nuclear power plants;
- safety analysis of thermonuclear fusion reactors;
- analysis of new generation nuclear power plants;
- analysis of thermal-hydraulic accident and transient processes;
- assessment of change of thermal-hydraulic parameters in NPP containments and other premises;
- simulation of transport of radionuclides and aerosols in premises;
- analysis of reactive accident processes of nuclear reactor and justification of modifications in reactor core;
- safety assessment of decommissioning and dismantling of nuclear installations;
- reliability estimation and control of energy systems;
- level 1 and level 2 probabilistic safety assessment of NPPs;
- strength analysis of structures, piping and components in complex technical systems;
- failure analysis and engineering assessment for complex technical systems;
- risk and hazard assessment of industrial objects;
- assessment of security of energy supply;
- modeling and reliability assessment of processes in energy supply networks;
- probabilistic modeling and analysis of unusual events;
- analysis of sensitivity and uncertainty of modeling results;
- fundamental research in thermal physics.

In 2014, the researchers of the Laboratory together with other national and foreign subjects were implementing 30 projects: 3 budget subsidy funded research works; 2 projects funded by the national research program *Energy for the Future*; 1 long-term institutional scientific research and experimental development program; 22 international projects (8 projects of the EU 7th FP); 2 projects ordered by Lithuanian economic subjects.

1. NATIONAL RESEARCH PROGRAM *ENERGY FOR THE FUTURE*

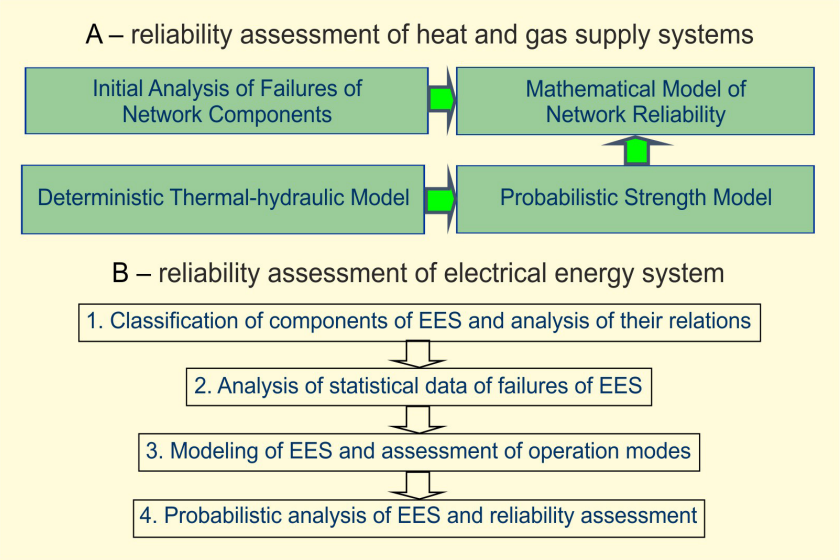
In 2014, the researchers of the Laboratory continued two projects of the national research program ***Energy for the Future*** financed by the Research Council of Lithuania.

The aim of the project ***Reliability and risk study of Lithuanian energy systems*** (ATE-04/2012), implemented in 2012–2014 by the national research program ***Energy for the Future*** administered by Research Council of Lithuania, is to perform reliability and risk study for the Lithuanian energy systems based on the

methodology developed during Project ATE-10/2010 implemented in 2010–2011.

The study covers the main parts of the energy system: electricity, district heating supply, and gas pipeline systems. A complex methodology, including probabilistic and deterministic methods, was applied for the assessment of reliability of energy systems. The applied methodology includes probabilistic safety analysis, systems reliability theory, Monte-Carlo modeling, deterministic thermal-hydraulic analysis, and probabilistic and deterministic analysis of the strength of structures, performed by application of the finite element method (see Figure). In order to carry out reliability and risk analysis of energy systems, it is important to have a reliable primary database. Therefore, the project focused on collection of data on reliability of various energy systems and their components (and at the same time failures) and analysis. The collected data were primarily used for reliability analysis and modeling of probable accidents of individual energy systems (i.e., electricity, heat, and gas supply systems). The results of the accident modeling are especially important for the assessment of risk caused by systems. All energy systems are closely related and dependent on one another's functioning. In order to evaluate the interaction of individual energy systems, internal and external failures of energy system, safety systems and barriers, an overall risk analysis of the entire Lithuanian energy system was also performed by combining main Lithuanian energy systems into a single model.

After the investigation of static and dynamic modes of Lithuanian Electrical Energy System, (EES), it was determined that in 2014 during operation modes (during largest winter, smallest winter, largest summer, smallest summer loads), EES would satisfy N-1 reliability criterion, and in many operating modes of the system, a beyond-design N-2 criterion was satisfied. After the investigation of electrical energy system, it can be claimed that reliability of Lithuanian EES is high, and the system can work steadily.



Simplified reliability assessment schemes for electrical energy systems: A – for heating and gas supply systems, B – for electrical energy system

During performance of accident modeling and investigation of reliability of district heating systems (DHSs), Kaunas heating networks were selected as the main research object. Assessment of strength of DHSs pipeline and probabilistic analysis of structural integrity were performed for most dangerous sections of DHSs, selected in view of the failure statistics and results of thermal hydraulic analysis. Dependence of pipe failure probability on pressure and thickness of the pipe wall in corroded area and probabilities of rupture of separate routs of the transmission gas pipeline were determined.

During the analysis of transmission gas pipeline networks, statistical data analysis of characteristics and failures of Lithuanian transmission gas pipelines was performed. Causes and frequency of failures as well as trends of their change were identified, which were compared to gas pipeline accident statistics of other countries. One of the main causes of failure of Lithuanian transmission gas pipelines is pitting corrosion as well as joint defects, a significant part of which in connected to the manufacturing defects. After elemental analysis of metal of operated (27–45 y.) and standby (51 y.) pipes and mechanical tests, the necessary data for strength analysis of gas pipelines were obtained. After probabilistic assessment of structural integrity of transmission gas pipelines with slits, probabilities of rupture of transmission pipeline were determined, given the age and length of piping routs.

During integrated risk analysis of Lithuanian energy system (including electricity, gas, and heat supply systems), a new energy criticality methodology for critical infrastructures was implemented; it is used to assess infrastructures of mixed energy systems, while modeling functional relations between infrastructures and their components. During assessment of criticality of energy systems, it was determined that sections of one-pipe natural gas supply systems usually cause disruptions in energy needs for consumers of urban district heating supply systems (when a two-pipe system transitions into a one-pipe system). In terms of electrical system, critical components and their combinations also consist of components of the natural gas supply system, because natural gas is the main fuel used at high-capacity plants. After evaluation of security assessment methodology, developed and

applied during National Research Program ATE project ***Lithuanian energy security research and assessment of energy security level***, and energy security indicators used in it, reliability indicators of the examined energy systems, necessary for assessment of energy security, were presented.

In 2014, another three-year project ***Investigation of Lithuanian energy security and assessment of energy security level*** by national research program ***Energy for the Future*** that was carried out together with Vytautas Magnus University was completed. The main objective of the project was to assess Lithuanian energy security in accordance with the methodology developed in project ATE-08/2010 funded by the Research Council of Lithuania. This should maximally ensure the continuity of project ATE-08/2010 and achievement of the objectives of measure 1.1 *Development and research of Lithuanian energy security analysis model*.

This study is an interdisciplinary work involving modeling of energy systems, technical, economic, natural, socio-political, and other risks and analysis of their consequences, the assessment of integral energy security level. For this reason, the project has been conducted by researchers from various fields (energy, mathematics, political science, sociology).

The results obtained in the research can be summarized as follows: economic and probabilistic assessment models for energy system designed for modeling of energy disturbances and assessment of their consequences were developed. The economic model is aimed at modeling of various long-term scenarios of the energy system development and at reduction of energy production costs and effects caused by disruptions. The probabilistic model is based on probabilistic safety analysis and allows probabilistically evaluating all the possible scenarios of development of disruptions and their effects. The resulting probabilistic characteristics of consequences precondition the assessment of most dangerous disruptions for energy system, and most effective protective measures in terms of energy security.

The methodology for assessment of the energy security level, created during the research, is based on compilation of security indicators and multi-criteria analysis. Indicators include all parts of energy security and enable expressing energy security as one integral characteristic. A dynamic model for assessment of indicators, created during the research, is based on Bayesian approach, ordinary least squares methods, pair correlations, and algebraic methods, and it enables forecasting the indicator values, calculating the energy security level until the year 2020, and comparing the impact of various energy projects on the energy security level. Based on the developed technology for assessment of energy security, the Lithuanian energy security level was assessed. By means of indicators, the energy security level in the Baltic States was compared. The obtained results were used for updating the Lithuanian energy strategy.

2. RESEARCH ON SAFETY OF NUCLEAR POWER FACILITIES

Researchers of the Laboratory participate in most advanced international nuclear energy research projects designated to develop new nuclear reactors and their future application not only in electricity but also heat production, and projects designated to deal with other important issues related to nuclear energy safety. Cooperation in projects, related to training and knowledge transfer to other countries' nuclear energy infrastructure organizations, has been continued. All these activities help strengthening Lithuanian competence in the nuclear energy field, which is necessary for each country in possession of nuclear energy objects (nuclear power plants, nuclear fuel and radioactive waste storages and repositories, etc.), and executing national nuclear program.

Long-term institutional R&D program
Scientific research of safety important processes in nuclear fission and fusion facilities

The objective of this five-year long program, initiated in 2012, is to prepare a complex safety assessment methodology for deterministic and probabilistic analysis of nuclear and thermonuclear installations with the regard of uncertainties and severe accident scenarios. Currently, there is no unified safety assessment methodology, whereas deterministic and probabilistic safety analyses separately employed for safety assessment do not estimate the aspects of interrelations. The performed work is complex; here integrated deterministic and probabilistic analysis methodology is developed and applied for safety assessment encompassing the fields of neutron kinetics, thermal-hydraulics, strength analysis, material science, mathematical modeling, etc.

In 2014, investigation on suitability of tools used for deterministic accident analysis of new generation nuclear reactors and nuclear fusion facilities has continued. Processes taking place in nuclear fuel assemblies during severe accidents were modeled using the experience, gained during the modelling the QUENCH experiments; in this way, validation of the created computer models was performed. Development of models for heat removal circuits of nuclear fusion devices and plasma vessels using RELAP5 computer code and modeling of mixing and combustion of hydrogen at NPP containments by means of ASTEC computer code continued. In parallel, investigations of aerosol and radioactive nuclide transport and deposition in the reactor cooling circuit and containment were carried out. In the area of strength analysis, a methodology for

assessment of structural integrity of main circulation circuit of nuclear reactors and an overview of design features of nuclear fusion facilities were prepared. In addition, the assessment methodology for the structural integrity of concrete structures under the influence of static loads was prepared. In the field of material science, investigation of welding seam fatigue under the conditions of high temperature controlled deformation was carried out. All the mentioned-above studies and numerical investigations later will be combined and used to develop an integrated umbrella complex (deterministic and probabilistic) safety analysis methodology.

Research performed during implementation of the program and accumulated experience are important for improving the competence of Lithuanian researchers working in the field of nuclear energy, which is necessary seeking to estimate safety of nuclear power plants constructed or to be constructed both in Lithuania and neighboring countries during all NPP lifetime stages – selection of NPP, design, construction, operation, its shutdown and management of radioactive waste. Participation in design and analysis activities of nuclear fusion facilities will enable the Laboratory to keep up with the most up-to-date technologies and retain high-level scientific potential.

Baltic Region Initiative for Long Lasting InnovAtive Nuclear Technologies

Although security of energy supply is the predominant question in all the country's regions, nuclear energy situation in the region of the Baltic States is specific, and there are a lot of hindrances for its development. The research institutions of Poland, Lithuania, Latvia and Sweden and GE-Hitachi Company prepared and submitted project ***BRILLIANT Baltic Region Initiative for Long Lasting InnovAtive Nuclear Technologies*** of the Horizon2020 EURATOM program. The aim of the project is to establish real hindrances, which are faced by the development of nuclear energy, and prepare to overcome them. Project participants agree that individual difficult obstacles experienced by a country can be easier overcome by cooperation on the regional level. The project covers such issues as energy systems of relatively low power, impact of nuclear energy programs on microeconomics and energy security, strengthening of the capabilities in nuclear energy research and development in the region, regional cooperation in development of closed cycle technologies for nuclear waste management and nuclear fuel, public information on the benefit of nuclear energy, and strengthening of national and regional capabilities in development and application of new technologies.

NUclear GENeration II & III Association

NUGENIA association, encompassing activities of Sustainable nuclear energy technology platform (SNETP) and competence networks NULIFE and SARNET, has continued its works in 2014. The association unites industry, research and safety organizations, executing general research and development projects in the field of nuclear energy. The association initiates and coordinates relevant research for the II and III generation nuclear reactors operated in EU states. The activity of NUGENIA is organized for eight research directions and includes directions, defined in SNETP ***Strategic Research Plan***. In 2014, NUGENIA association became very actively involved in preparation of Horizon2020 EURATOM project proposals. For this reason, NUGENIA open innovation platform was created, where all the prepared projects are stored, and anyone connected to this platform could find information, add comments, etc. In this way, due to joint efforts of members of the association, the projects are brought to perfection. However, project proposals prepared for Horizon2020 calls may be submitted for evaluation only after obtaining NUGENIA label of the Board that guarantees the quality of the project.

LEI is a member of NUGENIA association and along with other participants is actively involved in all the eight NUGENIA association research and developments areas.

Using open access innovation platform, LEI was able to join the activity of a variety of projects under preparation. Five of seven project proposals that the specialists of the Laboratory submitted for the Horizon2020 EURATOM 2014–2015 call were prepared because of the open access innovation platform.

The association additionally organized call for projects NUGENIA+. The purpose of this call was to additionally support the NUGENIA association by enhancing its role and coordinate European research in the area of safety of nuclear devices of II and II generation, also initiate international cooperation. For this call, LEI together with other members of the association prepared and submitted another two research projects. The destiny of all the submitted project proposals will be decided in the early 2015.

ETSON | EUROPEAN TECHNICAL SAFETY ORGANISATIONS NETWORK

European Technical Safety Organizations Network

The researchers of the Laboratory of nuclear installation safety since 2009 have participated in the activity of ***European Technical Safety Organizations Network*** (ETSON). ETSON consists of nine member organizations: Bel V (Belgium), GRS (Germany), IRSN (France), VTT (Finland), UJV Rez (Czech Republic), LEI (Lithuania), VUJE (Slovakia), PSI (Switzerland), INRNE BAS (Bulgaria), and three associated member organizations: SSTC (Ukraine), JNES (Japan), and SEC NRS (Russia). The main objectives of ETSON are as follows:

- stand for an exchange forum on scientific research and development of nuclear energy safety;
- contribute to fostering the convergence of nuclear safety practice in Europe and beyond;
- plan nuclear safety scientific research programs and promote their implementation;
- speed up the application of the EU Directive on nuclear safety;
- cooperate in implementation of safety assessment and research projects.

The representatives of the Laboratory actively participate and have their representatives in all the main structures and groups of ETSON organization. Fourteen expert groups are established in ETSON network in key nuclear safety research areas. The representatives of the Laboratory participate executing all the listed activities, with the exception of electrical system analysis:

1. Operating Experience Feedback, including Incident and Precursor Analysis;
2. Mechanical Systems;
3. Electrical Systems;
4. Severe Accidents;
5. Equipment certification for environmental conditions;
6. Safety Fluid Systems, including auxiliary systems;
7. Influence of Human and Organizational Factors;
8. Probabilistic Safety Analysis;
9. Lifetime-Management (equipment ageing);
10. Thermal Hydraulic Analysis (Transients, Accidents);
11. Safety concepts, Defense-in-Depth;
12. Processes in reactor core;
13. Emergency preparedness;
14. Radioactive waste and NPP decommissioning.

Working in expert groups, the specialists prepare Technical Safety Assessment Guides. These documents present recommendations on how the institutions performing the expertise should assess safety issues related to the nuclear activity. The goal of such documents is to achieve that independent technical analysis in every ETSON member state is performed following the same rules/methodology. In this way, it is sought to coordinate and maintain a high level of nuclear safety practices in ETSON member countries. Before 2014 in all the countries, three Technical Safety Assessment Guides were coordinated and approved:

- Review of events and analysis of precursors;
- Deterministic analysis of severe accidents;
- Analysis of human and organization factors of construction of nuclear facilities and modification processes.

In 2014, new Technical Safety Assessment Guide *Transients and design basis accident analyses* was prepared and approved. Also, *Manual for assessment of heat carrier safety systems* is prepared and will be officially published.

In the meetings of ETSON expert and coordinating groups, the participation of ETSON members in planned and ongoing EU projects, e.g., Horizon2020, is constantly discussed. At these meetings of experts from European states, one can learn about the latest ideas of performance and application of deterministic safety, risk assessment and probabilistic analysis and contribute to the implementation of new research and applied works in the field of nuclear safety analysis.

SAR GEN IV

Safety Assessment of Innovative Reactors

International EU 7 FP project ***SAR-GEN-IV***, the objective of which is to create a coordinated methodology of European countries for safety assessment of the fourth generation fast neutron spectrum reactors planned to be constructed in Europe, was officially completed at the end of 2013. In 2014, the coordination of reports on the fifth task *Creation of research and development methodology for fast neutron spectrum reactor safety in the European countries* was completed and finalized. The objectives of this task were:

(1) dissemination of works executed during other tasks;
(2) raising questions that remained open in previous tasks;
(3) proposal of preliminary work program for scientific research and development of fast reactor safety.

LEI participated in the identification of unsolved issues related to the research of fast neutron spectrum reactor in the field of

safety. Using the accumulated experience, received in applying a variety of program codes, new scientific investigations were identified, covering all processes occurring at fast neutron spectrum reactors and enabling to create and verify computer program codes, necessary for modeling those processes. LEI has also participated in preparation of recommendations for the safety analysis report on fast neutron spectrum reactors.

In this way, through cooperation with 22 EU institutions (among those LEI) participating in the project and under coordination of the Institute for Radiological Protection and Nuclear Safety (IRSN, France), all ***SARGEN-IV*** project tasks were successfully completed.

Assessment of Regional Capabilities for New Reactors Development through an Integrated Approach

In 2014, the works of EU 7BP ***ARCADIA*** project have continued. This project covers two nuclear energy implementation areas foreseen in Strategic research and innovation plan of SNETP technological platform:

1) ESNII through support of construction of Generation IV liquid lead-cooled nuclear fast reactor in Romania and
2) NUGENIA through support in dealing with the remaining safety issues of Generation III nuclear reactors.

26 organizations from European countries take part in the project, which is coordinated by Romanian company INR. The project covers seven work packages, and LEI participates in five of them. The Institute is the coordinator of two of those (*WP5 – Cooperation and dissemination* and *WP6 – Research Reactors* networking for LFR technology and improved LWR safety). In 2014, two meetings took place: the first one on June 11–13, 2014 in Bologna (Italy); and the second meeting took place on October 14–17, 2014 close to Prague (Czech Republic), at the research center Rež. The focus of this meeting was the introduction of other ongoing projects in the field of nuclear energy, for example, ALLEGRO, ALLIANCE, ASAMPSA_E, SUSE, etc.

NC2I-R
Nuclear Cogeneration Industrial Initiative – Research

Nuclear Cogeneration Industrial Initiative – Research and Development Coordination

In 2014, 7BP EURATOM initiated international project **NC2I-R** ***Nuclear Cogeneration Industrial Initiative – Research and Development Coordination*** has continued. A strategic objective of the project is to structure the European public and private sector R&D capabilities for delivering a nuclear energy cogeneration industrial object-demonstrator, which fully meets the market needs. During the project, coordinated by the Polish Nuclear Research Centre NCBJ, where research institutions as well as industry enterprises of various countries participate (a total of 21 participants), a possibility to use nuclear power plants not only for electricity but also for heat production will be assessed.

The researchers of the Laboratory conducted works foreseen under the project Task 3, *Safety and Licensing*, i.e. they collected material on Lithuania's experience in implementation and development of nuclear cogeneration, as well as performed an overview of the legal framework, and prepared a chapter for the report summarizing guidelines and instructions on how to carry out a licensing process for prototype cogeneration power plant at the European level. Representatives from LEI attended the annual project coordination meeting.

cesam

CODE FOR EUROPEAN SEVERE ACCIDENT MANAGEMENT

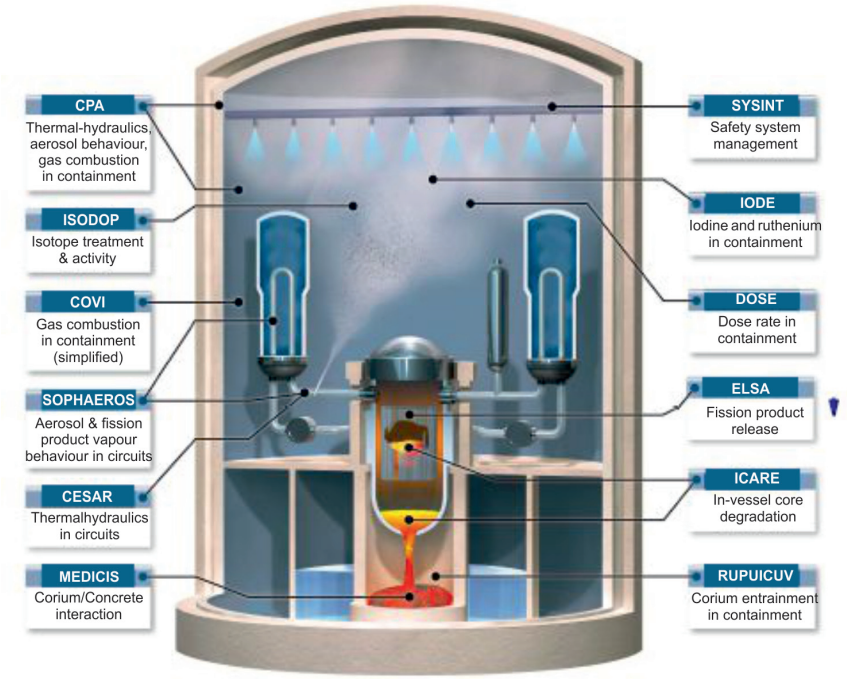
Approval of ASTEC computer code as a mean of severe accident management in Europe

EU seventh joint research, technological development and demonstrational activity program the project ***CESAM Code for European Severe Accident Management*** began on April 1, 2013. The objective of the project is to establish ASTEC code in Europe as a main mean for severe accident management in all Generation II and III European NPP (PWR, BWR, CANDU). The duration of the project is four years; it is divided into four parts:

- scientific management of ASTEC code, i.e. implementation of new models in the code;
- development of new models, taking into account information on existing physical models;
- validation of the computer code using experimental data and performance of benchmarking calculations;
- application of ASTEC computer code to analysis of power plants and during enhancement of efficiency of severe accident management, and development of typical "reference" input decks for European PWRs and BWRs type reactors.

18 EU institutions, including Lithuanian Energy Institute, participate in this project. LEI researchers participate in the working package *Plant applications and Severe Accident Management (SAM)*, which is coordinated by the EC Joint Research Centre (JRC). During the project, LEI specialists together with partners will develop a model of a nuclear power plant with GE BWR4-Mark I type reactor using ASTEC code and using ASTEC and RELAP/SCDAPSIM codes will perform benchmarking calculations of spent fuel pools of a selected BWR type nuclear power plant .

In 2014, LEI specialists using module MEDICIS of code ASTEC-V2.0R3p2 developed a part of initial model of GE BWR4-Mark I type power plant. Using MEDICIS module can be simulated the interaction of molten corium with concrete. A method of lumped parameters with the averaged melt layers is used for modeling. The model developed by LEI specialists allows investigating processes of concrete ablation, melt oxidation, and emission of non-condensable gases (H_2, CO, CO_2) into the containment. LEI prepared initial BWR type power plant model of spent nuclear fuel pool, created using V2.0R2p2 version of ASTEC code, modified taking into account the type of power plant chosen for the investigation and changes in ICARE module of ASTEC code that occurred during transition from version ASTEC-V2.0R2p2 to V2.0R3p2. Also, the initial RELAP/SCDAPSIM model of spent nuclear fuel pool was complemented taking into account the specifics of GE BWR4-Mark I type power plant.



Structure of ASTEC integral code

ASAMPSA_E ***(Advanced Safety Assessment Methodologies: Extended PSA) Advanced safety assessment methodology through application of extended Probabilistic Safety Analysis (PSA)***

Since 2013, LEI participates in the Consortium, managed by the Institut de Radioprotection et de Sūreté Nucléaire (IRSN), by implementing new EU 7BP project ***Advanced Safety Assessment Methodology: Extended PSA***). The project activity began on July 1, 2013; the duration of the project is 36 months. 28 organizations from 18 European countries are the partners of the project; several associate members also take part in the project: US-NRC, JANSI, and TEPCO.

In 2014, the initiated activities have continued in all five main project work

packages:

- WP10: Relationship with End-Users;
- WP21: Initiating events (internal and external hazards) modeling;
- WP22: How to introduce hazards in Level 1 PSA and all possibilities of events combination? ;
- WP30: General issues regarding extended PSA scope and applications;
- WP40: Specific issues related to Level 2 PSA.

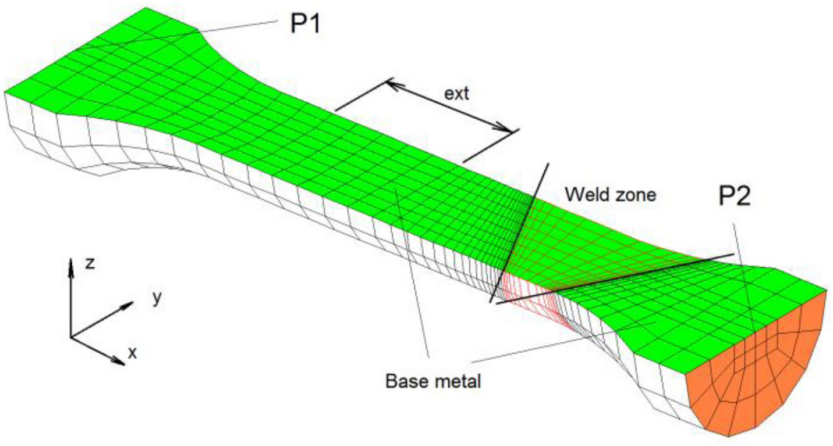
In 2014, by participating in the activity of all project work packages, LEI had given the most attention to the activities related to the identification of initial events (internal and external hazards) and literature references covering project activities as well as questionnaire for beneficiaries and analysis of the collected information. A special seminar was organized to consider the responses of beneficiaries to the questionnaire for the project ASAMPSA_E, where ~60 participants from various European and other countries (e.g., Japan, North Korea, Ukraine, and USA) took part. At the seminar for beneficiaries, the most attention was given to discuss the responses, taking into consideration the earlier prepared questionnaire. The questionnaire for NPP operators and regulators was made up of almost 100 questions on advanced safety assessment methodology applying extended probabilistic safety analysis. The attention was also focused on the analysis of various external extreme events (meteorological, seismic, and other events), but at the same time, discussion of activities carried out in separate project packages took place. At the end of the seminar, surveys of responses to the questionnaire were formulated, and the recommendations for further execution of the project were prepared. In continuing the work, it is planned to take into account all 64 recommendations summarized during the seminar. Moreover, it was decided that in WP21 work package, LEI would be responsible for coordination of the area of assessment of meteorological events. In WP22 work package, AMEC and LEI are together responsible for work area: *Link between external initiating events of PSA and NPP design basis conditions*. In other work packages, LEI together with other organizations also linked their activities to cooperation in ETSON PSA expert group and with preparation of IAEA documents.

Participation in this project revealed that recently, a lot of research institutions that were not even directly related to NPP (e.g., University of Vienna) are focused on probabilistic assessment of events and safety, development of corresponding methods, and wide application of them ensuring and demonstrating NPP safety. Participation in such European state projects as ASAMPSA_E allows immediate access to the latest ideas on performance and application of risk assessment and probabilistic analysis and contribution to new scientific and applied research in the field of safety analysis. In the future, it will be sought to develop and intensify bilateral cooperation with ASAMPSA_E project participants.

MATTER ***MATerials TEsting and Rules***

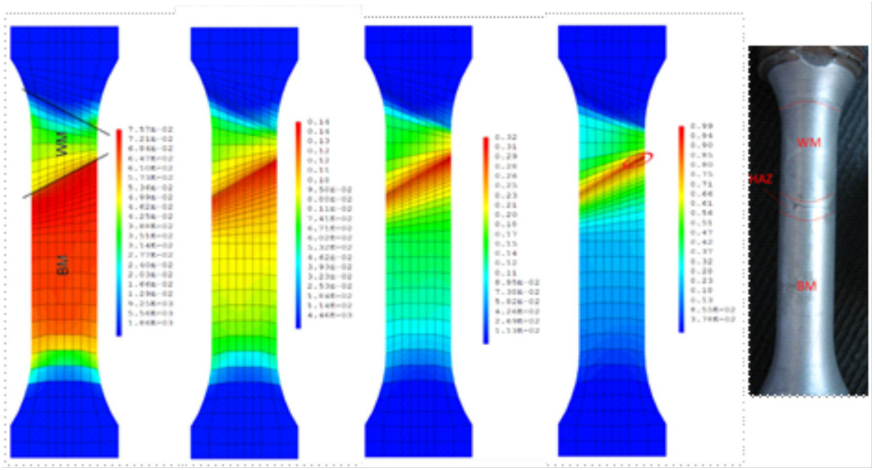
EU 7BP project ***MATTER*** has continued (it has begun on January 1, 2011). During implementation of the project, it was aimed to carry out detailed studies on the behavior of materials under the operating conditions of IV generation reactor. The researchers from the Laboratory of Nuclear Installation Safety and the Laboratory of Materials Research and Testing participate in the study. In 2014, studies on fatigue of P91 cross-weld specimens were carried out, and values of welded joint coefficient in air at the temperature of 550 °C were determined, taking into account given values of strain. These studies were executed by the researches of the Laboratory of Materials Research and Testing in air on P91 cross-weld specimens.

Parallel to these experimental studies, numerical fatigue studies of a welded sample were performed applying the finite element method. Results of finite element analysis allowed a more comprehensive understanding of the behavior of material in case of specimen fatigue. The numerical study of fatigue used finite element program Cast3m created and still undergoing



The model of finite elements with transverse welded joint

development at the Atomic Energy Centre CAE, France. Using this software a finite element model with a cross-weld was created. Representative results of the fatigue damage accumulation as the cycle number grows at strain range of 0.7% are presented in the figure below. These studies were executed by the researchers of the Laboratory of Nuclear Installation Safety.



Forecasting of damaged section of a welded sample at 0.5% deformation

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

European Nuclear Safety Training and Tutoring Institute

ENSTTI was established in 2010. This Institute was established by ETSON organizations, urged by the Institute for Radiological Protection and Nuclear Safety (IRNS). The founders of ENSTTI are IRSN (France) and LEI (Lithuania). Currently, the members of the Institute besides the mentioned organizations are also GRS (Germany) and Bel V (Belgium). The Institute is closely related to the European Technical Safety Organization Network ETSON and technical safety organizations participating in this EU community. The objective of ENSTTI is to provide training, consulting and practical services in the assessment of nuclear and radiation safety. It is intended for technical support organizations to share their experience on enhancing nuclear safety, dissemination of news and practical experience in the field of nuclear safety culture.

As every year, in 2014 ENSTTI organized a traditional four-week summer introductory nuclear energy safety training course that took place on June 11 – July 6 at GRS research center in Germany. The researchers of the Laboratory delivered lectures on the strategies of dismantling of nuclear power plants and the issues of dismantling Ignalina NPP. Yet, the ENSTTI activity is not limited only to such preparatory introductory courses. From 2013, by the order of the European Commission, a two-phase training project ***Training and tutoring for experts of the Nuclear Regulatory Authorities and their technical support organizations*** has been implemented. For the first part of the project (LOT1) *Nuclear safety regulation, licensing and enforcement*, a consortium consisting of institutions regulating nuclear safety and technical safety organizations has been established. Besides the four afore-mentioned organizations constituent of ENSTTI, consortium involves: FANC (Belgium), ASN (France), CSN (Spain), BBM (Austria), RCR (Czech Republic), SSTC (Ukraine). For the second part of the project (LOT2) *Nuclear safety assessment and inspection*, another consortium consisting of technical safety organizations that besides ENSTTI includes CIEMAT (Spain), ENEA (Italy), RCS

Organizations participating in ENSTTI activity

Participants and lecturers of training course ***Criticality safety and thermal hydraulics*** *(LEI, May 16, 2014)*

(Czech Republic), VUJE (Slovakia) and SSTC (Ukraine) has been established. The trainings are aimed at developing countries and countries developing (or planning on developing) nuclear energy: Tunisia, Indonesia, Malaysia, Jordan, Belarus, Georgia, Vietnam, Morocco, Philippines, Ukraine, Armenia, Egypt, Mexico and Brazil. Listeners from other countries can also attend the course upon paying the participation fee. During the course, specific issues on nuclear installation safety are addressed; the courses are aimed at experienced listeners, and the specialists delivering the lectures to them have to be experts in respective fields.

In 2014, researchers from LEI delivered lectures in six training courses, two of which were hosted by LEI:

1. *Radiation protection and containment systems*, Paris, France, March 17–21.
2. *Aging and mechanical analysis*, Köln, Germany, March 24–28.
3. *Criticality safety and thermal hydraulics of reactors*, Kaunas, Lithuania, May 16–20.
4. *Safety of nuclear fuel cycle*, Marcoule, France, September 08–19.
5. *Safety of nuclear reactors I*, Bologna, Italy, November 17–21.
6. *Regulatory framework for decommissioning of nuclear facilities*, Kaunas, Lithuania, December 08–12.

Participants and lecturers of training course ***Regulatory framework of decommissioning of nuclear facilities*** *(LEI, December 8, 2014)*

Active participation of LEI specialists in the activity of this project helps to gain experience in organizing similar courses and enhance their qualification. Such experience can be useful upon the initiation of construction of Visaginas NPP, when its new employees and employees of overseeing organizations will have to be trained.

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

In 2014, works of BY3.01/09 (BE/RA/07-A) project ***Development of technical cooperation in nuclear safety in the field of assistance to regulatory authorities*** have continued. The objective of this project is to support Belarus *Gosatomnadzor* in nuclear safety regulation activities, certifying the license application for Belarus NPP under construction, also training Belarus experts to properly perform the review of documents related to nuclear activity. In 2014, LEI executed works under task 2.2 *Review of selected safety issues addressed in the preliminary safety analysis report.* Besides LEI, this work involved experts from IRSN (France), GRS (Germany), STUK (Finland) and SSTC (Ukraine). The representative of IRSN was in charge of the works. EU experts addressed individual safety issues selected

during implementation of the earlier project. The analyzed results were discussed with experts from Belarus Nuclear Safety Regulating Institution and the workers from Joint Institute for Power and Nuclear Research (SOSNY), carrying out a review of Belarus NPP safety analysis report. Belarus specialists were trained to address technical issues and how to prepare conditions for the validity of license. LEI addressed issues related to the assessment of plane crash possibility, resistance of reactor buildings to earthquake, resistance of reactor containment to external impact, and issues of cooling of spent nuclear fuel pools. During execution of work, also IAEA seminar was organized for training staff of Belarus *Gosatomnadzor*. A representative of LEI delivered lectures on issues of emergency preparedness. During implementation of the project, conditions for license validity were prepared for all the addressed issues, which require presenting additional safety justification information. Belarus *Gosatomnadzor* called a work group of 27 local specialists that took part in the project and learned. These specialists will review safety analysis reports in the future and will prepare license conditions for both the first and the second reactors of Belarus NPP.

Such support to the neighbor country is necessary in order to ensure timely and effective supervision of the constructed nuclear power plant by Belarus nuclear regulation institutions. This is very important not only for Belarus, but also for Lithuania (at the border of which this power plant is constructed) and for the entire Europe.

FUSENET the European Fusion Education Network

FUSENET association is the ***European Fusion Education Network***, uniting European universities, research centers and industrial organizations, participating in scientific research of thermonuclear fusion. ITER international organization also belongs to this network. Since mid 2013, LEI has been a member of this association. Participation in this activity provides a possibility for doctorate students and junior researchers to more effectively participate in different trainings and exchange programs in all organizations of *Fusenet* association. On February 4, 2014 in Barcelona (Spain), the 3rd ***Fusenet*** General Assembly meeting took place, where a representative from LEI E. Urbonavičius participated for the first time. Business and financial reports of the year 2013 and work plans for 2014–2015 were discussed at the meeting; new ***Fusenet*** council members have been approved.

4. SCIENTIFIC RESEARCH OF FUSION

The project ***EURATOM–LEI Association Agreement*** implemented under the program 7BP ended on December 31, 2013. However, nuclear fusion investigations in Europe have not ceased, and in 2014, the preparation of a new project *EUROfusion* was completed and signed with the European Commission. The coordinator of this project is Max-Planck-Institut für Plasmaphysik (IPP). This is the first and the largest project not only in financial terms, but also in terms of ambitiousness of the EU research and innovation program. LEI along with 28 partners also actively work on it and had been participating in nuclear fusion research activities already since 2007. ***EUROfusion*** consortium enables European national laboratories to more effectively focus their resources by implementing increasingly complicated, larger projects, for instance, ITER, DEMO, W7-X. The program has two main objectives: get ready for experiments in the experimental ITER that is under construction, and create concepts of nuclear fusion demonstrational power plant. Universities and research centers, after receiving financial aid through European educational program Horizon2020, are already conducting the necessary investigations. This research program, as compared to the previous one, involves industry to a greater extent into designing components and into the process of searching for technical solutions.

LEI continues the previously started research under ***EUROfusion*** project. In this project, the researchers of the Institute are responsible for coordination and implementation of several activities. Doctorate students and young scientists are involved in the project activity. The greatest input by LEI is in the work package WPSAE, designed for safety assessment of nuclear fusion reactors. During performance of the work plan, the review of computer codes designed for safety assessment was conducted, a program for quality assurance of safety analysis was initiated, and analysis of systems of DEMO reactor began. Probabilistic analysis of DEMO reactor is implemented in WPPMI work package. WPJET work package is designated for works, related to currently largest operated nuclear fusion reactor in Europe JET. Most of the experiments conducted at JET are directly related to the research of plasma behavior. One of the measurement parameters is distribution of plasma power in a vacuum vessel, which is indirectly measured by bolometer devices. LEI performs bolometer data analysis, when the analogous device signal is converted into tomographic plasma power map in tokomak vacuum vessel.

During the nuclear fusion reaction, large part of generated energy falls to the share of neutrons; this is why the analysis of neutron processes is highly important. LEI conducts radiation impact assessment for constituent components of materials of nuclear fusion reactor. The result of the analysis provides valuable information about radiation activity and dose rate of JET device components.

LEI Researchers by W-7 device during work visit (Greifswald, Germany)

LEI cooperation with the Max-Planck-Institut für Plasmaphysik IPP established in Greifswald (Germany), which owns experimental thermonuclear synthesis device Wendelstein7-X (W7-X), began in 2007 and continued till 2014. One of the latest activities related to this cooperation was the analysis of ***Reliability, Availability, Maintainability and Inspectability of W7-X plasma vessel.***

For efficient work of experimental thermonuclear device W7-X, efforts were put in ensuring the lowest possible likelihood of failure and minimizing its unpreparedness for operation, i.e. minimizing downtime due to failures and the number and duration of repairs. In 2013, continuing international cooperation, LEI and Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald have signed an agreement ***Reliability Analyses of the Divertor Target Cooling Circuit ACK10 & Plasma Vessel / Ports Cooling Circuit ABK10***, the purpose of which was to carry out an analysis of reliability and preparedness of two W7-X cooling circuits and present recommendations on how to ensure effective work of this device. The main result of this R&D work is the assessment of the level of reliability and preparedness of target plasma cooling circuit ACK10 and plasma vessel cooling circuit ABK10 for different W7-X device operation cases. Also, main aspects causing system unpreparedness (possible equipment failures and personnel errors) were determined. Based on the conducted research, recommendations for technical reliability and preparedness and general safety enhancement of thermonuclear W7-X device were presented.

EUROfusion agreement signed – Robert-Jan Smits and Prof. Sibylle Günter (Teamwork © Fred Guerdin)

At the same time, due to the efforts of the researchers of LEI, new system reliability models have been developed and created, when methods of creation of fault trees and reliability block diagrams are applied, and specially designed software RiskSpectrum PSA is used. Application fields of these models, methods and software are much broader than it has been intended by the implemented agreement. This is related to decision-making based on safety analysis and risk assessment of various thermonuclear and other complex devices.

5. ASSESSMENT OF ENERGY SUPPLY SECURITY

In 2014, three-year research ***Development and implementation of methods for assessment of critical energy infrastructures*** funded by budget subsidies was completed. During this work, methods of probabilistic criticality assessment for critical energy infrastructures were created; they have been applied for the analysis of Lithuanian energy system. A new methodology for assessment of criticality of infrastructure of energy systems was developed; it takes into consideration interconnections of system elements, reliability, risk and stochastic system activity. Criticality assessment is conducted with the respect to consumers. The created methodology and models enable more precisely determining critical elements of systems and their groups, which have the highest criticality for energy systems, taking into account stochastic environment of the entire system. The results of the performed research allow for assessment of criticality of infrastructure of energy systems and comparison of impact of various energy development scenarios on infrastructure criticality. This enables determining most critical elements of energy infrastructures and interference processes in the energy systems caused by them. Based on the obtained results, criticality of infrastructure of Lithuanian energy systems was assessed, most critical element groups were determined, and the influence of gas development scenarios on criticality of energy systems was evaluated.

Baltic Energy Security Research Platform

In 2014, the activity of **Baltic Energy Security Research Platform** has continued. The objective of this platform is continue the cooperation of scientists of the Baltic Sea region states that perform investigations on the topics of energy security and critical infrastructures, and to perform comparative studies of energy security in the Baltic Sea region. In July 2014, EC Joint Research Centre and Institute of Physical Energetics in Riga organized a conference, where the platform participants presented their ongoing works in the field of energy security and critical infrastructures.

6. DECOMMISSIONING OF NUCLEAR INSTALLATIONS

In 2014, works under the contract with GNS (Gesselshaft für Nuklear-Service mbH, Germany) ***Modification or replacement of auxiliary maintenance systems for spent nuclear fuel casks at Ignalina NPP spent fuel pool halls*** have continued. The work is performed under cooperation with SC *TECOS* and machinery plant SC *ASTRA*. During implementation of the project, it is planned to manufacture and install six absorbers in the INPP fuel storage pool halls (three different absorbers at each Ignalina NPP Unit) and other equipment for maintenance of spent nuclear fuel casks. The purpose of the main components of this equipment, i.e. absorbers, is to absorb energy in case of accidental drop of casks loaded with spent nuclear fuel or

The assembly process of absorber type 1 in spent nuclear fuel pool at Ignalina NPP Unit 1

Preparation for transportation of absorber type 2 to spent nuclear fuel pool at Ignalina NPP Unit 1

an earthquake, and ensure that the loads on the building and cask structures will not exceed the permitted limits.

In 2014, the structure of absorbers of the third type was enhanced, and three out of six absorbers were successfully manufactured and assembled at SC *ASTRA* plant. One absorber of the first type was installed at Ignalina NPP Unit 1 in the spent nuclear fuel storage pool. Also, one absorber of the second type was successfully delivered to Ignalina NPP Unit 1 and prepared for installation.

A.L.A.R.A.
As Low As Reasonably Achievable

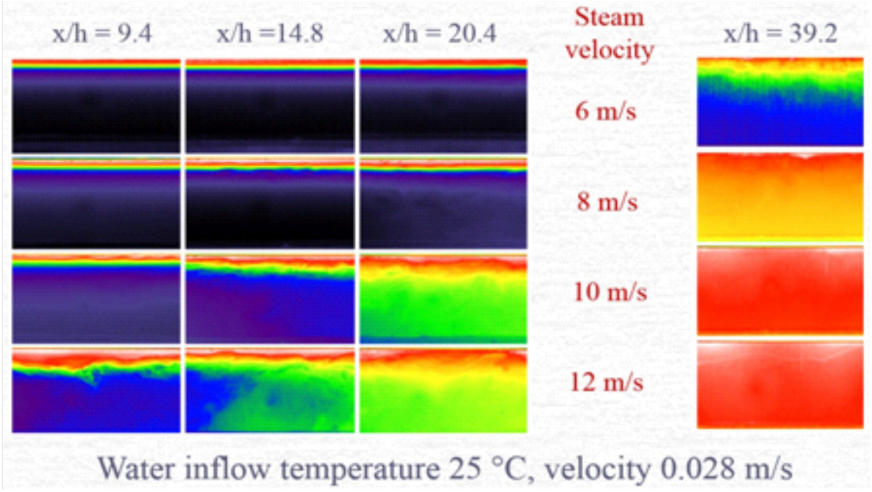
Preliminary studies for the decommissioning of the reactor compartments of the former Paldiski military nuclear site and for the establishment of a radioactive waste repository

In 2014, works under the contract with the company of the Republic of Estonia AS A.L.A.R.A ***Preliminary studies for the decommissioning of the reactor compartments of the former Paldiski military nuclear site and for the establishment of a radioactive waste repository*** have begun. The work is executed through cooperation with the company JSC *Eksortus* and Federal Centre of Nuclear and Radiation Safety (FCNRS) in Russia. During the implementation of the program, it is foreseen to choose the optimal concept for dismantling of two nuclear reactors on the existing Paldiski site, offer the best concept for radioactive waste disposal, and perform economic assessment of the mentioned works.

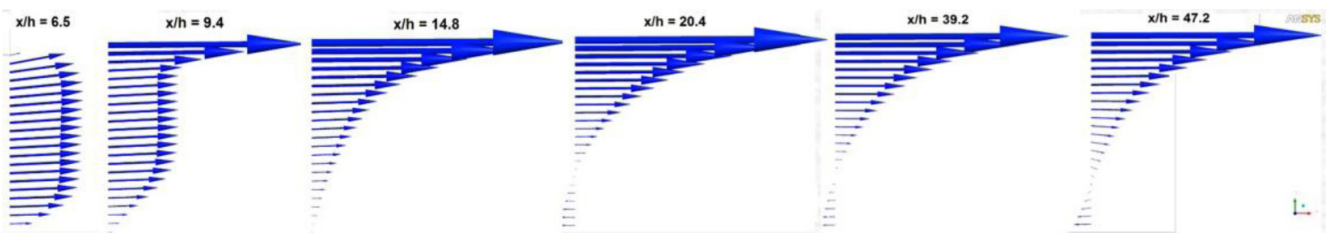
7. OTHER PROJECTS

In 2014, the work ***Research of condensed two-phase flow velocity field in horizontal rectangular channel*** funded from the budget has been completed. During it, a high-resolution method for outside measuring of water temperature in the boundary layer was designed and developed. During its application, the phenomenon of interfacial interaction inducing turbulence in the water was discovered and started to explore. For facilitation of interpretation of temperature and field velocity measurement results of natural experiments, a digital two-phase flow simulation by computational hydrodynamics package ANSYS CFX was invoked.

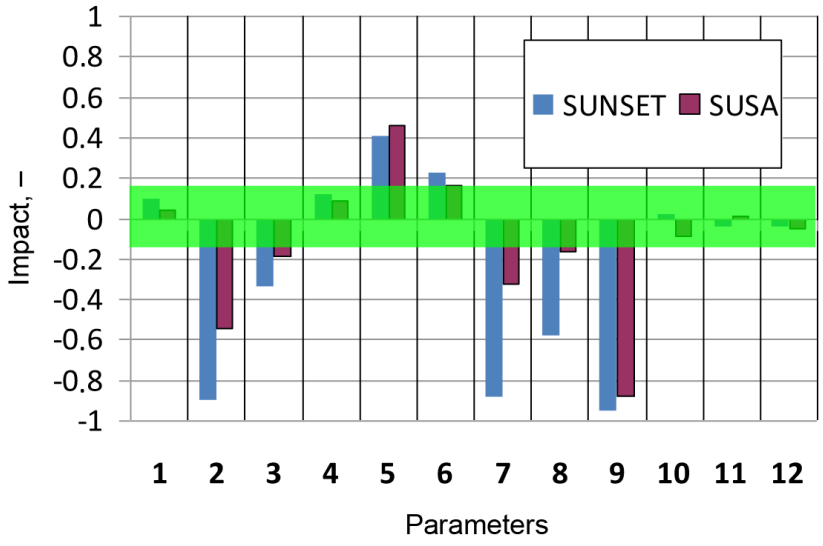
In 2014, the work funded by subsidies from the budget of the Republic of Lithuania ***Application of best-estimate method in analysis of thermal-hydraulic processes in nuclear and thermonuclear devices*** that started last year has continued. In 2014, the analysis of uncertainties and sensitivity of QUENCH-03 and QUENCH-06 experiment modeling results was performed. During QUENCH experiment, the situation of cooling of overheated nuclear fuel assemblies with water was simulated. Based on the analysis of results of these experiments, input data sets for program codes RELAP/SCDAPSIM and ASTEC were compiled, as well as sets of minimal and maximal calculation results. These sets allow obtaining calculation results that "envelop" values of experimental measurements. The experience gained from modeling is applied for modeling processes occurring in spent fuel pools in case of severe accidents. The com-



Movement of turbulence excitation place depending on the speed of vapor



Acceleration of water surface due to interfacial interaction



Parameters

1 *Cooling water flow*
2 *Water vapor flow*
3 *Argon flow*
4 *Cooling water temperature*
5 *Water vapor temperature*
6 *Argon temperature*
7 *ZrO_2 thermal conductivity*
8 *ZrO_2 specific heat*
9 *Resistance of fuel simulator contacts*
10 *Cooling water pressure*
11 *Water vapor pressure*
12 *Argon pressure*

Influence of undefined parameters on calculation results of hydrogen release

parison with the results of measurements performed during the experiments allows making decisions about possible uncertainties, also about the correctness of choosing modeling correlations. In 2014, the analysis of uncertainties of spent fuel pools of the second Ignalina NPP reactor was conducted.

In 2014, the preparation of numerical models of BWR reactors by applying program code RELAP/SCDAPSIM began; design basis accidents at BWR reactors have been reviewed. This work is a preparation for future projects.

Best-estimate method is also applied for analysis of thermal-hydraulic processes in nuclear fusion devices. Systematic analysis program code for thermal-hydraulic processes with integrated assessment of uncertainties of computing results was used. The case of coolant loss in cooling system of internal elements of nuclear fusion experimental device W7-X was modeled using program code RELAP/SCDAPSIM mod4.0. Calculation results showed that even after assessment of uncertainties, the pressure in the pipe upstream of the automatic valves would not reach the safety criterion, and the cooling system would not be damaged. This work, funded by budget subsidies, will continue next year.

ESReDA *(European Safety, Reliability & Data Association)*

ESReDA is a European association, providing a possibility to communicate and exchange information on the issues of safety and reliability in the field of scientific research. LEI is a part of this association. ***ESReDA*** constantly organizes seminars and initiates projects aimed at preparation of publications (books) in the relevant fields of scientific research on reliability and safety of energy and industrial objects. LEI takes part in preparation of such joint ***ESReDA*** publications, and currently participates in the project ***Reliability-based Optimization of Life Cycle Cost of Structures.***

In 2014, G. Dundulis participated in the 46th ***ESReDA*** seminar *Challenges in Structural Safety and Risk Analysis*. The paper *Reliability Analysis of Pipeline Network* was delivered during the seminar, in which methodology for reliability assessment of pipeline network and its application in case of Kaunas heat pipeline networks was reviewed. During the seminar, the goals of planned ***ESReDA*** project ***Infrastructure Preparedness and Resilience*** (i.e., prepare a book on critical infrastructure analysis), tasks and duration were discussed. During this meeting, experience of the Laboratory in performance of critical infrastructure analyses was presented. It should be noted that this topic is related to the project ***Assessment methodology and investigation of reliability of energy systems and its impact on energy security*** implemented by the Laboratory.

Product and Process Design for AmI Supported Energy Efficient Manufacturing Installations

Researchers of the Laboratory in 2014, further published the research results of the completed international project ***DEMI*** under EU 7BP research, technological development and demonstrational activity program. The project is intended for products and processes design for AmI (Ambient Intelligence) supported energy efficient manufacturing installations. The project was implemented along with eight partners from seven EU

countries. The coordinator of the project is Spanish technological research center Tecnalia.

Based on the project program implemented in the recent years, for ***DEMI*** project LEI created a prototype of information and communication technologies (ICT) component *Energy Simulator* and implemented its integration with other ICT components.

Methodology of development and application of *Energy Simulator* for industry and business specialists was prepared. In this way, applying the accumulated experience on modeling of hybrid systems and acquiring new possibilities for ICT creation, a universal software and related to it modeling methods were developed during ***DEMI*** project. These means of assessment and modeling of energy consumption operate taking into account: system configuration determined remotely by ICT component *Energy Analyzer*, design requirements, and boundary conditions. Different control of system and ongoing process variables (e.g., temperature) as well as different system models reflecting different working conditions are developed using MATLAB (Simulink and SimScape) software and applying the created means for automatic modeling and assessment of energy consumption.

At the end of 2014, an agreement ***Expertise services for compliance with the requirements of Reference document for this type of installations for the status of aboveground liquid fuel storage tanks MR-2, 31, 32, 33 installations and their related infrastructure*** was signed with Company *Lietuvos Energijos Gamyba*, during which it is planned to investigate technical and operational design documentation of fuel tanks and their engineering networks, assess compliance of this equipment to the requirements in the EU document *Emissions from Storage* for this type of installations and present recommendations and suggestions for enhancement of the status of these installations and their engineering networks, so as to eliminate the identified incompatibilities. In November, LEI experts visually inspected fuel tanks located in the town Elektrėnai, assessed the existing state and the strength of the foundation.

8. TRAINING OF SCIENTISTS AND PUBLICATION OF SCIENTIFIC RESULTS

In 2014, there were four doctoral students at the Laboratory of Nuclear Installation Safety. Two doctoral dissertations in the field of energetics and power engineering were defended – ***Investigation of energy systems disturbances impact on energy security*** (L. Martišauskas) and ***Study of the thermal hydraulic processes in nuclear fusion devices during loss of coolant event*** (T. Kaliatka). Young doctors together with experienced scientists of the Laboratory presented the investigation results obtained in 2014 in science research reports and papers. 37 scientific articles were published (20 out of those in the journals listed in *Thomson-Reuters Web of Science Core Collection database*), and 17 papers were presented at scientific conferences. The researchers of the Laboratory participated in the events related to nuclear energy and presented papers in all main international conferences, where safe operation of nuclear power plants and physical phenomena occurring in them were analyzed. The researchers actively participated in different international and national training programs, IAEA seminars, committee and coordinating meetings, activity of FUSION development committees and other organizations and scientific institutions.

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LABORATORY of ENERGY SYSTEMS RESEARCH

MAIN RESEARCH AREAS OF THE LABORATORY:

- analysis of macroeconomic development scenarios, modelling and forecasting of energy demand;
- analysis of medium- and long-term energy supply scenarios using widely approved optimization models;
- evaluation of environmental impact of the energy sector, analysis of pollution reduction technologies and implementation of environment protection policies;
- energy management and marketing research;
- research of efficiency of support means for renewable energy sources;
- generalization of the energy sector restructuring and liberalization experience in the European Union and Central and East European countries and its application implementation of reforms in the Lithuanian energy sector;
- development of energy information system, collection of statistical data on the energy sector development in Lithuania and worldwide.

In 2014, implementation of a long-term program of institutional research and experimental (social, cultural) development ***Economic and sustainability analysis for the energy sector development*** has continued in co-operation with the experts of Laboratory for Renewable Energy and Energy Efficiency and Laboratory of Systems Control and Automation.

In the long-term perspective, an ambitious objective was set to solve the following tasks:

1) to develop a theory of harmonious progress in the energy sector on the basis of sustainable development and interrelations with knowledge-based economy concepts;
2) to analyze possibilities of perspective development in the Lithuanian energy sector and prepare recommendations related to rational directions of perspective technical development of the energy sector, changes in fuel and energy balance, environmental factors;
3) to form methodological basis for the assessment of efficiency of sustainable energy development promotion measures in municipalities, to evaluate the efficiency of already applied and proposed new support measures;
4) to investigate possibilities of synchronous operation of the Lithuanian power system with ENTSO-E, taking into account the perspective development of generating capacities.

While implementing the second task in 2014, the investigations aimed at expansion of modelling base for the energy sector development and solution of specific tasks were continued in the Laboratory. Experience in the previously conducted analysis of the energy sector development was efficiently applied in performing research on perspective development of the Lithuanian energy sector. At this stage of research, the structure of a mathematical model for perspective development and functional analysis of the energy sector was formed; it assessed internal and external relations, energy policies, environmental restrictions, and external factors. The most important results enabling to perform a comprehensive analysis of the Lithuanian energy sector development in

a long-term perspective are as follows:

- A mathematical model was prepared, which integrally describes development of power system, district heat supply system and fuel supply system as well change of final energy demand in a long-term perspective, including their seasonal, weekly, and daily variations;
- The model allows determining economically most efficient heat production technologies in individual cities (from a large number of existing, modernized, and new), the type and amount of used fuel, capacity of heat and electricity production, ensuring the necessary reserve capacities and without violating environmental restrictions;
- The model allows determining optimal structure of the generating capacities in the power system and their utilization by evaluating expedience of electricity and reserve capacities exchange with individual foreign countries, which is determined by the needs of electricity markets in neighbouring countries (export from Lithuania), possibilities of supply (import to Lithuania), electricity prices, capacity of interconnections, etc.;
- Fuel supply to power plants and heat plants is modelled taking into consideration the existing and feasible in the future supply infrastructure (capacities of pipelines and terminals, natural gas storage, etc.), prices of the supplied fuel and volumes of the consumed fuel. The rationality of usage of local and renewable energy sources for individual heat and electricity supply technologies is established taking into consideration the potential and prices of these sources;
- The information input database was updated and expanded: the recent information on consumption of primary energy sources in Lithuania, EU countries and worldwide and in particular tendencies in changes of prices of electricity and natural gas, development of technologies for electricity and heat production, their accessibility, technical and economic indicators is accumulated.

An optimization model prepared by applying MESSAGE software package enables researchers to determine from the set of all available and probable future technologies the optimal structure of capacities for generation of electricity and district heat, types and amounts of primary energy sources, volumes of electricity and heat production, volumes of import-export of electricity and reserve capacities. The determined mix of energy supply and transformation technologies meets the foreseen country's final energy demand at the least cost (and at the same time at least prices for end-users) in the long-term perspective. The energy sector development was modelled over the period up to year 2050, taking into consideration operation conditions and efficiency of different types of power plants at different operation regimes, adequately balancing production and consumption of electricity and heat in Lithuania and flows of electricity imported from networks of Scandinavian countries and continental Europe as well as from third countries or exported to neighbouring markets.

The optimization model enables to analyse several tens of possible scenarios for development of the energy sector, which are formed by evaluating strategic goals for the Lithuanian energy sector development, requirements determined by the EU directives and international commitments, probable changes in energy markets of neighbouring countries and in structures of generating capacities, achievements defined by the Lithuanian energy security or other criteria, etc.

The project funded by the *Research Council of Lithuania* ***Assessment of potential for greenhouse gas emission reduction in households in Lithuania*** (project supervisor D. Štreimikienė) was successfully completed. Energy consumption and greenhouse gas emissions in households were analyzed in the project and basic social-economic and technological as well as cultural factors influencing greenhouse gas emissions in households were identified. A monograph ***Greenhouse gas emission reduction in households*** summarizing the results of the project was prepared and published. The monograph summarizes general social, economic, and behavioural factors, causing greenhouse gas emissions in households, and evaluates the potential of reduction of greenhouse gas emissions due to behavioural innovations in this sector. The conducted investigations and the obtained results may be useful for researchers, working in area of environment and energy as well as climate change mitigation, and for policy makers as well as for the bachelor and master degree students studying subjects directly related to environmental policy and energy policy.

The project ***External economic effects of development of energy sector: quantitative assessment*** launched in 2014 by the groups of scientists of the ***Research Council of Lithuania*** is significant for confirmation of qualification of the researchers of the Laboratory. It is sought to prepare in this project a system of quantitative assessment for external economic effects of perspective development of the energy sector and assess external economic cost and benefits of the Lithuanian energy sector development scenarios. In the project, the assessment of directly measured economic effects and those depending on the specifics of technologies

is integrated in models applied for energy planning and formulating development scenarios, whereas modelling of general economic equilibrium is used to assess the intersectoral relations in a broader way. Such analysis enables researchers to cover changing relations with other branches of the economy due to structural changes in the energy sector. The ongoing project will broaden the knowledge about external economic effects of the energy sector development and will significantly contribute to economic energy planning and enhancement of methods applied in analysis of energy and economy relations: solutions of modelling, enabling to reflect better economic variables and restrictions in energy planning models, will be created; methods for assessment economic effects of perspective development of the energy sector, enabling to assess direct and indirect as well as induced effects of perspective development of the energy sector, will be developed and adjusted to the Lithuanian environment.

RESEARCH PAPERS FOR COUNTRY'S ECONOMY

Under the agreement with the Government Office of the Republic of Lithuania, a study ***Analysis of the perspective development of Lithuanian energy sector taking into consideration EU strategic initiatives in the field of energy*** was prepared. Rapid development of the Lithuanian economy, the increased dependence on the import of energy sources from a single country, constantly renewed EU energy policy and directives consolidating new guidelines, the increased strategic importance of integration of Lithuanian energy systems into EU systems and in the created common EU energy market, high prices on imported fossil fuel in world markets, intensive strengthening of the role of renewable energy sources in the Lithuanian energy balance, and tense geopolitical situation of the country force to adjust the Lithuanian energy policy and update the National Energy Independence Strategy approved by the Seimas of the Republic of Lithuania on June 26, 2012 by resolution No. XI-2133.

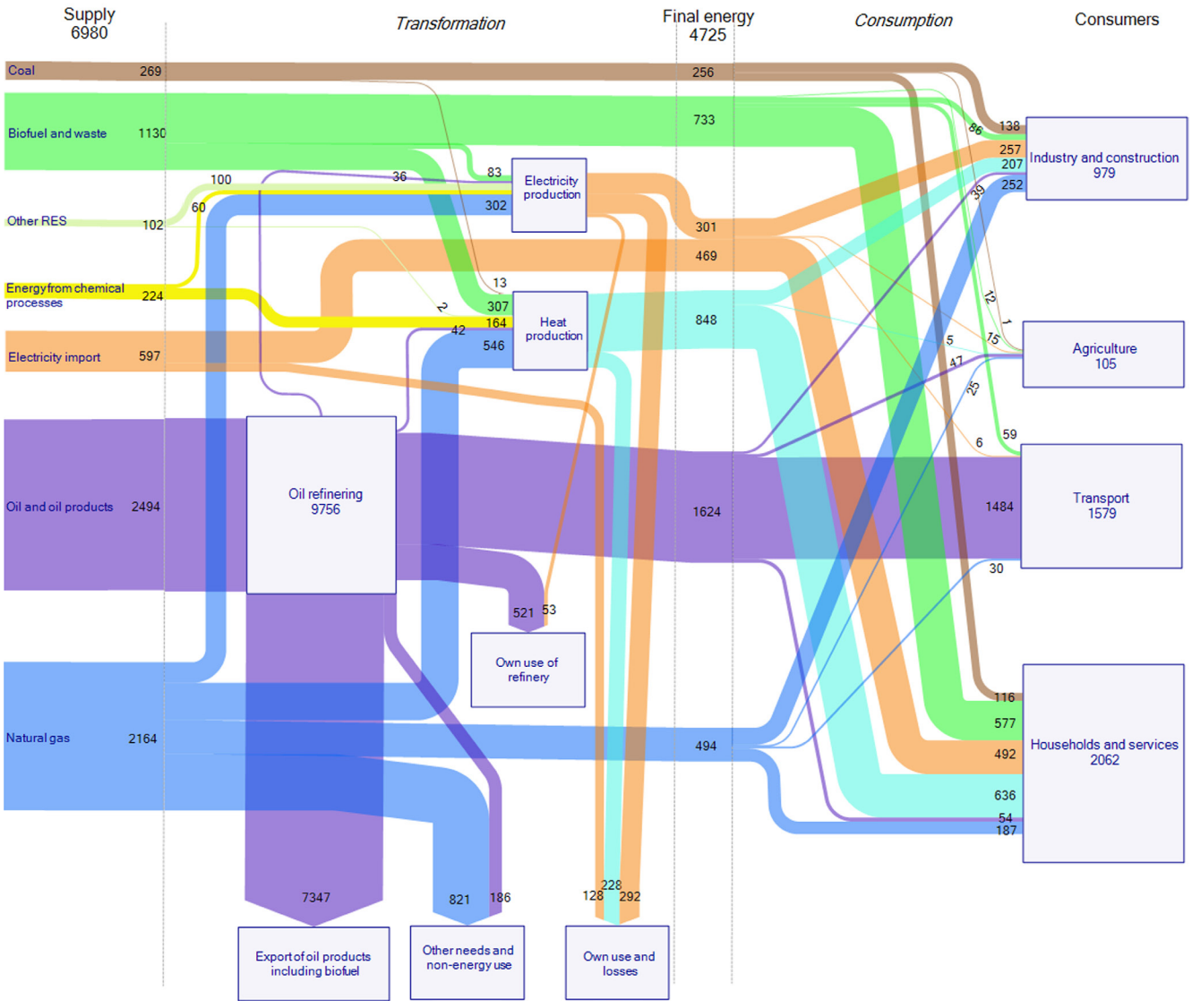


Diagram of the main fuels and energy flows in Lithuania in 2013, ktoe

Carrying out specified contractual duties, the interim report ***Feasibility assessment of development of high-efficiency cogeneration and district heat supply and recommendations for the National program for development of heat sector in 2014-2020*** was prepared. District heat supply system was addressed as an integral and inseparable part of the energy sector, tightly related to power system by technological and energy flow relations, fuel supply (especially natural gas), and other systems. Perspective development and functioning of district heating supply systems were analyzed by applying a mathematical model created for this purpose. Complex modelling enabled to determine most efficient heat generation technologies in the largest cities (evaluating the volume of investments necessary for their installation, constant and variable operating costs, possible fuel types and efficiency factors, the life time of technologies and their construction period, environmental characteristics), capacities of heat and electricity generation in thermal power plants, the volume of fuel consumption, the volume of necessary investment and other indicators.

The final report presents: analysis of geopolitical environment; strategic goals of the energy sector; scenarios of economic development and perspective demand for electricity and district heat as well as direct fuel consumption in branches of the economy related to economic growth; forecast of fuel prices; analysis of the present state of the energy sector; modelling concept of its development and long-term functioning; directions of development of power system and district heating systems; dynamics of generating capacities, electricity and heat production and changes in structure of fuel consumption; volumes of investments; emissions of pollutants; principles of distribution of the European Union support and rational support volumes for individual technologies.

Based on a thorough and comprehensive analysis of scenarios for development of the Lithuanian energy sector and summary of optimization results, an updated project of the country's National Energy Strategy was prepared and submitted to the Government Office; the project defines the main provisions of the State on development of the energy sector until year 2030 and guidelines until year 2050. These provisions and guidelines are justified by the aspects of enhancement of economy, energy security, environmental protection and management improvement, fully combining them with the needs of the State and the recent international requirements. The strategy identifies the ways and means of energy supply that ensure the strategic

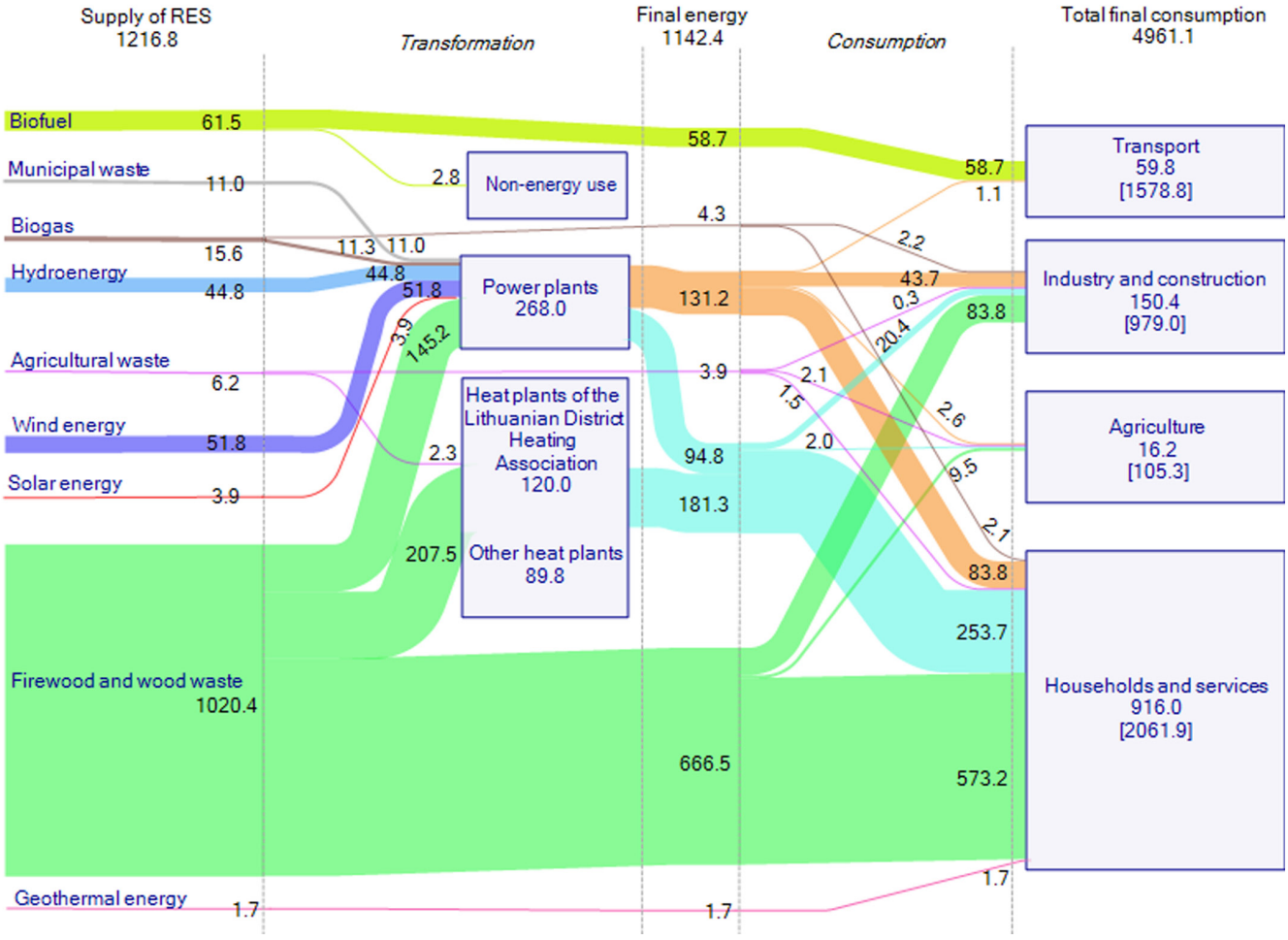


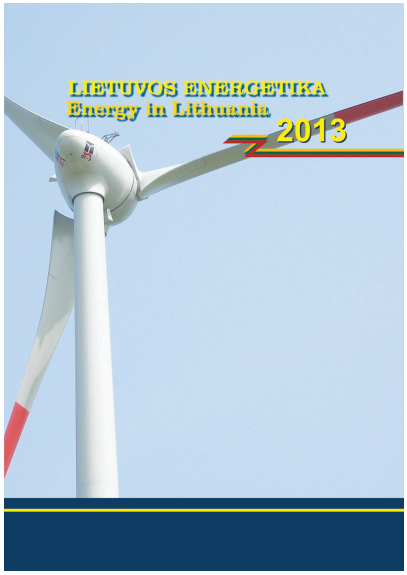
Diagram of renewable energy sources flows in 2013, ktoe

security by minimizing negative impact of dependence on the dominant energy source supplier.

Under the agreement with JSC *Fortum Heat Lietuva*, a scientific research ***Technical-economic assessment of modernization projects of heat production and supply in the integrated network of the Kaunas city*** has been conducted. The evaluation of the existing state of district heat supply and directions of development of existing and potential new heat producers in legal, technical, and economic terms is presented in the final report. Performing investigations under this agreement, the analysis of tendency in changes of heat consumption and of influence of fuel market development on district heating supply system in the city of Kaunas was carried out, a model of heat market was proposed, the state of heat supply pipelines was evaluated, the methodology applied to the analysis was presented and the assumptions were described – forecast of heat demand and fuel prices, possible options of heat sources development. Alternatives of the actually existing or planned new generation sources in district heating network of the Kaunas city are analysed in the study. However, determination of the optimal long-term directions of development of integrated heat network and heat production sources, which do not only encompass heat supply to consumers, but also supply of electricity and other energy sources, as well as overall social and economic benefit, was not foreseen in the contract. The essential result of this investigation is analysis of scenarios specified by the client and their thorough assessment.

The annual issue of statistical data ***Energy in Lithuania 2013*** was published and transferred to the Ministry of Energy. This issue presents the latest systemized information describing tendencies in the development of the Lithuanian energy sector and its branches in 2010–2013 as well as detailed energy balances and the key indicators of the national energy sector. Based on the latest information presented in databases of statistical departments of the Baltic States, the issue presents statistical data of 2012 and 2013 on Estonian, Latvian and Lithuanian total primary and final energy consumption, electricity and district heat production and consumption in branches of economy, growth of gross domestic product (GDP) as well as comparative indicators defining current status of the Lithuanian energy sector and the national economy. The issue presents the amounts of greenhouse gas emissions in 1990 and 2012 and their structure by the sectors in the countries that signed Annex 1 to the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

The comparative analysis of indicators of the EU-28 countries, the largest world countries and countries of the Organization for Economic Co-operation and Development as well as summarized general world economic and energy indicators (GDP, energy consumption per capita, energy intensity, etc.) for the years 2011 and 2012 are presented in the publication. This analysis was prepared following the latest data and methodology published by the International Energy Agency. According to methodological principles of this agency, in electricity consumption in all the countries listed in the publication, losses in the network are not assessed, and final energy consumption includes non-energy use.



The publication summarizes the changes in the national economy and the energy sector. After a dramatic decline in 2009 (-14.8%) Lithuanian GDP has been recovering; over the period 2010–2013, it was increasing approximately by 3.7% annually. In 2013, the country's GDP in chain-linked volume amounted to 110 billion LTL (base year – 2010) or 37.2 thousand LTL per capita. In 2013, the primary energy consumption decreased by 5.5% and comprised 6.98 million toe. The final energy consumption for energy needs in branches of the economy decreased by 2.3% and comprised 4.73 million toe, final electricity consumption increased by 0.4% and comprised 8.96 TWh. In 2013, the primary energy consumption per unit of GDP dropped by 8.5%, whereas intensity of final energy consumed in branches of the economy decreased by 5.3%.

The publication ***Energy in Lithuania 2013*** was prepared after comprehensive analysis of data presented in databases of Departments of Statistics of Lithuania, Latvia and Estonia and international statistical data publications. The information invoked in the preparation of the publication was taken from the publications of the country's Department of Statistics (Fuel and energy balance – 2010, 2011, 2012 and 2013) and databases, State Prices and Energy Control Commission, and annual reports of energy companies and other institutions as well as from information publications and databases prepared by international organizations (International Energy Agency, Eurostat).

Under the agreement with the ***Ministry of Environment***, a scientific project ***National Greenhouse Gas Emissions Inventory for Energy Sector Preparation 2014*** was carried out. While implementing the above-mentioned project, a National greenhouse gas emission inventory for the energy sector for the

period 1990–2012 was prepared following the requirements of the European Parliament and Council decision No. 280/2004/EC on the mechanism for monitoring of greenhouse gas emissions in the European Communities and implementing the Kyoto Protocol and the methodology of Intergovernmental Panel on Climate Change. Dr. I. Konstantinavičiūtė, being a member of the National greenhouse gas emission inventory preparation commission, National climate change committee and NER 3000 financial instrument project selection commission, actively contributed to seeking the solutions in this field of research.

PARTICIPATION IN INTERNATIONAL PROGRAMS

In 2014, a three-year long project ***Sustainable development analysis of Lithuanian renewable and other energy sources, earth, and water use*** coordinated by the *International Atomic Energy Agency* (IAEA) was completed. This research provides guidelines for sustainable development of the Lithuanian energy sector, earth, and water use. Usage of renewable energy sources (RES) has influence on sustainable development since it enables to reduce negative environmental impact, promotes national and regional economic development, determines attractive energy prices, creates additional job positions, etc.

Country's energy security (ensuring energy demand for socially acceptable price) is also an inherent part of sustainable economic and social policy. In order to implement the objectives, it was sought to encompass and analyse the entire chain of energy flows, starting from the use of natural energy resources and finishing with separate energy types obtained from these resources seeking to meet society demands, including the use of non-renewable energy sources and assessment of their environmental impact, taking into account country's international commitments as well as strategic objectives and aiming to supply energy for consumers at possibly lowest prices. Taking into account the above-mentioned criteria, an optimization model realized by application of MESSAGE software package was created.

Relevant for Lithuania issues of the energy sector development as well as wider deployment of RES and aspects of increase of energy consumption efficiency are analysed in international projects of ***Intelligent Energy Europe Program***. In 2014, two projects ***Policy Dialogue on the assessment and convergence of RES policy in EU Member States (DIA-CORE) and Monitoring of energy efficiency in the EU (ODYSEE MURE 2012)*** have continued.

By the project ***Policy Dialogue on the assessment and convergence of RES policy in EU Member States (DIA-CORE),*** it is aimed to ensure the continuity of RES support schemes assessment and to develop a productive

Employees of the Laboratory of Energy Systems Research and colleagues who worked in the Laboratory before

discussion on future support policy for RES use in electricity, heat production, and transport sectors. The project coordinator is the Fraunhofer Institute for Systems and Innovation Research ISI (Germany). Project partners: Vienna University of Technology, Energy Economy Group (Austria), Ecofys (Netherlands), Eclareon (Germany), National Technical University of Athens (Greece), CEPS (Belgium), DIW Berlin (Germany), Utrecht University (Netherlands), and AXPO (Austria).

During implementation of the project ***Monitoring of energy efficiency in the EU (ODYSEE MURE 2012,*** it is aimed to conduct a thorough monitoring of energy consumption efficiency and policy measures for increasing the efficiency of energy consumption in all EU countries and in all sectors of the economy. Project coordinator is ADEME (France). 32 partners from all EU countries participate in this project.

Experience gained in the Laboratory was widely used on the international level:

- Preparing specialists for modelling of the energy sector development in trainings organized in Austria and Sweden – Dr. A. Galinis, as an expert delegated by the IAEA and responsible for application of the MESSAGE model in solving tasks of long-term energy planning, shared his experience and performed practical training for experts of modelling, involved in program for long-term development of the energy sector;
- Modelling specialists carrying out practical training in Tunisia (Regional course for West Africa), Cameroon (Regional course for Central Africa), and Uganda (National course) – the experience was conveyed by the IAEA delegated expert Dr. D. Tarvydas.
- Analyzing 2014–2015 calls for energy research *Program Horizon2020* – Dr. D. Štreimikienė participated in meetings of Energy advisors group of the European Commission *Program Horizon 2020*.

In 2014, researchers of the Laboratory improved their qualifications:

- On July 2–12, 2014 Dr. E. Norvaiša participated in the seminar organized by IAEA on the sustainable energy development, energy strategies prepared by European countries, and the role of nuclear energy in present and future balance of electricity production. The seminar was combined with the international nuclear engineering conference ICONE-22, where experts of nuclear energy field from various countries presented papers, which provided opportunities to learn more about development of nuclear energy worldwide.
- On November 18–26, 2014 Dr. E. Norvaiša participated in the course ***Sustainable Energy Solutions*** organized by the United Nations Industry Development Organization (UNIDO). This course provided knowledge about the essential factors that have great influence on development of sustainable energy on the global scale. The program of the course consisted of lectures delivered by lecturers, a field trip to a model region of development of sustainable energy Güssing (Austria), information about application of the best examples of policies and solutions for development of sustainable energy in various regions worldwide, development trends of technologies using most advanced renewable energy sources. Participants of the course had to perform various specific tasks, related to energy development challenges in different regions of the world, present possible methods for solving specific issues. In his paper on the situation of sustainable energy development in Lithuania, E. Norvaiša described to participants of the course scenarios of long-term energy development, renewable energy problems and perspectives.

In 2014, the researchers of the Laboratory participated in international conferences in Germany, Italy, Philippines, Poland, Spain, Turkey and other countries, where eight papers were presented. The researchers of the Laboratory published twelve scientific articles in Lithuanian and foreign journals, in proceedings of international conferences, etc. (six of those in journals listed in *Thomson-Reuters Web of Science Core Collection* database).

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LABORATORY for RENEWABLE ENERGY and ENERGY EFFICIENCY

On January 2, 2015, after restructuring Institute's divisions, a new Laboratory for Renewable Energy and Energy Efficiency was established uniting three former divisions: Laboratory of Renewable Energy (10), Energy Efficiency Research and Information Center (11) and Laboratory of Regional Energy Development (19). This publication presents the overviews of the performance activities of the former individual divisions in 2014.

LABORATORY of RENEWABLE ENERGY

MAIN RESEARCH DIRECTIONS OF THE LABORATORY:

- research and modeling of wind flow variation in different regions of Lithuania;
- development and research of models and methodologies for forecast of variation of wind power plant capacity;
- research of the aspects of performance efficiency and environmental impact of industrial and small wind power plants, preparation of feasibility studies of wind power plants;
- research of development of solid biomass sources, fuel preparation and combustion technologies;
- research of biogas and biofuel production processes and environmental problems;
- analysis and research of use of sustainable development of renewable energy sources;
- analysis and promotion of advanced energy production technologies using local and renewable energy sources, compilation of databases, services and consultations to users, dissemination of information to the society.

RESEARCH OF DEVELOPMENT OF RENEWABLE ENERGY TECHNOLOGIES

The Laboratory carries out research related to wind, solar, and biomass energy as well as research related to development of technologies designed to ensure sustainable development of usage of renewable energy sources (further RES) in the country, promote development and implementation of new technologies, and reduce dependence on imported energy sources.

In 2014, a scientific research financed by the state subsidies ***Research of application and intensification and development possibilities in Lithuania of small-scale wind power plants and solar energy systems*** was completed. During the implementation of this study, the analysis of technical characteristics and possibilities of development of small-scale wind power plants (WPP) in the country was carried out; efficiency of small-scale WPPs and its dependence on the wind conditions were assessed. The results of the research show that wind power plants with larger

relative rotor area can produce up to two times more energy than the standard small WPP; therefore, in the regions with smaller wind resource it is reasonable to build small WPPs with relatively larger rotors.

Based on the analysis of the complex methodology of assessment of technical-economic efficiency applied to small capacity WPP, it was determined that the analyzed small WPP with horizontal axis is about 5.5 times more efficient than the small WPP with vertical axis. The results of investigations of the wind power plant mounted on the rooftop of LEI led to installation of the direction stabilizer, a so called "tail". Production of electric power was stabilized and the capacity factor of the turbine increased.

A database for the wind speed prediction model was compiled, the accuracy of statistical methods during the forecast of wind speed for 6–48 hours was assessed, the method of artificial neural network was applied for wind speed prediction. The application of neural network has positive impact on error reduction. It was also found that error values depend on the length of time series used for calculations.

During the research of wind conditions, measurements of wind speed and direction were performed in Kaišiadorys and Lazdijai districts; the impact of meteorological conditions, surface roughness and terrain on the operation of wind power plants was analyzed.

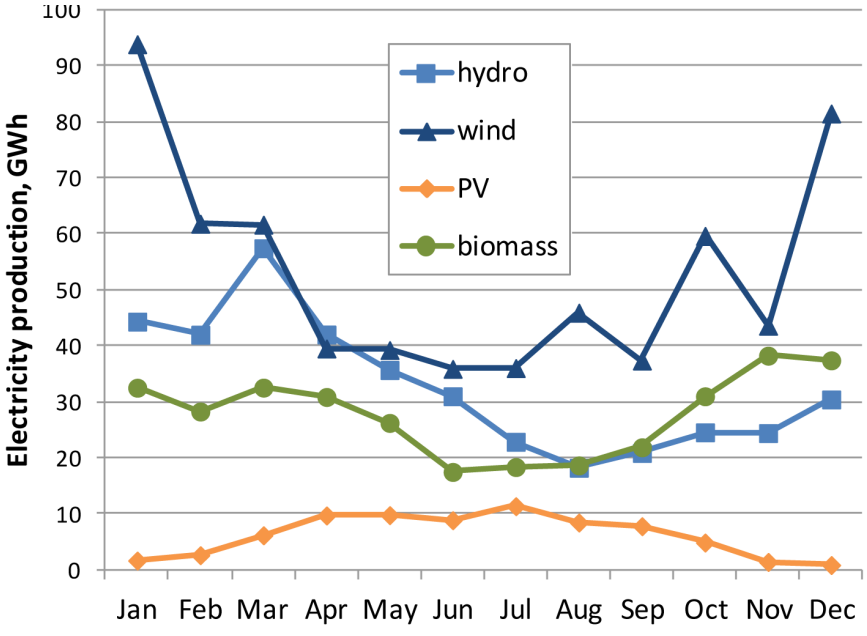
Moreover, the efficiency of power production at photovoltaic power stations in various regions of the country was analyzed in the study, the impact of environment air temperature was assessed, feasibility research of production of electric energy at solar power plants not integrated into electric network and hybrid solar-wind power plants was performed.

Since 2013, during the research of small wind power plants, a doctoral dissertation ***Investigation of renewable energy technologies and application in urban environment*** has been prepared. The research of the forecast methods for the capacity of wind power plants was also conducted for another doctoral dissertation ***Investigation of the impact of meteorological and topographical conditions on short term wind power prediction***.

In 2014, together with other divisions of the Institute, a long-term program project ***Research of RES application for efficient energy production and environmental impact*** of institutional scientific research and experimental development (further – R&D) continued. In 2014, the information about small farms, potential for use of low-capacity bioreactors there, their construction, operation principles, and applicability was collected. Technical

Mounting of direction stabilizer in the wind power plant on the rooftop of the Institute

Research Council of Lithuania



Production of electric power from various RES in Lithuania in 2014

and economic indicators, installation and mounting costs of bioreactors were assessed. It was determined that for the farms raising up to 20 heads of cattle, 20 m^3 bioreactor module is the most suitable. For the farms raising a larger number of cattle heads, it is more efficient to install bioreactors of 50 m^3 capacity.

After the research of the wind conditions, it was determined that the mean annual wind shear coefficient in Kaišiadorys district at the height of 30–50 m reaches 1.55. Measurements at a greater height indicate that the wind shear at the height of 80–100 m is by about 20 % smaller. Due to this reason, the rotors of the lower wind power plants experience greater dynamic loads, and this affects the performance indicators of power plants.

The situation of power production from renewable energy sources was overviewed: in 2014, about 12 % of the consumed electric power was produced from RES, and their largest part (44 %) was comprised by the energy produced in WPP parks.

Solving the issues of environmental impact from wind power plants, causing dissatisfaction of the local communities, the research of the noise produced by wind power plants continued in cooperation with the researchers from the department of Physics of the Faculty of Environmental Studies at VMU. A portable noise analyzer 2250 Bruel&Kjaer and special software were used for this research. Noise measurements were performed at the municipalities of Kalvarija and Vilkaviškis districts nearby 250 kW wind power plants at various distances. It was determined that during a quiet sunny day, the level of background environment noise achieves 33–35 dBA, while at a stronger than 10 m/s wind, the level of background environment noise (50–60 dBA) exceeds the permissible noise made by WPP. At the wind of 5–6 m/s, noise level of 45 dBA is exceeded only up to 50 m from the WPP.

Noise measurements conducted nearby 250 kW capacity WPP

PARTICIPATION IN INTERNATIONAL PROGRAMS

COST program

Since March 2014, the researchers of the Laboratory participate in COST activity Wind energy technology reconsideration to enhance the concept of smart cities **(**WINERCOST). This activity is aimed at collecting and systematizing the information about expertise of European countries in developing wind energy in the urban environment and assessing the potential of application of wind power plants in smart future cities. Technical, economic and social obstacles and the most efficient measures, fostering development of wind power plants in urban built environment are analyzed. During implementation of this activity, work group meetings, international conferences take place, and summer camps are organized for specialists of various levels.

SCIENTIFIC APPLIED RESEARCH

In 2014, cooperation with business companies continued: the researchers of the Laboratory conducted applied research for six projects, financed by the Agency for Science, Innovation and Technology (MITA) under support means **"Innovation vouchers**." During the projects, the analysis of efficiency and aspects of environmental impact of small-scale wind power plants was conducted, noise and shading zones were modeled, the analysis of wind conditions was performed, the perspectives of construction of WPP of various power were assessed, feasibility studies were carried out.

Furthermore, the analysis of technical characteristics of solar power plants installed in Lithuania and patterns of production of electric power at a chosen solar power plant was conducted; a system for the monitoring of meteorological conditions at the operating 30 kW solar power plant in Alytus district was installed. Measurements of intensity of solar radiation and energy produced by solar power plants were performed; efficiency of energy production and its variation in different seasons was assessed; the influence of air temperature on energy production by solar power plants was investigated.

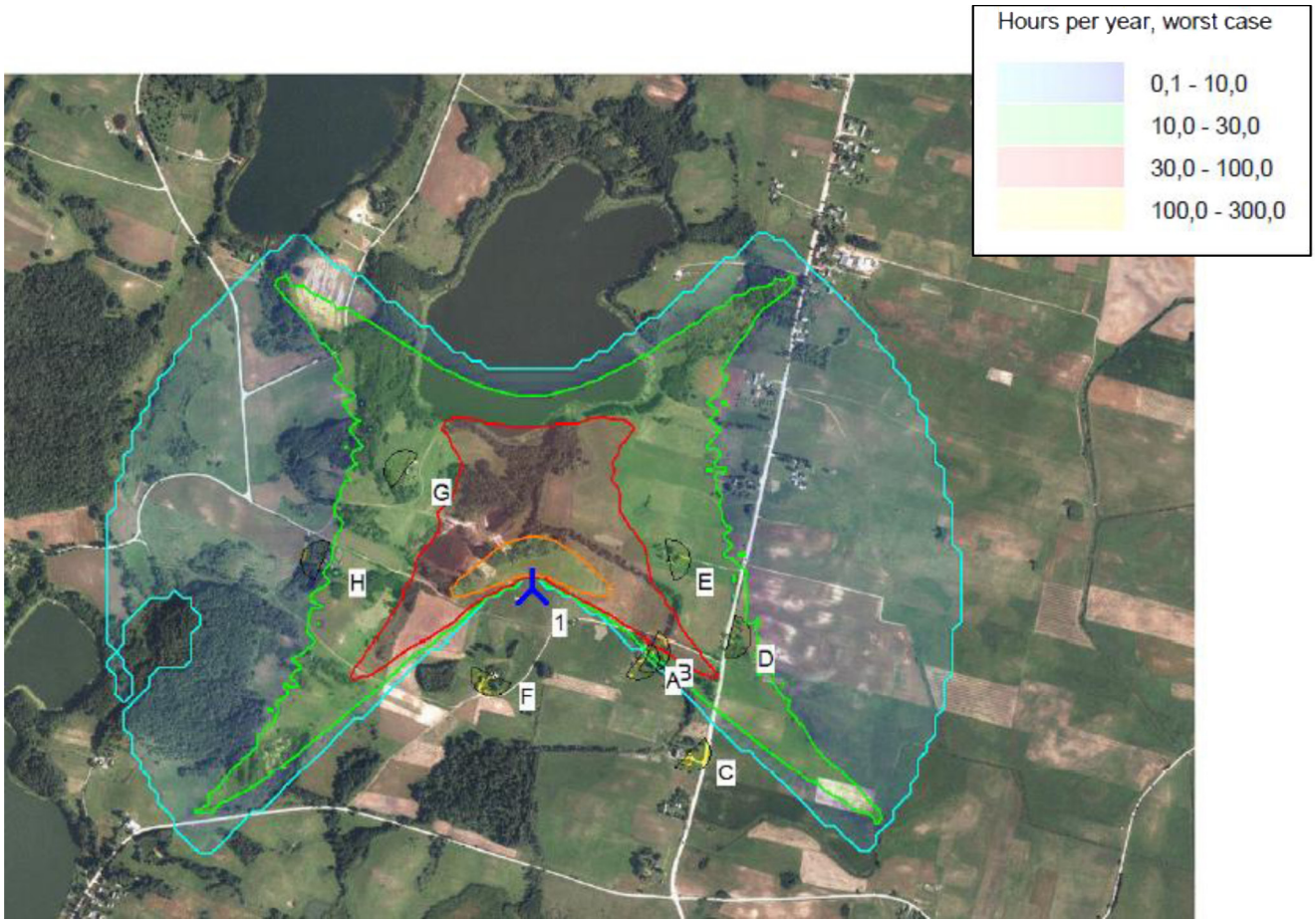
In cooperation with IE *Entiumas* and JSC *Aedilis*, a unique mobile equipment for registration and storage of data about wind speed, direction and capacity of wind power plants *Vėjo fabrikas* was developed. Application of this equipment enables to determine and adjust WPP power curves, observe operation of WPP under different wind conditions and analyze their efficiency.

SCIENCE PROMOTION ACTIVITY

Through the implementation of scientific research and international projects, the society is introduced to scientific ideas and results of the performed research, which encourage the public to be interested in diversity of RES and opportunities of practical application.

In 2014, **Wind energy information center** established at the Laboratory hosted practical training for the third-year students of the department of Environmental Sciences at the Faculty of Natural Sciences at Vytautas Magnus University, who analyzed features of electric power generation at wind power plants and got acquainted with the principles of operation of solar photovoltaics. Moreover, ten excursions for students from various schools of Lithuania were organized. The participants of courses and excursions were introduced to the possibilities of application of small-scale wind power plants, they analyzed specific practical examples, enhanced their calculation, construction and scientific experimenting skills.

Students show active interest in development of RES application, do interns hips at the Laboratory, write term and thesis papers under supervision of the researchers of the Laboratory. In 2014, the researchers of the Laboratory supervised a Master's thesis ***Research of efficiency of small-scale wind power plants*** by the graduate of the department of Physics at the Faculty of Natural



Results of the modeling of shading zones of wind power plants

Mounting of monitoring system for wind and WPP capacity

Monitoring system sensors for meteorological conditions mounted at the solar power plant

Practical activities for students of Vytautas Magnus University: research of efficiency of photovoltaic module (on the left); Visit of seventh graders from Kaunas Holy Kazimieras middle school to LEI (on the middle); A lecture to the tenth graders of Šiauliai district Pakapė middle school (on the right)

Sciences at Vytautas Magnus University; two third-year students completed their internships at the Laboratory: they worked on developing a meter for power generated by solar photo-module and conducted a statistical analysis of power curves of wind power plants. In the future, with the assistance of the Laboratory researchers, the students plan to perform a more detailed research and choose study programs related to application of RES technologies.

In 2014, researchers of the Laboratory published four research articles in international and Lithuanian reviewed scientific publications, made four presentations at scientific conferences, published one science promotion article.

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LABORATORY of REGIONAL ENERGY DEVELOPMENT

MAIN RESEARCH AREAS OF THE LABORATORY:

- methodological justification of sustainable energy development conception;
- development of methods and measures for energy demand planning on the municipal and regional level;
- research on demand of measures for the promotion of sustainable energy development and efficiency of their application.

SCIENTIFIC RESEARCH CARRIED OUT IN THE LABORATORY

In 2014, a new study ***Research on efficiency of implemented measures for sustainable energy on the municipal level*** financed by the state budget was launched. In the first year, the analysis of measures for sustainable energy development and experience, applied methods and criteria, possibilities of their application under existing conditions in Lithuania were researched, based on the analysis of reports on implemented measures; furthermore, a methodological ground for the assessment of these measures was prepared, taking into consideration the strategic goals of the county's energy sector.

The implementation of this study is aimed at systematization and generalization of the legal framework provisions (Heat, RES, Territorial planning, Renovation of blocks of flats and other laws), allowing and binding municipalities to participate in the development of RES and lead to a wider uptake of the RES technologies and potentials. Economic, financial and legal preconditions for increase of RES and energy efficiency on the municipal level were analyzed and summarized.

LONG-TERM INSTITUTIONAL SCIENTIFIC RESEARCH PROGRAM ***Economic and sustainability analysis of energy sector development.***

The first task of the program is to develop a theory for harmonious energy progress based on sustainable development and knowledge-based interfaces of economy concepts.

In 2014, investigations were performed in two directions for the solution of this task: 1) Analysis of economic preconditions for development of advanced energy technologies in the country and 2) Analysis of Lithuanian education system in terms of formation of mentality of sustainable development and its comparison to the experience of the most advanced foreign countries.

Research Council of Lithuania

LONG-TERM INSTITUTIONAL ECONOMY SCIENCES RESEARCH PROGRAM 2012–2014 ***Lithuanian challenges of long-term economic competitiveness***.

Seven universities and researchers of the Lithuanian Energy Institute participated in implementation of the program. The program was completed in 2014. They participated in the activity concerning two topics:

Topic 2.3. (Supervisor V. Klevas) Assessment of Renewable Energy Sources (RES) and acquisition of energy saving technologies in wide scope on GDP and foreign trade balance in order to make economic presumptions for justification of the state's support. Analysis of economic presumptions for development and spread of RES technologies.

Topic 5.1. (Supervisor V. Klevas) Identification of assessment principles for the use of state budget and available structural funds and various fiscal-financial measures for advanced energy technologies (RES, energy efficiency, etc.).

The topics were completed, a monograph in English was written, reports were prepared.

New Business Opportunities for Solar District Heating and Cooling

A 36-month duration project *New Business Opportunities for Solar District Heating and Cooling (SDHplus)* continued in 2014. The project is coordinated by the partners from Germany Research Institute for Solar and Sustainable Thermal Energy Systems, SFZ Solites. The project involves 18 partners from 12 EU member states. SDHplus project is aimed at a wider integration of solar plants in district heating networks and meeting heating needs in buildings.

The objectives of SDHplus project are to foster a wider application of solar energy in district heating systems by describing and promoting successful examples of solar energy integration into district heating systems; developing and implementing new pilot business models, taking into consideration the fact that the use of RES in buildings is assigned to measures for increasing energy efficiency, also developing and implementing new market strategies for solar energy in district heating sector (e.g., the green tariff, purchasing models).

It is estimated that the activities of the project will help to develop new business models and market strategies, will provide new opportunities for heat suppliers and other market stakeholders, and will directly contribute to the growth of market for solar district heating supply (SDH). During preparation of pilot projects, possible hindrances will be determined (combined operation of solar collectors and cogeneration, high costs, etc.). According to the assessment of European experts, the power of solar heat plants in new EU member states might reach 500 MW by 2020.

Information dissemination, international SDH seminars, and visits of participants of district heating markets to the existing SDH plants are of great importance. In 2013, two meetings of project participants were held. In April, a conference, dedicated to technical decisions of solar DH systems and discussion of city planning and business models, took place in Malmö, Sweden.

The second meeting of the project partners took place in the city of Graz in Austria, where mounted 1 MW power solar collectors directly supply heat to district heating system. Generally, decentralized solar heat supply of the city DH is handled by energy service companies (ESCO).

Solar heat collectors in Graz City, Austria

Integration of solar thermal collectors systems into a large city's district heating system is innovative, and currently, it is not the cheapest way to produce heat by applying the existing infrastructure. In Hamburg City district heating system, solar thermal collectors with seasonal heat storage produce only 3 percent of the annual heat production. The investments of the project amounted to €22 million, which was financed by the EU and private funds.

In June 2014 a symbiotic approach to the application of systems of solar thermal collectors in combination with cogeneration or operation of wind power plants, taking into account the change of electricity prices in the market, was presented at the project meeting and at the conference in Hamburg. Moreover, the reasons for difficult development of the idea of green settlements even in West European countries with a high standard of living were assessed and discussed.

In the final year, the project focused on Lithuania, where climatic possibilities for the use of solar heat are practically the same as in Germany, Denmark or Sweden. Several Lithuanian DH companies have already installed solar collectors; their produced heat is used for preparation of hot water for companies' needs. The first project has been implemented in Dūkštas DH system,

Solar heat collectors in Hamburg City, Germany

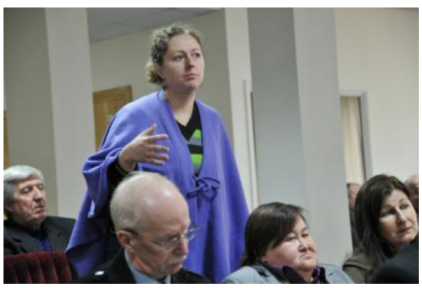
when the sun generated heat is supplied to the town heat supply system. Project participants have visited Dūkštas boiler house, where they have inspected the installed solar heating system, got acquainted with peculiarities of its functioning, design and operational limitations.

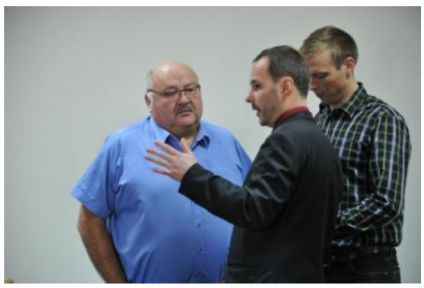
Visit to Dūkštas boiler house

For pilot possibilities calculations of solar energy used for heat production, several small DH systems in Lithuania were selected; they are located in small towns, where the installation of such solar system could be technically and economically reasonable. Primary assessments of the possibilities of Radviliškis and Raseiniai DH systems were elaborated. Based on technical and economic data presented by the companies, also on the Danish experience, a technical-economic analysis of solar heat production and supply was performed there.

On November 4, 2014, Lithuanian Energy Institute arranged a seminar-training, where LEI and Danish experts presented the interested heat suppliers, manufacturers and developers of solar collectors, also consultants and experts the experience of various countries in installation of solar heat systems in district solar supply, technical and economic aspects of such systems, first experience in Lithuania, and possibilities of implementation of a greater number of projects.

The possibilities of using solar heat in Lithuanian district heat networks were analyzed while implementing the project. The analysis covered 17 DH systems, most of which are in smaller towns. Primary results of the analysis enabled to expect that solar energy systems may be competitive with other ones, for example,





Moments of the seminar

biomass technologies in case of relevant financial support. Such systems along with short-term thermal energy storages would allow covering heat demands during summer season and saving significant volumes of biomass and other fuel. The main benefit of solar energy integration into DH systems if compared to individual facilities is scale economy and lower investments due to the fact that there is no need to install regulation and control devices, heat accumulators, pipelines, circulation pumps in each house, issues of overheating of collectors are easier dealt with.

More detailed information on the project activities is provided on the website **www.solar-district-heating.eu** .

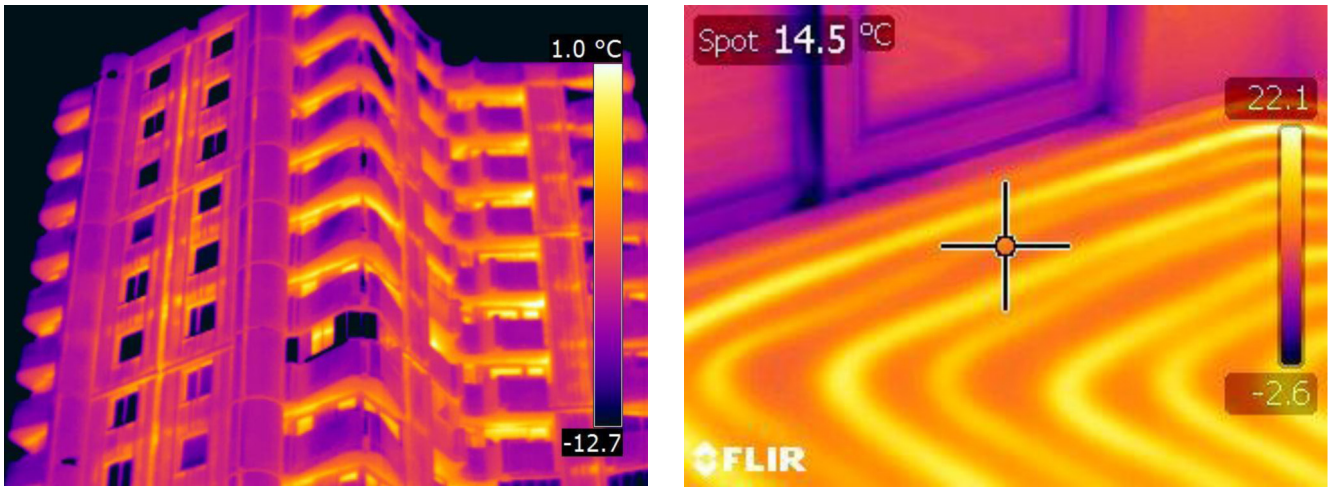
SERVICES PROVIDED BY THE LABORATORY

Consultation activities

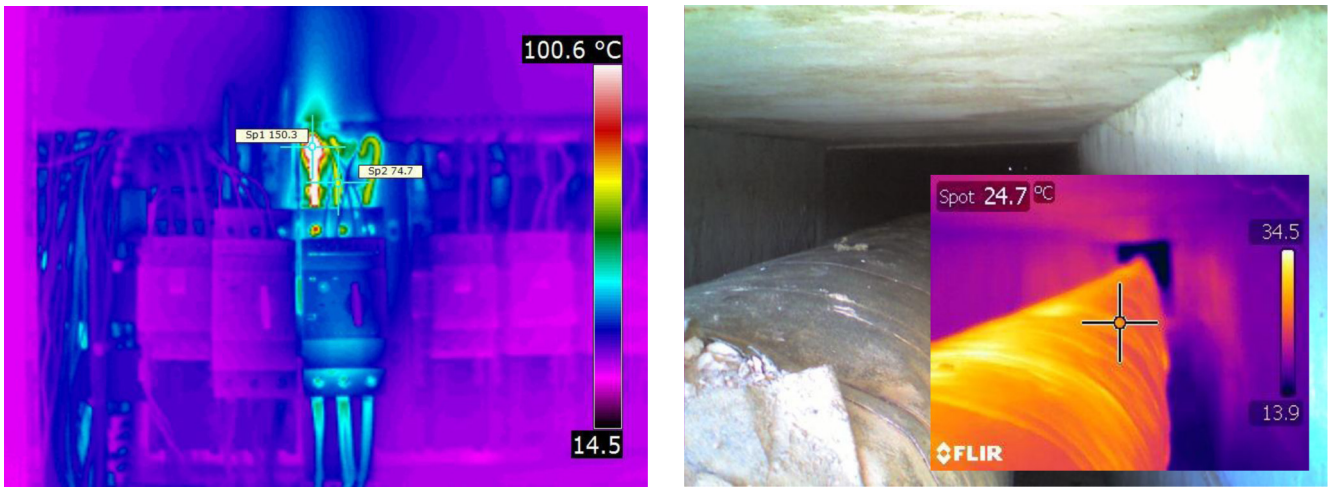
Researchers of the Laboratory broadly use their scientific competence and experience by providing consultations to municipal employees, industry enterprises, state institution employees, giving presentations at qualification improvement training courses for specialists and officers of state institutions.

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

Thermo-vision is a non-contact measuring technology for surface temperatures based on measuring heat radiation intensity. Thermo-visual research is applied for investigating and maintaining residential houses and industrial buildings, roofs, piping, electrical installation, chimneys, and mechanical facilities. It is also used for determining liquid leakage issues, filling levels in the tanks/containers, monitoring and controlling the quality of processes. Thermo-visual research is carried out using thermal imaging camera *Flir B400*, the measurement of surface temperature ranges from -20 °C to +350 °C.



Thermo-visual research of buildings



Thermo-visual research of electricity sector and heating pipes

Certification of energy efficiency for buildings

Expert on certification of energy efficiency in buildings carries out the certification of energy performance for buildings. Certification of energy performance of a building is a process regulated by legislation, during which energy consumption of the building is determined, the building is assigned to a performance class, and a certificate of energy efficiency of the building is issued.


PASTATO ENERGINIO NAUDINGUMO SERTIFIKATAS

Nr. GV-0000-0000

Unikalus pastato Nr.:	0000-0000-0000
Pastato adresas:	
Pastato paskirtis:	Gyvenamosios paskirties vieno ir dviejų butų pastatai
Pastato naudingasis plotas:	218,86 m²

Pastatų energinio naudingumo klasifikavimas į klases*: Nustatyta pastato energinio naudingumo klasė:

A++ A+ A B C D E F G

C

* A++ klasė yra laikoma aukščiausia, nurodo energijos taupiai nevartojantį pastatą, G klasė nurodo energetiškai neefektyvų pastatą.

Skaičiuojamosios sunimes energijos sąnaudos vienam kvadratiniam metrui pastato naudingojo ploto:	176,64 kWh/(m²*metai)
Pagrindinis pastato šildymui naudojamas šilumos šaltinis:	Skysto kuro katilas, automatinis reguliavimas
Energijos sąnaudos pastato šildymui:	150,44 kWh/(m²*metai)
Sertifikato išdavimo data:	2012-01-01
Sertifikato galiojimo terminas:	2022-01-01
Sertifikatą išdavė ekspertas	Atestato Nr.

00000

Sample energy efficiency certificate of the building

Energy audits

In 2014, the expert S. Masaitis was awarded the qualification of auditor by the PE Energy Agency enabling him to perform energy auditing in devices and technological processes.

DISSEMINATION OF SCIENTIFIC RESEARCH RESULTS

The most active PhD student of 2014 in the Institute L. Murauskaitė won the contest of young scientists called for by the Research Council of Lithuania and the right to participate at the conference in Stockholm, Sweden. On September 6–10, 2014, she made a presentation there ***Challenges and options for the interaction of producers and consumers in district heating: a case study in Lithuania.***

In 2014, the researchers of the Laboratory submitted one book, one article in the journal listed in Thomson Reuters data base Web of Science Core Collection, one article in the scientific publication, registered in the international scientific information data base. Five papers were presented at international and national conferences, five articles on dissemination of science in professional journals and Internet websites were published, and one brochure was produced.

*PhD student Lina Murauskaitė delivers a report at the symposium in Sweden (**International Symposium on District Heating and Cooling**)*

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ENERGY EFFICIENCY RESEARCH and INFORMATION CENTER

MAIN RESEARCH AREAS OF THE CENTER:

- to accumulate, analyze and transfer to experts and society the experience of efficient energy production, transfer, distribution and final consumption in Lithuania and abroad during scientific research;
- research related to the National program for enhancement of efficiency of energy consumption;
- participation in international projects, organization of seminars and training courses.

RESEARCH ON ENERGY PRODUCTION AND ENERGY EFFICIENCY IN LITHUANIA

In 2014, the scientific study ***Research of application of new generation heat pumps for heat production*** financed by the state subsidies was completed.

During implementation of the research, statistical data on the existing one-flat (1-2 flats) buildings, multi-flat (3 and more flats) buildings and buildings of other designation in Lithuania were systematized and analysed.

Reduction of energy consumption in buildings and usage of renewable energy sources in the building sector is one of the priority strategic fields of the European Union. In 2010, for implementation of these goals, a new EU Directive 2010/31/ES (PEND) for enhancement of energy efficiency in buildings was approved. By implementation of this directive, the European Commission encourages that all newly built buildings no later than from December 31, 2020 comply or are close to requirements of energy efficiency of passive or zero energy buildings.

This presents an opportunity in the production field for such technologies as heat pumps, thermal energy designated to heat buildings.

The main requirements that have to be met during design of the heating, ventilation, and hot water preparation systems with heat pumps are discussed in this work. A geothermal analysis of heating systems with horizontal and vertical deep-water collectors, as well as building heat supply using heat pump with thermal pole, was performed.

Lithuanian legislation approved in 2009–2013 and foreseeing measures for installation of heat pumps in Lithuania was overviewed. Scarce works designated for monitoring of the performance of heat pumps operating in Lithuania in real conditions were overviewed. A technical-economic feasibility expertise for heat pumps in apartment houses was presented.

Geothermal heating by application of heat pumps for years has been a subject of discussions in Lithuania; it is called the leader in residential heating. The number of such installed heating technologies is increasing in Lithuania. However, one of the factors preventing a more rapid installation of these technologies in Lithuania is a too high heat consumption in buildings, which currently amounts up to 120 kW/m^2 per annum in multi-flat buildings, and in one-flat buildings and public designation premises this amount is even higher. At such high heat consumption, for radiator (not floor heating) heating systems in buildings, the option of using

heat pumps is not very economically attractive. Starting from 2020, under EU Directive 2010/31/ES (PEND), thermal energy consumption in buildings will be extremely reduced and will not exceed the amount of 15 kWh/m^2 per annum.

Under these conditions, heat production by applying heat pumps may become most advanced technology for thermal energy production. This would substantially reduce the use of fossil fuels and the amount of greenhouse gas emissions. During the preparation for this period, it is necessary to develop scientific research, pilot projects, applied research works for the installation of heat pumps in Lithuania. This requires enhancement of knowledge and competence for experts working in the field and educational activities.

The report presents an overview of European Union and Lithuanian legislation, regulating the use of freons, design and manufacture of heating systems with heat pumps, and qualification requirements for the natural and legal persons installing and maintaining these systems. The propagation means for installation of heat pumps in Lithuania are presented.

It is estimated to use the results of the research to renew the National program for enhancement of efficiency of energy consumption, to draft new legislation of the Republic of Lithuania, regulating construction of passive and almost zero energy buildings and thermal energy production for heating of the mentioned buildings, also regulating expansion of heat pumps in Lithuania.

The obtained results were presented at international and national conferences and in scientific journals. Representatives and specialists of the interested residential houses, educational institutions, and other organizations were introduced to the research results. All the above will help to accelerate the development of technological progress in Lithuania.

The results of the research were used in implementation of the projects ***Public energy alternatives – Strategy for sustainable development as an opportunity for the region development***, (*BSR Interreg IV B* 2007–2013 program) and ***Increasing transparency of energy service markets*** (EU *Intelligent Energy Europe* program).

PARTICIPATION IN INTERNATIONAL PROGRAMS

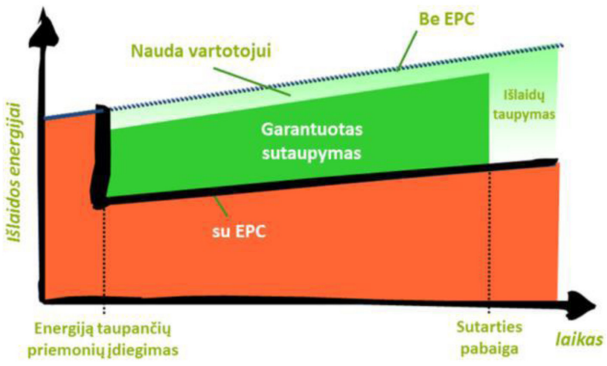
In 2014, an international project launched in 2013 ***Increasing transparency of Energy service markets*** continued. The project is implemented based on the EU program *Intelligent Energy Europe* together with partners from 20 European countries (Czech Republic, United Kingdom, Germany, Slovenia, Sweden, Belgium, Austria, Bulgaria, Italy, the Netherlands, Poland, Portugal, Slovakia, Spain, Greece, Hungary, Denmark, Norway, Latvia, and Lithuania). The duration of the project is three years. Coordinator of the project is Czech Center for Effective Energy Use (SEVEn).

Currently, for financing projects for enhancement of efficiency of EU energy consumption *Energy Performance Contracting – EPC* model is applied, which enables achieving good energy saving results. The main characteristic of the agreement on efficiency of energy consumption, i.e., agreement between beneficiary and service provider (Energy Service Company, *ESCO*), is that the service provider ensures (using their financial resources) the saved amount envisioned in the agreement, which will be achieved after installation of energy saving measures at the customer's place. The beneficiary (customer) pays off the provided services (in full or partially, taking into consideration the bilateral agreement) not at once, but during a certain period (envisioned in the agreement) from the profit, gained for factually saved energy or energy resources.

European Parliament and Committee Directive 2012/27/ES also obliges the application and expansion of this model. This directive envisions the program for common measures aimed at propagation of energy efficiency in the European Union in order to ensure that the goal of 20 % efficiency of energy consumption is achieved by 2020, and the further enhancement of energy efficiency is enabled.

The main objective of the international project ***Transparense*** is to collect most comprehensive information on the activity of Energy Service Companies in the EU, to enable the exchange of experience between individual countries on the achievements and challenges of the mentioned companies.

A pilot form of the agreement on energy efficiency was prepared and approved by the Minister of Economy of the Republic of Lithuania by order No. 4-511, on October 27, 2008. The approval of this agreement form was initiated due to requirements of the European Parliament and Committee Directive 2006/32/ES.



Scheme of implementation of the Agreement on energy efficiency

The main difference between *the Agreement on energy efficiency* as compared to currently used various forms of agreements is that after signing the mentioned agreement, the provider of the services ensures saving the amount of energy foreseen in the agreement for the receiver of the services, which will be achieved after installation of energy saving measures at the service receiver's place. If the actual amount of the saved energy is smaller than that envisioned in the agreement, the service provider covers the incurred financial losses. In this way, the service provider (energy service company) takes all the technical and financial risk related to installation of measures for saving energy at the service receiver's place.

On September 11, 2014, Lithuanian Energy Institute held training for the application of *ESCO* model for implementation of the projects for enhancement of energy efficiency. The basics of application of *Agreements on efficiency of energy consumption*, EU documents, promoting the market of energy services in EU countries, projects for enhancement of efficiency of energy consumption, financial frameworks, the strategy for their funding, and other issues were presented during training. Representatives of Ministry of Energy, Energy Agency, Agency for public investment development, Police department, energy service companies, residential houses and other organizations participated in training.

During the implementation of the project, a *Code of Conduct for Energy Service Companies* was drafted. Compliance with this code enhances the transparency of the activity of Energy service companies and ensures the quality of the provided services. The obtained results enrich the knowledge about the activity of Energy service companies and their capabilities in individual EU countries. Main issues analyzed in this project are presented in the scheme.

The results obtained during implementation of the project will enhance the knowledge about activities of companies providing energy services and their capabilities in different EU countries. The results of the project will be continuously presented during training and at various seminars. The experienced EU energy specialists will help to initiate and implement pilot projects in the 20 countries that participate in the project.

In 2014, researchers of the Laboratory published four articles in foreign journals, one paper was delivered at a scientific conference in Lithuania; five research papers on dissemination of science were published.

Moment of training for the basics of application of the ESCO model for the implementation of efficient energy consumption projects

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LABORATORY of SYSTEMS CONTROL and AUTOMATION

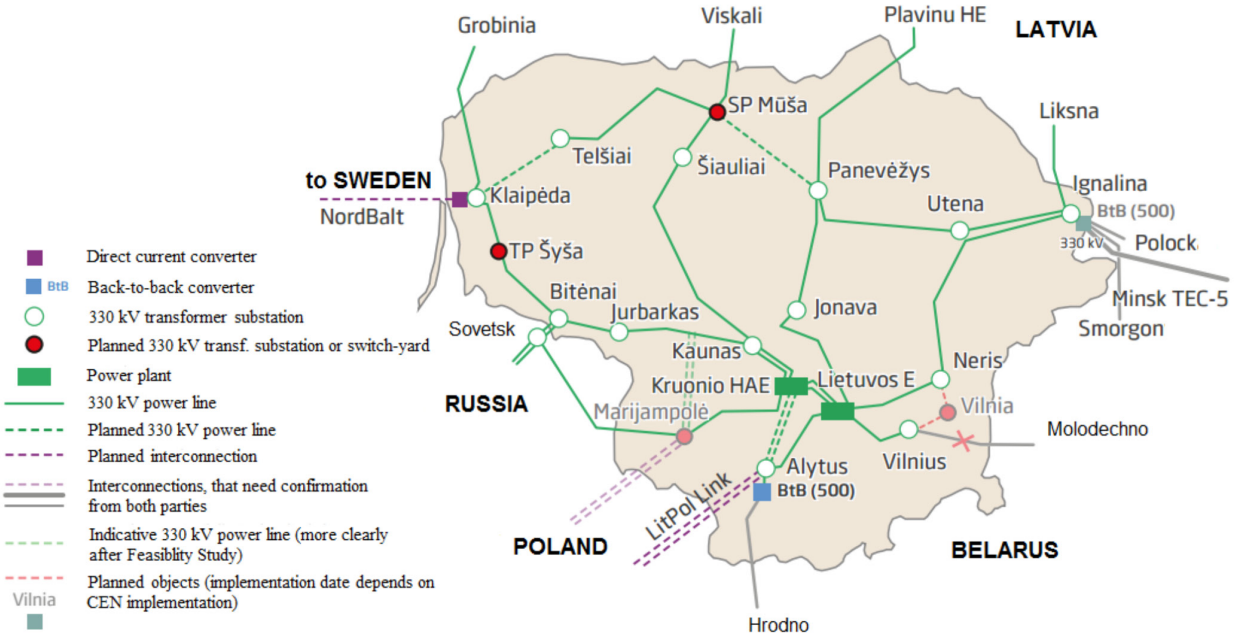
MAIN RESEARCH AREAS OF THE LABORATORY:

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

Power system (PS) is one of the most complex technical and organizational systems covering generators, power networks and consumers, which operate synchronously, i.e., under the same mode and with the same current frequency in large areas. The operational modes of PS, specified by energy, powers, currents, voltages, phase angles and other parameters, are characterized by continuous change. All the modes should be kept within the predetermined parameter limits, and this is the major responsibility of the PS operator. Control is a rather complex task even under normal operation; however, systems often get into stressed modes, sometimes emergency and post-emergency modes, the control of which is more complicated. Out-of-control operational modes may lead to loss of stability, voltage collapses, and failures of individual parts or total blackout. System and preventive automatics with protection relays and multiple digital controllers, and systems of data communication, connecting generators and network substations with dispatch control centers, help the dispatchers to control the systems and networks and protect them from emergencies. Operators prepare control measures (equipment switch-over plans, settings of automatics, dispatch control signals) based on modeling, i.e. on calculations. This is an activity requiring a great deal of scientific knowledge and methods: adequate algorithms, assessment methodologies and analysis procedures need to be developed.

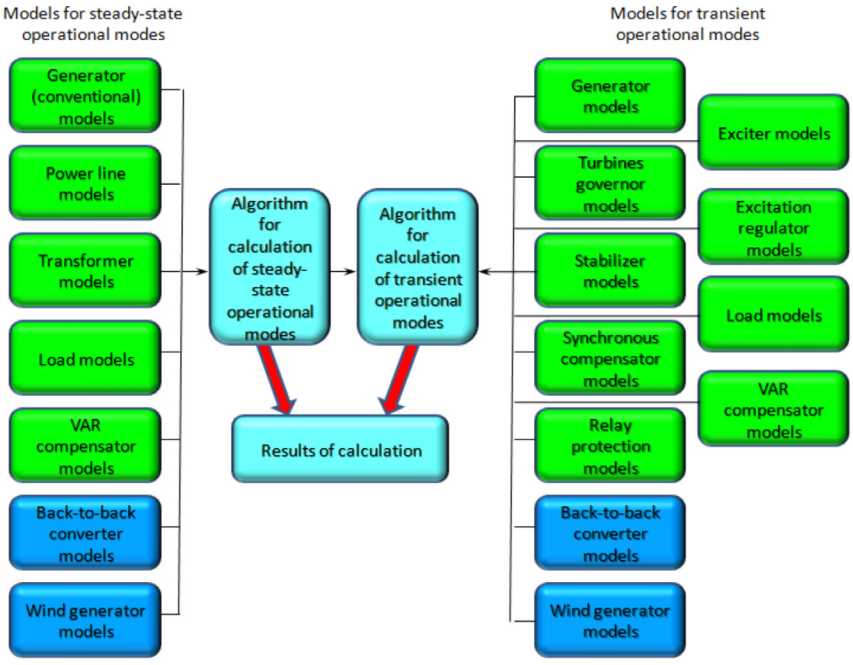
Laboratory of Systems Control and Automation *carries out research and offers services* in the following fields:

- mathematical modelling of power systems, analysis and assessment of their parameters;
- investigation of PS control issues and development of respective algorithms to deal with frequency regulation, active and reactive power control, static and dynamic stability, minimization of transfer losses, electric power quality, emergency prevention;
- investigation of advanced PS control methods and application of new automatic control devices and information and communication technologies (ICT);
- analysis and assessment of PS reliability, security and risks;
- optimisation of PS operation in competitive market environment, development of competitive balancing mechanisms and ancillary service mechanisms;
- research on the integration of renewable energy sources (wind, solar, etc.) and distributed generation into PS;
- legal regulation of PS control and use-of-electricity issues;
- economic efficiency analysis related to PS control and extension, and use of electricity;
- promotion of smart grids.



Lithuanian Power System

Huge changes are traced in the evolution of modern PS. Cross-system electricity trade that will incorporate a variety of new market products (active power reserves, other ancillary services, forward financial transactions) is expanding geographically as well as in volume. Electricity consumers and small generators are increasingly involved into electricity trade and provision of ancillary services. Electricity is becoming more environment-friendly due to growing share of generation based on renewable sources, and probably, due to expansion of nuclear energy. Power systems will become more resistant to disturbances; reliability of power supply and energy quality will improve (near-to-regular shape of voltage sine curve, minimization of voltage flickers, etc.). Such changes are mostly induced by smart technologies, based on ICT. Their uptake is determined by new concepts as *smart generation, smart grids, smart relays, smart meters* and even *smart house*. Smartness is based on logic devices (controllers with microprocessors) and their intercommunication, including links with power network dispatchers. Smart technologies enable power network operators to more efficiently and reliably control their networks in real time and even simplify this work in certain sense (since a part of control and monitoring functions is performed by smart controllers without human intervention). On the other hand, control becomes more complex and sophisticated for operators, since more additional algorithms and software programs are embedded into controllers, their operation has to be monitored and coordinated, controllers have to be reprogrammed in order to eliminate the detected operation errors.

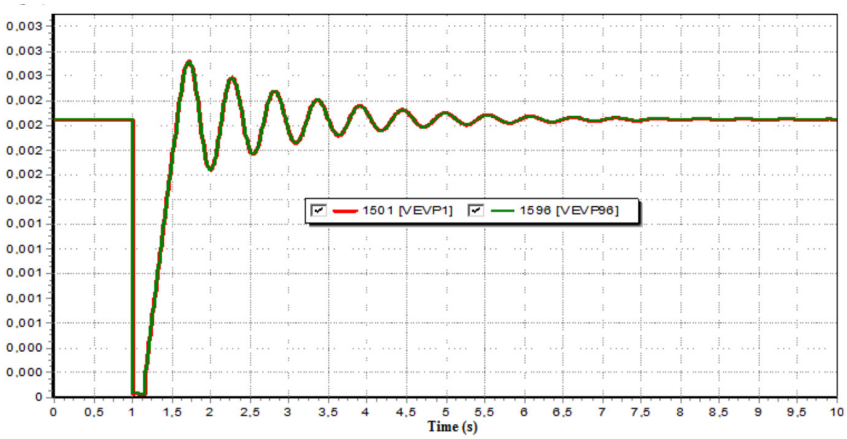


Structural scheme of mathematical model for calculation of power system operation modes

In 2014, the Laboratory (together with the researchers from the Laboratory of Nuclear Installation Safety) completed the project ***Research and Assessment Methodology of Energy Systems Reliability and its Impact on Energy Security*** under the national research program ***Energy for***

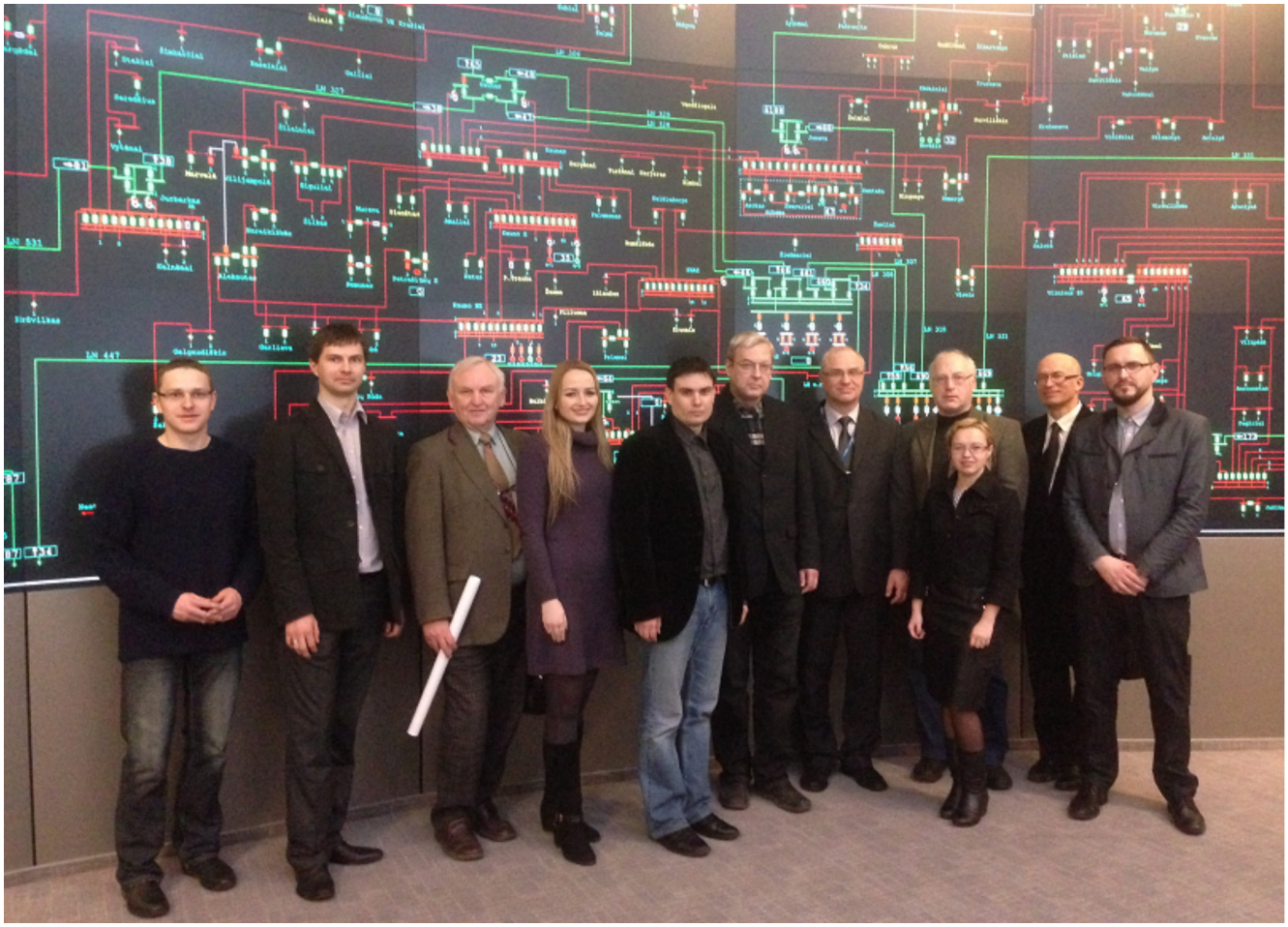
Research Council of Lithuania

the Future. The program is administrated by the Research Council of Lithuania.

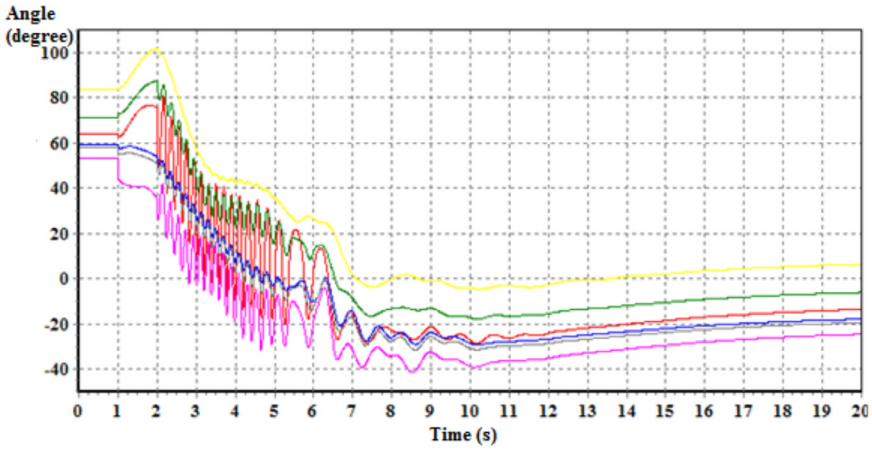


Fluctuations of wind power generation in case of short-circuiting of Lithuanian system

Power system modeling software **PSS™E-33** was used to investigate operational modes of Lithuanian PS. The calculations were performed for the current 2014 scheme and the perspective 2020 scheme basing on winter and summer maximum and minimum loads. Simulation schemes were composed of Lithuanian, Latvian, Estonian PS, Kaliningrad (Russia), Belarusian, Ukrainian, Northwest and Central Russian PS, also NORDIC and Continental Europe equivalent nodes. In 2020 scheme, Baltic PS and Kaliningrad PS synchronically work with Continental Europe Network (CEN). The interlinking with Russian and Belarusian PS was simulated via DC cross-border links in Estonia, Latvia and Lithuania (e.g., in Lithuanian-Belarus case - via the single 330 kV line Alytus-Hrodna, other four cross-border lines being disconnected). Lithuanian PS comprised 1123 nodes, 812 power transmission lines and branches, 368 generators (out of which 310 are wind turbine generators). Imitating various combinations of outages in 330 kV network, post-contingency modes were simulated, and then networks were examined for overloads and stability.



Laboratory staff on the visit to SC LITGRID

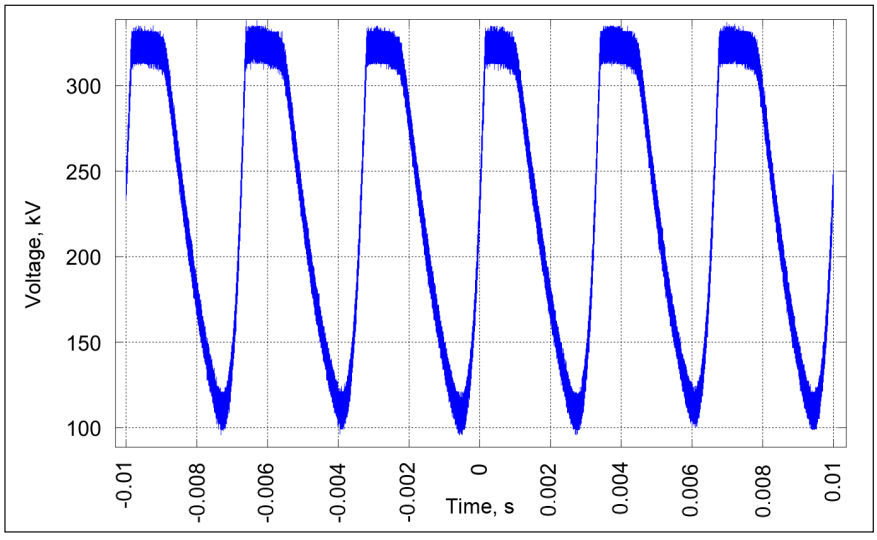


Transitional processes of Lithuanian and Belarusian PS, when they are linked by one interconnection

Under the contract with SC LITGRID, the project ***Analysis of asynchronous operation (swings) in cross-border sections*** was carried out and completed in 2014. The following tasks were investigated and solved:

- drafting of Methodology for choosing the measures for automatic elimination of asynchronous mode (swings) and the respective settings;
- scenarios of emergence of asynchronous modes and identification of triggering events;
- examination of operability of existing out-of-step automatics on Lithuanian-Latvian cross-border section, with the view to the year 2017;
- feasibility of installing the out-of-step automatics on all lines of Lithuanian-Latvian cross-border section;
- examination of operability of existing out-of-step automatics on Lithuanian-Belarusian cross-border section, with the view to the year 2017;
- feasibility of installing the out-of-step automatics on all lines of Lithuanian-Belarusian cross-border -section;
- necessity of installing the out-of-step automatics on Lithuanian-Kaliningrad cross-system section, with regard to the existing automatics in Kaliningrad CHP.

In 2014, under the topic ***Possibilities of Lithuanian power system synchronous operation with ENTSO-E taking into account perspective development of generation sources*** (in the framework of national long-term institutional program), the Laboratory carried out the research on the adequate load-frequency control methods for Lithuanian PS, with the view to the perspective of synchronous operation with ENTSO-E.



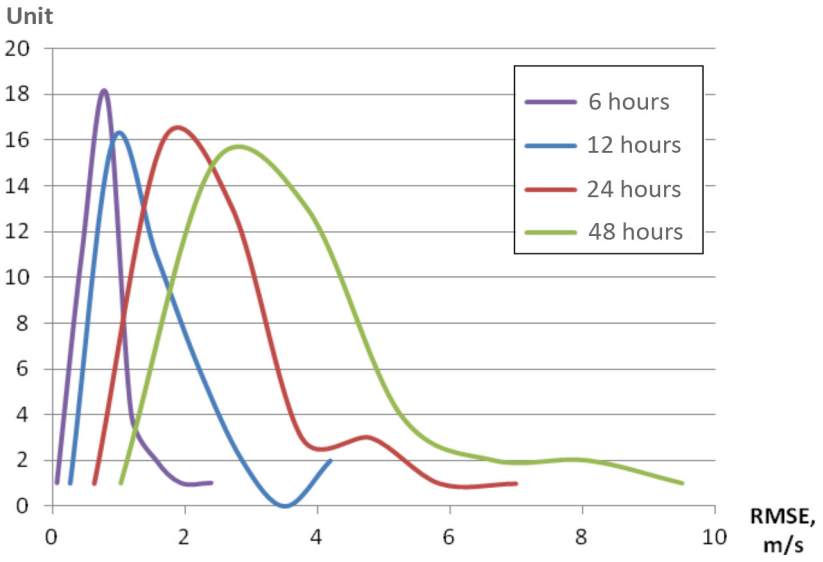
Voltage oscillograms

One of the critical aspects in negotiation with ENTSO-E on the conditions of synchronous connection of Lithuanian PS (Baltic PS) to Continental Europe Network is the evidence of ability of Baltic PS to work independently, i.e. in "island mode" (Baltic PS must not disturb the operation of neighboring PS).

To comply with such requirement and to minimize probable frequency deviations and their durations, it is necessary to develop algorithms that effectively control the active power reserves. As one of the most promising alternatives, a fuzzy logic is proposed to be included into the algorithms for secondary load-frequency control. In scientific publications, quite a few algorithms applying fuzzy logics are presented; however those are not sufficiently capable to take into account the size and characteristics of the smaller systems.

The research was focused on the most heavy operational mode when Lithuanian PS works within the isolated Baltic PS under summer minimum loads. In order to examine the effectiveness of fuzzy regulator for secondary load-frequency control, the critical disturbances were imitated caused by an abrupt change in generation/consumption loads.

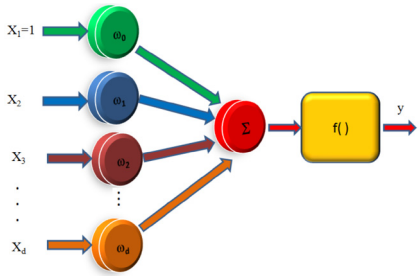
The simulations showed that under normal operation of isolated Baltic PS the fuzzy regulator eliminates frequency deviations significantly better than traditional one. This was also confirmed for the cases when wind power plants operate, no matter what is the wind speed correlation (high, low) between these power plants. As for large disturbances, the fuzzy regulator also demonstrated better results reducing the



Root mean square errors (RMSE) histograms of wind speed forecast for 6–48 hours

transient processes by several times and successfully coping with small frequency deviations. Nevertheless, in critical case, the stability of the system can be lost. The research results will be employed in joint work ***Economic and sustainability analysis of development of energy sector*** that is implemented by the Laboratory staff together with the Laboratory of Energy Systems Research and the Laboratory for Renewable Energy and Energy Efficiency.

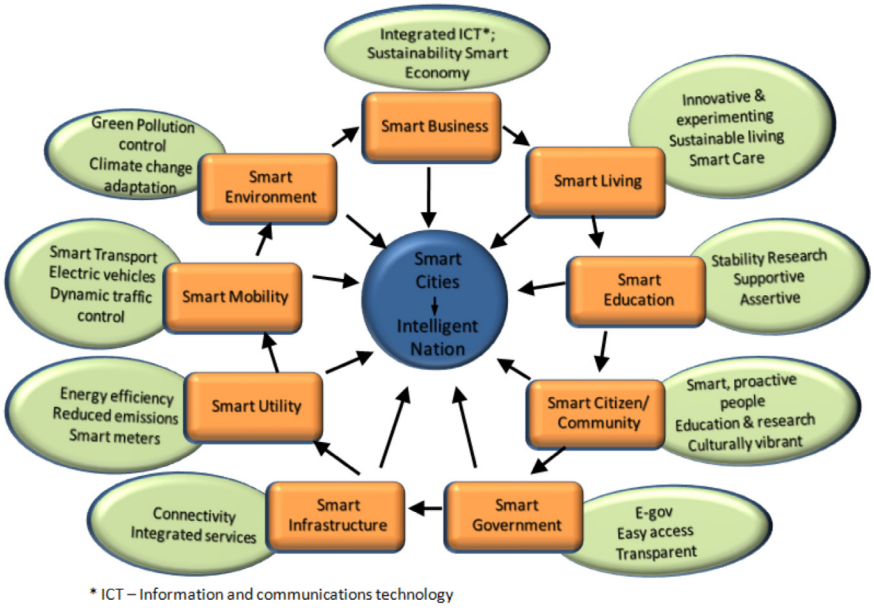
Researchers of the Laboratory together with the Laboratory for Renewable Energy and Energy Efficiency carried out the state-funded project ***Research of intensity of application of low power wind power plants and solar energy systems and their development possibilities in Lithuania***. In this study, the forecasting model of wind generated power was developed employing artificial neuron networks (ANN).



Scheme of artificial neuron

The study ***Technical expertise of unplanned power supply interruption for the Druskininkai city*** was performed together with the researchers of the power system department of Kaunas University of Technology. On April 8, 2014, failures occurred at Druskininkai transformer substation, which caused a series of outages and cut off the power supply to consumers of the Druskininkai city for more than 2.5 hours. The study identified the reason of failures and presented recommendations on how to prevent the similar power supply interruptions in the future or, if occurred, reduce their scope and durations.

Active role of the Laboratory in activity of Lithuanian Smart Technologies Association (SMARTTA) did not go unnoticed. Working on an international scale, SMARTTA became a partner of consortium of the project ***Planning of Energy Efficient Cities*** (code name PLEEC) under the 7th European Framework Program. The major part of tasks designated to SMARTTA was performed by the Laboratory. The objective of the project is to increase energy efficiency of a *smart city* at the planning stage. The drawback of the current planning is that many development strategies are designed for individual aspects of city economy, infrastructure and social life. The strategies are presented by various



Vision of energy efficiency cities

interested parties that are interested in their individual aspect only. Such method of planning hinders strategic planning of energy efficiency of the city. It is hoped to overcome this drawback by forming an integrated planning approach, the key point of which is a smart city. Such planning shall be based on principles of sustainable development and innovativity.

The problem solution will be enabled by better coordination of individual strategies and building upon the experience from the best practice examples. The major outcome of the project will be a new energy-efficient city-planning model. The specialists of the Laboratory carried out a technological assessment of the best practice projects submitted by PLEEC partners (public lighting and other activity sectors of the city) and prepared baseline reports on technology progress.

In 2014, the results of research were presented in the proceedings of one international conference, also in an article in the journal listed in *Thomson-Reuters* database *Web of Science Core*.

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LABORATORY of HYDROLOGY

MAIN RESEARCH AREAS OF THE LABORATORY:

- analysis of climate change and river run-off variation;
- research of impact of enery and transport objects on water bodies;
- collection and analysis of data of the Lithuanian water bodies (rivers, ponds, the Curonian Lagoon, and the Baltic Sea).

OBJECTS AND TASKS OF RESEARCH

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

Applying the information collected in the hydrographic and hydro meteorological database and the modern digital modeling systems, the Laboratory solves the following tasks:

- impact of climate change on water bodies;
- analysis of change of extreme hydrological phenomena of water bodies;
- digital modeling of waves, hydrological and hydrodynamic processes and sediment transport in water bodies;
- environmental impact assessment of anthropogenic activities on water bodies and justification of environmental protection measures;
- environmental assessment of new sea ports and the ports under reconstruction;
- exploitation of sea harbors and waterways, ensuring the nautical depth;
- modeling of pollution dispersion in water bodies;
- sensitivity and uncertainty analysis of hydrological and hydrodynamic processes.

The Laboratory of Hydrology carries out fundamental and applied research in the field of environmental engineering. The basis of the research is numerous hydrographic, hydrologic, morphometric and meteorological data, collected by the Laboratory of Hydrology for many years, and innovative digital modeling software (system MIKE 21, developed by Danish Hydraulic Institute, for the modeling of wave, hydrodynamic and sediment movement processes, and pollution dispersion; hydrological process model HBV, developed by Swedish Meteorological and Hydrological Institute, as well as geographical information systems GIS). This enables solving the most important environmental issues by assessing the impact of anthropogenic activities and climate change on environment and justifying environmental protection measures.

In the recent decade, the Laboratory has been implementing research related to the assessment of the impact of climate change on water resources. In the period 2013–2015, a state funded research project ***Research of Extreme***

Hydrological Phenomena of Lithuanian Rivers (advisor Dr. J. Kriaučiūnienė) has been under implementation. Research of extreme hydrological phenomena (floods and droughts) is relevant in designing and operating the most important infrastructures, such as polders, bridges and culverts, as well as for general flood risk management and planning in order to avoid human casualties and material loss. The preparation of such measures for Lithuanian rivers is based on the observations of river run-off, their analysis and digital simulation. Overview of the research on extreme hydrological phenomena and modern flood forecasting methods in different countries was carried out; original methodology of spring and flash floods assessment during perennial period was developed as well as methodology of extreme hydrological phenomena forecasting (climate change models and hydrological simulation), the analysis of conditions for formation of extreme hydrological phenomena of Lithuanian rivers was performed, change of extreme parameters of river runoff over time was assessed along with forecast of these phenomena following the latest climate change scenarios in the 21st century.

In 2014 together with other divisions of the Institute, long-term institutional research and experimental development (further R&D) program **Analysis of usage of renewable resources for efficient energy production and environmental impact** were continued. Objectives of the Laboratory research in 2014:

1) to create wave dissemination model for the Baltic near-shore, which would make it possible to assess the potential of wave energy in the territorial waters of Lithuania,
2) to investigate the possibilities of technical hydrokinetic resources, to identify accessible river sections and their distribution across the territory of Lithuania.

In 2014 wave dispersion model for the Baltic near-shore belonging to Lithuania was created using the world's widely recognized digital modeling system MIKE 21, developed by the Danish Hydraulic Institute. The wave model NSW (Near-shore Spectral Wind-Wave Module) of this system was applied to simulate parameters of the wind induced wave scattering for the Baltic near-shore. Modeled wave parameters will allow an accurate assessment of wave energy potential in the territorial waters of Lithuania. Using accumulated in 2012 and 2013 hydrographic, morphological and hydrological data base of Lithuanian rivers and created hydro morphological dependencies of rivers (dependence of river width, river depth and flow speed on the average multi-year discharge), River sections, in which flowing at less than 95% probability of flow the following conditions are met, were selected:

1) maximum speed in the flow is above 0.4 m/s,
2) river depth is above 0.5 m.

It was obtained that these conditions are met by only 328 river sections (22.1%) out of all 1487 analyzed river sections.

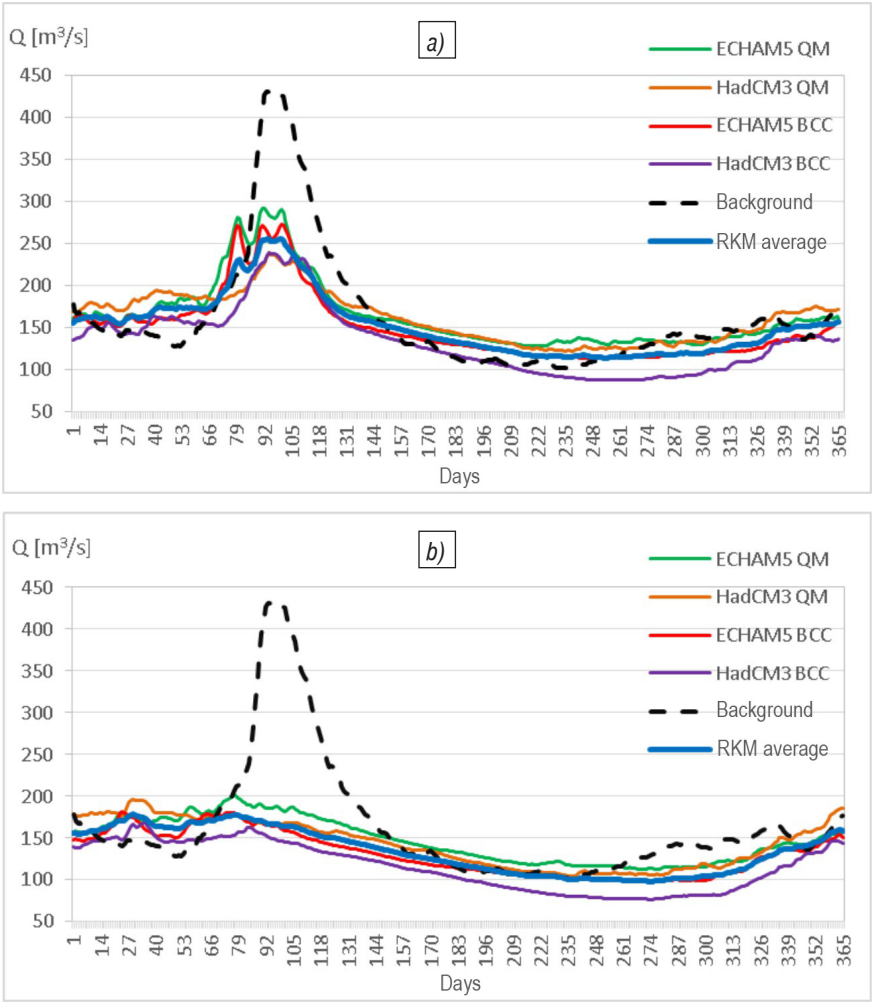

Figure 1. Hydrographs of the Neris based on four climate scenarios in periods 2011–2040 (a) and 2071–2100 (b)

INTERNATIONAL COOPERATION

FLOODFREQ COST Action ES0901
European Procedures for Flood Frequency Estimation

Project COST ES0901

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

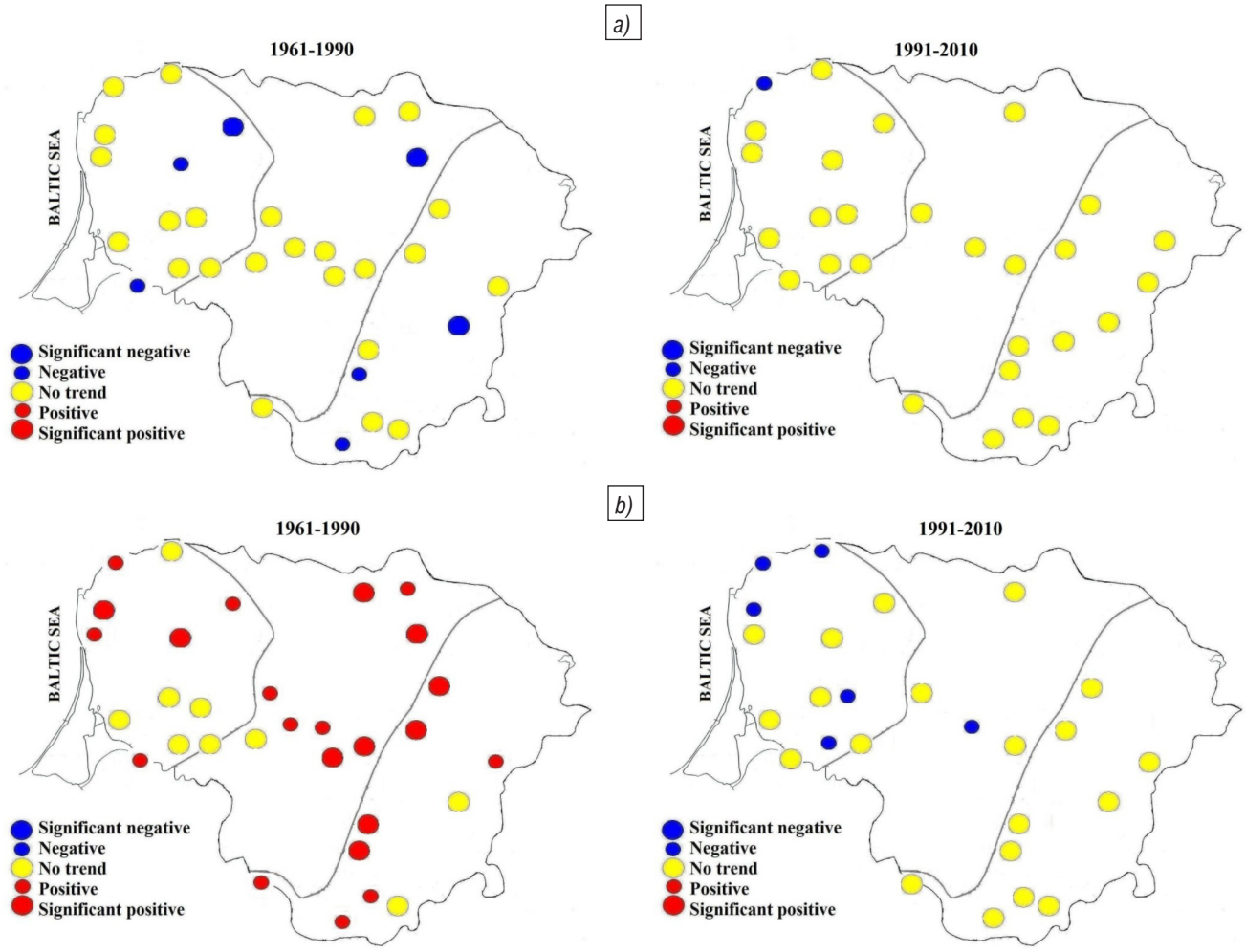

Figure 2. Territorial distribution of trends of spring (a) and flash (b) floods in different time periods

Laboratory participate in the COST ES0901 project ***European Procedures for Flood Frequency Estimation (2009–2014).*** They perform activities in two work groups, namely *Evaluation of statistical methods for flood frequency estimation* and *Impact of environmental change on flood frequency estimates*. On March 6–7, 2014 LEI researchers Jūratė Kriaučiūnienė and Diana Šarauskienė took part in the final conference of COST activities, where they presented a paper *Variability of spring and flash floods of the Lithuanian rivers in the past and future*. On August 3, 2014 researchers of the Institute participated in the COST activity ES0901 FloodFreq Steering Committee meeting. The results of research performed during the project, their dissemination, and possibilities to meet in the future to work in similar activities were discussed.

Latvia Lithuania
cross border cooperation programme 2007 - 2013

part financed by European Regional Development Fund

bringing neighbours closer

Latvia-Lithuania cross border cooperation network HOTRISK

On November 4, 2013 a new mutual Latvia-Lithuania cross border cooperation project *Towards a Harmonized Water Quality and Pollution Risk Management* HOTRISK was initiated. The project duration is 04 11 2013 – 31 12 2014. The project partners are Latvian Environment, Geology and Meteorology Centre and Laboratory of Hydrology of Lithuanian Energy Institute. The objective of the project is to achieve high quality of the surface water in the Lithuanian-Latvian frontier river basins by applying mixed zone evaluation method. This method could be applied for preparation of the corrected management plans for river basin of Venta district (RBD).

There are a number of laws related to the European Water Framework and Environmental Quality Standards (EQS) directives intended to protect or improve the quality of water bodies. However, there are no national legal documents that would define how to harmonize water policies and activities designed to achieve good water quality in the border region according to EQS Directive. Also there are no concerted methodologies for water status assessment in the transboundary river catchment. In order to improve the quality of surface water, Environmental Quality Standards Directive (2008/105/EC) proposes to apply a method of determin-

Figure 3. During the expedition, water samples were taken for chemical analysis, and measurements of flow in the rivers of Venta basin were carried out (photographs by D. Šarauskienė and D. Jakimavičius)

ing mixed zones. Mixed zone is a section of the river near the pollution discharge location, where concentrations of hazardous pollutants may exceed the appropriate environmental quality standard.

Since such hot spots as sewage pollution sources mostly affect the region water quality of Venta river basin at the Latvian-Lithuanian border, the project activities were carried out in the Venta rivers, located on the territory of Latvia and Lithuania. In Latvia the research of river water quality was mostly focused on southwest of Kurzeme region, including Rucavas, Priekulė, Vaiņode, Saldus, Aucė districts and on Liepaja and Aizputė. While in Lithuania, in the entire Mažeikiai region and in many places in Akmenė, Skuodas, Telšiai, Šiauliai and Kelmė districts.

In 2014 analysis of key pollutants of Venta rivers RBD was performed. Also the need to determine mixed zones was assessed in order to ensure water quality in rivers of Latvian-Lithuanian border region by cooperating with environmental institutions, local authority institutions and businessmen.

On December 4, 2014 Lithuanian Energy Institute hosted HOTRISK project seminar ***Mixing zones and water quality***. During the seminar, representatives of the Institute together with the researchers of Latvian Environment, Geology and Meteorology Centre presented results of the project. During the seminar, the project steering committee and seminar participants (representatives of Lithuanian Energy Institute, Šiauliai and Kaunas regional Environment Protection Departments, KTU APINI, Natural Heritage Foundation, Aleksandras Stulginskis University, Vytautas

Figure 4. Moments of seminar participants meeting in Kaunas

Magnus University and Kaunas University of Technology, Latvian Geology and Meteorology Center, Ministry of Environment of the Republic of Lithuania, Municipality of Riga, regional institutions of State Environmental service agencies) agreed that the results of the project can be used to update management plans for districts of Latvian and Lithuanian river basins.

European Network of Freshwater Research Organizations, www.euraqua.org

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

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

The XLIII meeting of EurAqua members took place on October 28–29, 2014 in Brussels (IRSA). The participants of EurAqua discussed the most relevant issues of European water policy: climate scenarios in the future, Implementation of common water directive at the background of climate change, analysis of uncertainties for prediction of changes of water resources. Also topical issues of *HORIZON 2020* projects and possible groups of researchers from EURAQUA institutions were discussed.

COOPERATION WITH SCIENTIFIC INSTITUTIONS

The Laboratory of Hydrology closely cooperates with the Institute of Environmental Engineering of Kaunas University of Technology and have been publishing a scientific journal ***Environmental Research, Engineering and Management*** since 1995. The researchers carry out complex environmental investigations together with the institutes of Ecology, Geology and Geography, and Botany of Nature Research Centre. Aiming at the development of up-to-date infrastructure for the common needs of Lithuanian sea sector scientific research and technological development, the Laboratory of Hydrology contributes to the activity of the association *Baltijos slėnis* (*the Baltic Valley*). The primary and main objective of the Integrated Science, Studies and Business Centre (Valley), concerning Lithuanian sea sector development, is to unite institutions and departments of maritime science. The initiators for establishing the Valley are Klaipėda University, Nature Research Centre, Lithuanian University of Health Sciences, Lithuanian Energy Institute and maritime business companies. Two directions of scientific research and experimental development are planned, that is, sea environment and maritime technologies. In pursuance of integrating the diffuse national scientific potential, working in the field of maritime science, and effectively using modern scientific research equipment and a ship, it is planned to establish a National Maritime Science and Technology Centre. The partners of the Baltic Valley (Klaipėda University, Nature Research Centre, Lithuanian Energy Institute, PE Space Science and Technology Institute in Lithuania, State scientific research institute Center for Physical Sciences and Technology) cooperating their experience, professional knowledge, capacities and business reputation, human, labor and technical resources, participate in implementing 2007–2013 Human Resources development operational program of priority 3: *Strengthening the capacities of researchers* means VP1-3.1-ŠMM-08-K of the project ***Development of Lithuanian marine sector technologies and environmental research.*** Researchers of the Laboratory together with KU researchers actively participate in the activity of subtopic ***Simulation of Hydrodynamic and Litodynamic Processes in the Baltic Sea Nearshore***.

MAJOR APPLIED WORKS OF THE LABORATORY

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

– Under the agreement with JSC *Sweco Lietuva*, the study ***Assessment of***

Hydrodynamic Conditions and Sediment Balance Changes was prepared, the results of which were used in preparation of ***The Expansion Plan of Maximum Deepening and Widening Possibilities for Klaipėda State Sea Navigation Channel***.

– Under the agreement with JSC *Sweco Hydroproject,* the study ***Mathematical Model of the Kiaulės Nugara Island Slope Erosion and Sediment Processes*** was prepared.
– Under the agreement with the ***Nature Research Center***, the assessment of water level fluctuation at Kaunas hydro power plant reservoir was carried out.
– Under the agreement with JSC *Ekotektonika*, the study ***Hydrodynamic Modeling of the Danes River Flow for Construction of Boat Pier*** was prepared.

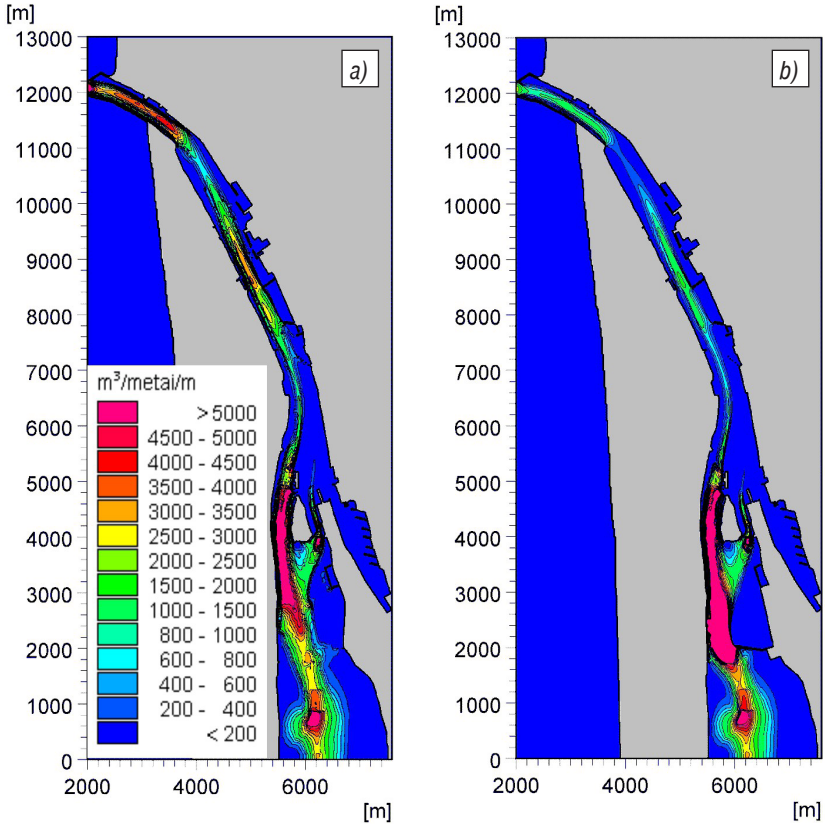

Figure 5. Structure of the Klaipėda Strait unit sediment discharge according Alternative 0 (a) and Alternative B (b), when a discharge of 2730 m³/s flows from the Curonian Lagoon to the Baltic Sea

MIKE 21 modeling system, developed in Danish Hydraulic Institute, was applied for the development projects of Klaipėda Seaport in estimating their impact on the environment and navigation conditions. In order to improve navigation conditions in the Klaipėda Strait *The Expansion Plan of Maximum Deepening and Widening Possibilities for Klaipėda State Seaport Navigation Channel* was prepared in 2013–2014.

Researchers of LEI Laboratory of Hydrology estimated possible impact of deepening and widening of seaport navigation channel on the Klaipėda Strait flow and sediment balance, erosion as well as accumulation processes and bottom changes and foreseen measures to mitigate this impact. Investigating changes of hydrodynamic and sediment processes of the Klaipėda Strait due to Klaipeda seaport expansion, the following main alternatives were investigated:

1. Alternative 0 – the current situation, when the seaport navigation channel is deepened up to 14.5 m and widened up to 150 m.
2. Alternative A – the maximum expansion possibilities after implementing the impact mitigating environmental measures (the inflow channel depth – 17.5 m, the navigation channel depth – 17 m and width 200 m, the depth of water for ships rotation in pond spots – 17 m, the water area depth behind the Kiaulės Nugara Island – 14 m, the installation of breakwater in the northern part of the Curonian Lagoon).
3. Alternative B – partial expansion possibilities after implementing the impact mitigating environmental measures (deepening and widening up to maximum parameters in the chosen water area sectors as well as installation of breakwater in the northern part of the Curonian Lagoon: the inflow channel depth – 17.5 m, the navigation channel depth – 17 m, the installation of breakwater in the northern part of the Curonian Lagoon).

After implementing the solutions of Expansion plan KSS for maximum deepening and widening of the navigation channel according to Alternative A (maximum expansion possibilities after implementing environmental impact mitigating measures), permeability of the Klaipėda Strait will drastically increase (up to 10.4%). The installation of the proposed southern breakwater in the northern part of the Curonian Lagoon will not compensate the increase of permeability.

The solutions of Alternative B (partial expansion possibilities after implementing additional environmental impact mitigating measures) will insignificantly (up to 1.6%) increase permeability of the Klaipėda Strait. Therefore, at the first stage of the port expansion, it is proposed to implement the solutions of Alternative B. The configuration of the proposed southern breakwater should be analyzed more thoroughly, since in this Expansion plan only one breakwater version was chosen

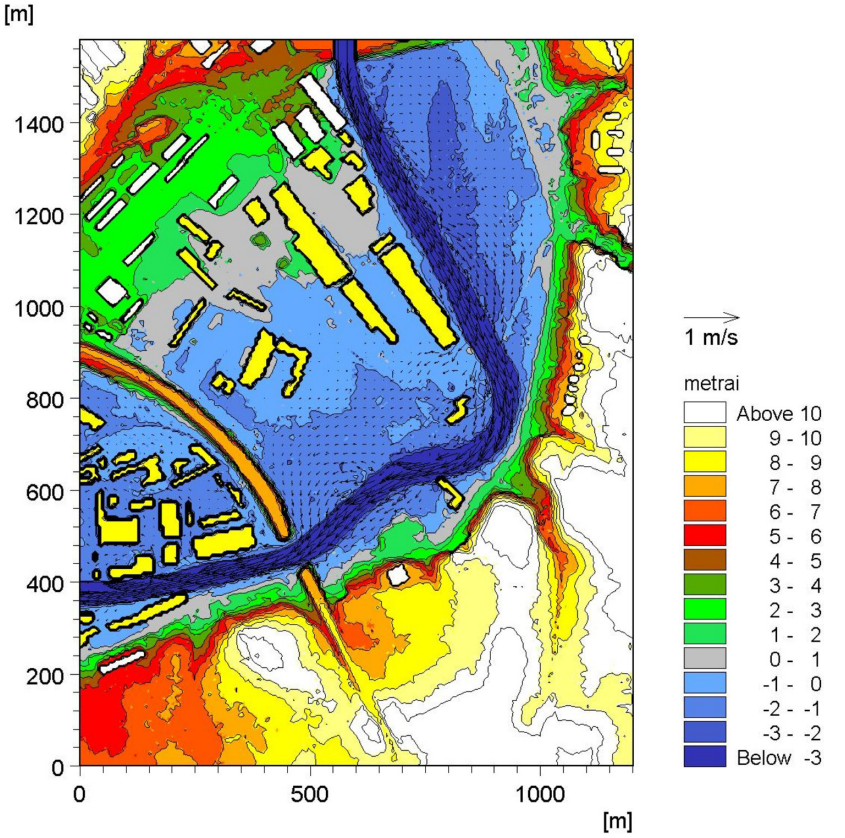

Figure 6. Flow distribution in the Danė river, flowing with discharge 164 m³/s

(700 m length breakwater, perpendicular to the shoreline). In the future such southern breakwater construction should be selected so that while implementing solutions according to Alternative B, the erosion processes would be avoided at a water area nearby southern breakwater and the Curonian Lagoon shore.

Opportunities for application of digital modeling system MIKE 21 in port development projects are broad. A study ***Hydrodynamic modeling of the Danes river flow for construction of boat pier*** was preformed in 2014. In Klaipeda city on a plot of land located in Danes (Akmena) valley, it is planned to construct a pier for small boats and restricted by hydro technical structures aquatory for storing of boats. A characteristic feature of the territory provided for construction is a small altitude above the sea level and water level changes in the Danes river that determine frequent flooding and inundation of the area. By means of the model of hydrodynamic modeling system MIKE 21, the impact of future hydraulic structures in the river valley on the structure of the Danes river flow and design height of the structures have been established; possible erosion processes in the Danes valley have been predicted. The results of the analysis will be used for the environment impact assessment of the planned economic activity and for providing mitigation measures to avoid negative consequences.

In 2014 the Laboratory researchers together with researchers from foreign countries published five articles, four of which are referenced in Thomson-Reuters Web of Science Core Collection database, and four science promotion articles and presented nine scientific papers at three international scientific conferences.

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YOUNG SCIENTISTS ASSOCIATION

THE YOUNG SCIENTISTS ASSOCIATION OF THE LITHUANIAN ENERGY INSTITUTE (LEI YSA) CARRIES OUT THE FOLLOWING TASKS:

- maintains and develops mutual cooperation ties with existing scientific and youth organizations in Lithuania and abroad;
- drafts, discusses and offers documents for projects related to the members' rights and their legitimate interests;
- organizes sociological surveys, meetings, discussions, workshops, conferences, forums, and other events on the issues of interest to members;
- carries out other activity, unforeseen and not prohibited by law of the Republic of Lithuania;
- represents interests of legitimate members and LEI doctorate students, defends their rights at LEI municipal bodies, state and public organizations, associations and public movements.

At the initiative of LEI YSA, the annual events organized and held at the Institute are:

- Researchers' night;
- LEI open doors day;
- International conference for doctorate students and young scientists *Conference of Young Scientists on ENergy Issues* (CYSENI).

Certainly, the most important event of the year that is distinctive for its popularity is the *Conference of Young Scientists on ENergy Issues.*

11TH INTERNATIONAL CONFERENCE *CYSENI 2014*

On May 29–30, 2014 LEI hosted an international conference focusing on the energy issues *Conference of Young Scientists on ENergy Issues 2014 – CYSENI 2014* for doctorate students and young scientists. The purpose of the conference was to invite doctorate students and young scientists from different countries to share the experience of solving energy issues, introduce colleagues to the ongoing research and the results of the latest implemented investigations as well as to develop public speaking skills for doctorate students and young scientists. The participants of the conference were given opportunities to learn how to review, evaluate peer articles, the relevance of the topic and importance of the obtained results.

The conference that took place is the eleventh event organized at the initiative of LEI young scientists. 73 annotations were submitted for the conference, 54 of which were accepted for presentation at the conference. From the submitted scientific publications, the experienced reviewers selected 48, suitable to be published as the conference material.

The papers at the *Conference of Young Scientists on ENergy Issues 2014* were delivered by doctorate students and young scientists from LEI, Vytautas Magnus University, Lithuanian Research Center for Agriculture and Forestry, and Mykolas Romeris University. The idea of the conference was actively supported by young scientists from neighboring countries and research institutions: Latvia University of Agriculture, Latvian State Forest Research Institute, Institute of Physical Energetics (Latvia), Latvian State Institute of Wood Chemistry, Riga Technical University (Latvia), A. N. Podgorny Institute of Mechanical

Director of Lithuanian Energy Institute Dr. Sigitas Rimkevičius and organizers of the Conference Dr. Diana Meilutytė-Lukauskienė and Dr. Viktorija Bobinaitė

Engineering Problems (Ukraine), National Technical University of Ukraine, Georgian Technical University, A. V. Luikov Heat and Mass Transfer Institute (Belarus), REZ Research Center (Czech), Tallinn University of Technology (Estonia), University of Life Sciences (Estonia). Also, young scientists from Technical University of Denmark, Energy Institute (UK), Department of Electronics and Electrical Engineering (India), University of Nigeria, University of New Mexico University (USA) participated in the conference by delivering presentations.

Opening of the conference and plenary sessions

11th international *Conference of Young Scientists on ENergy Issues 2014* was opened by the greeting of the participants by the Director of the Lithuanian Energy Institute Dr. Sigitas Rimkevičius. The organizers of the conference Dr. Diana Meilutytė-Lukauskienė and Dr. Viktorija Bobinaitė thanked the personnel of LEI for sincere help in organizing the conference.

Presentations in three plenary sessions were delivered to the participants of the conference. The head of JSC *Hnit-Baltic* Linas Gipiškis (Lithuania) presented the role of geographical information systems in management of the energy supply chain (the topic of the paper – *GIS in Energy Supply Chain Management*). Prof. Habil. Dr. Vidmantas Jankauskas from Vilnius Gediminas Technical University (Lithuania) shared his long-term experience in areas of development of European Union energy policy (the topic of the paper – *EU Energy Policy: the Latest Developments*). Research worker of the Institute of Physical Energetics Dr. Janis Rekis (Latvia) introduced the results of modeling of Latvian energy systems (the topic of the paper – *Modeling of Energy System Development: 2030 Climate and Energy Goals in Latvia*).

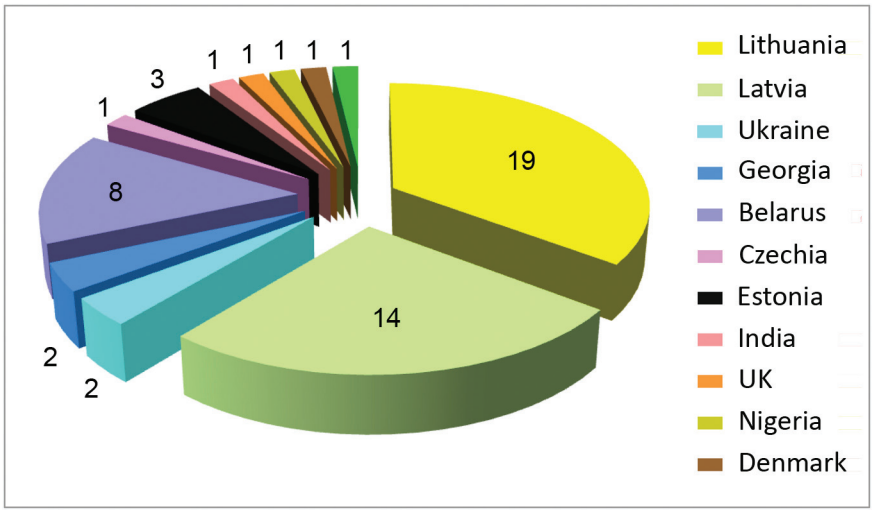
Parallel sessions

Twelve parallel sessions assembled participants of the conference to hear the papers by doctorate students and young scientists on the various research conducted by them in the science fields related to energy. Reviewers of the articles, renowned experts of technology and social sciences, participated in these sessions as well. They were given opportunities to get acquainted with the works submitted by doctorate students and young scientists and were assigned to evaluate the works based on a variety of criteria, also to evaluate the scientific novelty and relevance, consistency and novelty of the methodology, accuracy and reliability of the results, completeness of conclusions. At the conference, the reviewers presented questions, commented on the works by young scientists, and actively debated. In order to improve professional communication skills of doctorate students and young scientists, parallel sessions were chaired by young conference participants and representatives of the board of LEI Young Scientists Association.



Key speakers of plenary sessions (from left) Linas Gipiškis, Prof. Dr. Habil. Vidmantas Jankauskas and Dr. Janis Rekis

About 50 papers were presented during the two days of the conference. This year, the theme of the parallel sessions was broad; however, the greatest attention was given by doctorate students and young scientists to the research of problems of renewable energy sources. Fourteen papers were presented on this topic. Changes in energy policy, also measures, implemented on the European Union level and in each country individually, which are aimed at reduction of gas emissions causing greenhouse effect, ensuring energy security and solving other long-standing problems, lead to the fact that structuralized knowledge, necessary for formation of the energy policy, and energy efficiency and reliability became a scientific point of view for very pertinent topics – sixteen papers were presented.



Arrangement of the conference participant according countries

Scientific committee of the conference

In 2014, 24 members from Lithuania and fourteen foreign states comprised the Scientific committee of the conference.

Conference topics

Doctoral students and young scientists were invited to present papers on the following topics:

1. Hydrogen and fuel cells;
2. Renewable energy sources;
3. Smart energy networks;
4. Energy efficiency and reliability;
5. Knowledge for energy policy making;
6. Investigations in the fields of thermal physics, fluid mechanics and metrology;
7. Material sciences and technology;
8. Investigations of combustion and plasma processes;
9. Global change and ecosystems;
10. Fusion energy;
11. Nuclear fission and radiation protection;
12. Cross-cutting energy issues.

Material of the conference

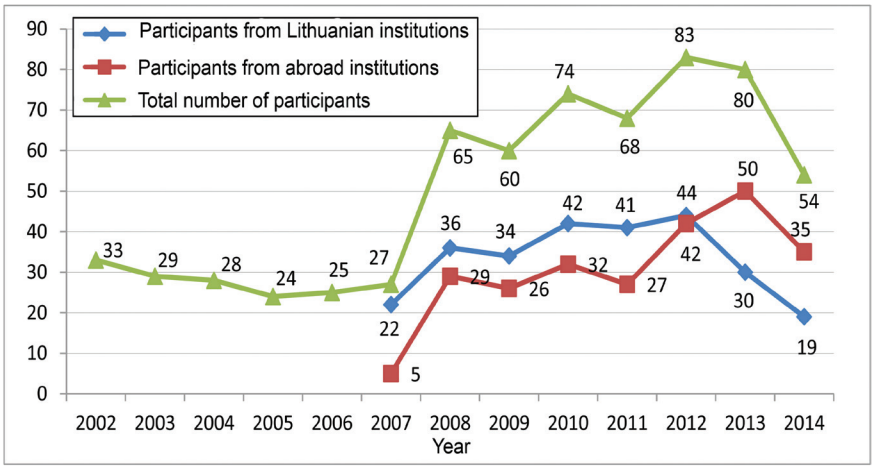
One of the mots significant conference results is the summary of the research performed by doctorate students and young scientists, preparation of qualitative scientific publications and their submission to scientific society. Scientific publications and annotations (in English) by the conference participants, published in the conference material, issued in electronic format (CD, ISSN 1822-7554), reach main research centers and libraries of the country and of some other countries.

The authors of the best works

After evaluating the experience of the conference participants in conducting research work, relevance of scientific problems in the articles, suggested solution methods, the importance of the obtained results, effective public speaking skills, the evaluation was performed in two groups. After summary of the official points and the points given by the young reviewer and the reviewer of the paper, the authors of the best works were announced.

In the group of graduate students and the first and second year PhD students:

1. Kristine Meile (Latvia);
2. Eglė Norkevičienė (Lithuania);
3. Marius Urbonavičius (Lithuania).



Variation of number of conference participants

Moments of excursion ***Panemunės pilys***

In the group of the third and forth year PhD students and young scientists:

1. Svetlana Danilova-Tretiak (Belarus);
2. Aleksandrs Lvovs (Latvia);
3. Anton Brin (Belarus).

Director of LEI Dr. Sigitas Rimkevičius congratulated the winners, conferred diplomas, and sponsor gifts.

Cultural program

On the first day of the conference, the participants were invited to have a traditional Lithuanian dinner. An excellent mood was created by the folk dance group *Rasa*.

On the second day, the participants of the conference visited Raudondvaris Manor, Raudonė and Panemunė Castles, and enjoyed the country's beautiful nature.

Organizers and sponsors

In 2014, the initiative of LEI YSA was as usually supported by the Institute's management that provided financial and technical support. Substantial financial support and gifts to participants of the conference were allocated by the conference sponsors *Linde Group* member *AGA*, JSC *Hnit-Baltic* and *JSC REO Investment*.

Authors of best papers with Director of LEI and organizers of the Conference

Invitation

Organizers of the conference constantly seek for famous, very experienced researchers, who conduct the research related to the topic of the conference and are willing to contribute to the education of strong young scientists, and invite them to be members of the conference editorial board.

We kindly invite all the interested parties to participate at the international *Conference of Young Scientists on ENergy Issues* (*CYSENI*), which is held at the end of May of every year at the Lithuanian Energy Institute. More detailed information can be found on the conference website **http://www.cyseni.com** or via e-mail **cyseni@lei.lt** .

OTHER ACTIVITIES

LEI YSA board has actively participated in preparation and implementation of the **Plan of means for enhancement of LEI researchers** by organizing surveys on various issues, analyzing needs of doctorate students (training, technical support, etc.), and submitting various suggestions to the Institute's administration.

In 2014, computer literacy enhancement courses were organized, and training on ***Effective presentation: Preparation and delivery*** was held. At the initiative of LEI YSA, the **Contest of the most active young scientists and PhD students** was organized.

The award of the most active young scientist (until the age of 35) was given to Dr. G. Stankūnas.

Dr. Darius Jakimavičius won the contest of Lithuanian Academy of Sciences 2013 research papers by Young Scientists in biology, medicine and geosciences work group *Changes of balance elements of Curonian Lagoon water and their forecast based on natural and anthropogenic factors* and received an award.

Lithuanian Energy Institute
Young Scientists Association

FINANCIAL HIGHLIGHTS

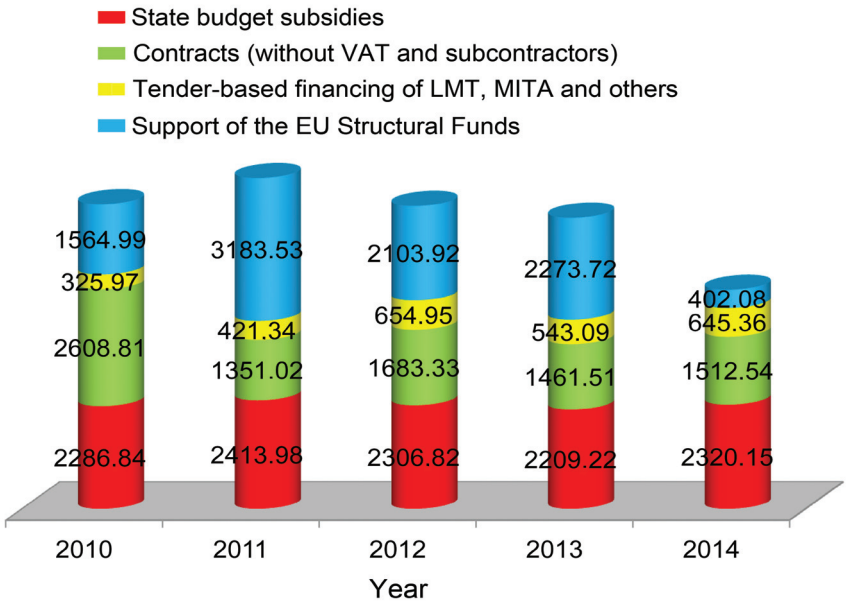
THE FINANCIAL SOURCES OF THE INSTITUTE CONSIST OF:

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

Structure of Income and Total Expenses (thous. Euro)

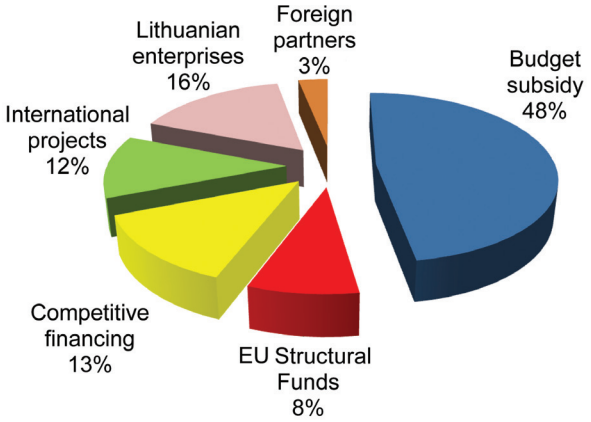
	2010	***2011***	***2012***	***2013***	***2014***
Income:					
State Budget Subsidies	*2286.84*	*2413.98*	*2306.82*	*2209.22*	*2320.15*
Contracts	*2709.68*	*1758.28*	*2309.78*	*1965.39*	*2107.74*
SF Support	*1564.99*	*3183.53*	*2103.92*	*2273.72*	*402.08*
Other Income	*28.88*	*27.66*	*28.50*	*30.24*	*50.16*
Total:	*6590.39*	*7383.45*	*6749.02*	*6478.57*	*4880.13*
Expenses:					
Salaries (soc. ins. incl.)	*4009.21*	*4133.75*	*3944.05*	*3971.56*	*4005.16*
Operating and other Expenses	*704.44*	*994.84*	*737.90*	*1729.90*	*913.43*
Capital Funds	*1773.05*	*3146.14*	*2205.86*	*871.87*	*75.30*
Total:	*6486.70*	*8274.73*	*6887.81*	*6573.33*	*4993.89*
Long-term Projects Assets	*1542.23*	*650.95*	*512.17*	*417.40*	*303.64**

** – A financial claim in the sum of 263.49 thous. € for the liquidated bank **Ūkio bankas AB***

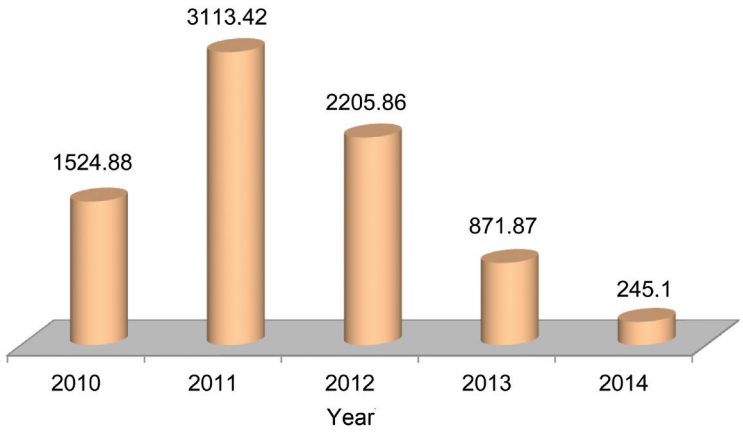


LMT – Research Council of Lithuania;
MITA – Agency for Science, Innovation and Technology.

Evolution of financial recourses, thous. €



The structure of finances obtained from the contractors of LEI for year 2014



Dynamics of assets devoted for equipment purchase, thous. €

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

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8. **Gaigalis V., Markevičius A., Katinas V., Škėma R.** Analysis of the renewable energy promotion in Lithuania in compliance with the European Union strategy and policy. *Renewable and Sustainable Energy Reviews.* ISSN 1364-0321. 2014. Vol. 35, p. 422-435.
9. **Gaigalis V., Škėma R.** Analysis of fuel and energy transition in Lithuanian households sector and its sustainable development in compliance with the EU policy. *Renewable and Sustainable Energy Reviews.* ISSN 1364-0321. 2014. Vol. 37, p. 273-287.
10. **Gaigalis V., Škėma R.** Sustainable economy development and transition of fuel and energy in Lithuania after integration into the European Union. *Renewable and sustainable energy reviews.* ISSN 364-0321. 2014. Vol. 29, p. 719-733.
11. **Grybėnas A., Makarevičius V., Kaliatka T., Dundulis G., Kriūkienė R.** Stress-induced Hydride Reorientation and Cracking in Fuel Cladding Tube. *Materials Science (Medžiagotyra).* ISSN 1392-1320. 2014. Vol. 20, No. 4, p. 403-408.
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changes in Europe: a state of-the-art assessment. *Hydrology and Earth System Sciences.* ISSN 1027-5606. 2014. Vol. 18, p. 2735-2772.

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THE MAIN EVENTS in 2014

10 January. Dr. J. Kriaučiūnienė and Dr. N. Pedišius conferred Engineering Industries Association of Lithuania (LINPRA) honorary awards

10 January. Prof. Dr. Habil. E. Ušpuras awarded a Commemorative Medal by the President of the Republic of Lithuania for his personal contribution to the Lithuanian Presidency of the Council of the European Union in 2013

16 January. Prof. Dr. Habil. E. Ušpuras and Dr. R. Urbonas received a letter of gratitude from the Minister of Education and Science of the Republic of Lithuania

17 January. Visit of students from Kazakhstan at LEI

10 February. Visit of members of Lithuanian Electricity Association at LEI

13 February. KTU, LSMU and LEI signed a joint activity agreement and established a National Innovation and Entrepreneurship Centre

6 March. Visit of representatives from SC *Achema* at LEI

6 March. Visit of representatives from NATO Energy Security Centre of Exellence at LEI

27 March. Public discussion *Features of national heat economy sector assessing practical experience and forecasts*

3 April. Open doors day at the Lithuanian Energy Institute

9 April. Board meeting of the *Santaka Valley* Association

16 April. Visit of representatives from the Embassy of France and the Ministry of Education and Science of the Republic of Lithuania at LEI

23 April. Dr. Habil. A. Pedišius awarded World Energy Council *Medal of Honor of Lithuanian energy specialists*, and Dr. V. Lekavičius conferred a letter of gratitude by Lithuanian WEC Committee

7 May. Guests from Minsk B.I. Stepanov Institute of Physics

12–16 May. ENSTTI training *Criticality safety and thermal-hydraulics*

13 May. Appointment of a new director Dr. Sigitas Rimkevičius of the Lithuanian Energy Institute

22 May. LEI Scientific Council elected

29–30 May. International *Conference of Young Scientists on ENergy Issues 2014*

12 June. Scientific discussion *Areas of Lithuanian energy development and Provisions of national energy strategy*

2 July. Visit of representatives from the Association LITBIOMA at LEI

29 July. Visit of Minister of Energy of the Republic of Lithuania J. Neverovičius

26 September. *Researchers' Night* at LEI

30 September. Dr. Habil. A. Kaliatka elected a full member of the Lithuanian Academy of Sciences

7 October. The European Commission officially launches the *Horizon2020* programme ***EUROfusion*** project

20 October. Prof. Dr. Habil. E. Ušpuras appointed a Chairman of MITA Physical and Technology Sciences Expert Council

21 October. LEI and NATO Energy Security Centre of Exellence signed a cooperation agreement

30 October. Business and science forum *Implementation of innovations and results of scientific research and experimental development – the guarantor of NEP breakthrough*

6 November. Lecture by Dr. A. Marchertas *How I "became" a representative of the Soviet Union in America*

10–17 November. Defense of the reports on scientific works financed by the state subsides

25 November. Vizit of Prof. E.N. Pysmennyj from the National Technical University of Ukraine in Kiev

4 December. Final workshop of the project HOTRISK *Mixed zones and water quality*

8–14 December. ENSTTI training *Regulatory Framework for Decommissioning of Nuclear Facilities*

12 December. Representatives of Ministry of Foreign Affairs of the Republic of Lithuanian and MITA at LEI

19 December. Prize-giving ceremony for the *Lithuanian product of the year 2014* nominations

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